Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

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Milking routines, milk yield and udder health on smallholder dairy farms in Baringo, Kenya

Mjölkningsrutiner, mjölkmängd och juverhälsa på småskaliga mjölkgårdar i Baringo, Kenya

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Abstract

The aim of the project was to investigate possible differences in milking routines, milk yield and udder health between smallholder dairy farms in the highlands (HL) and lowlands (LL) in Baringo county, Kenya, and identify management aspects that could be improved to increase milk yield. The objective was further to study milk handling practices of primary dairy cooperatives in Baringo and to describe challenges they are facing. Seven Farmer Cooperative Societies (FCS) were visited and interviewed, and 31 of their member farms were visited in total; 16 farms in the LL and 15 farms in the HL. Farmers were interviewed about management routines and observations were made of milking routines. Milk yield was registered (kg) and samples of whole udder and udder quarter milk were obtained. In total, 114 cows were included in the study. All milk samples were analysed for somatic cell count (SCC) and the pH was determined in whole udder milk samples. No clear differences were found in milking routines, udder health or milk yield between the HL and LL. The calculated average milk yield was 6.58 kg per cow and day and the milk SCC varied greatly between farms, cows and udder quarters. The median milk SCC was low in whole udder samples with 139 000 cells/ml, but 25% of the cows had ≥ 400 000 cells/ml in their whole udder milk and 38% of the cows had at least one udder quarter with ≥ 1 000 000 cells/ml. Milking intervals were uneven on many farms and intervals were ≤ 6 or ≥ 18 hours on 32% of the farms. Additionally, indications of a beneficial effect of restricted suckling on udder health were found and should be seen as an important practice to promote good udder health. Improving feed and water access on farms, increasing the number of daily milk deliveries from farmers to FCS in some regions, improving contracts with processors and finding ways of coping with the competition of informal milk vendors are aspects which likely would contribute to increased milk production in the Baringo area.

Sammanfattning

Syftet med detta projekt var att studera eventuella skillnader i mjölkningsrutiner, mjölkmängd och juverhälsa mellan småskaliga mjölkgårdar på höglandet (HL) och låglandet (LL) i Baringo, Kenya och att identifiera faktorer som skulle kunna förbättras för att öka mjölkproduktionen. Syftet var ytterligare att studera mjölkkooperativs mjölkhanteringsrutiner och att bedöma vilka utmaningar de står inför. Sju lantbrukskooperativ (Farmer Cooperative Societies (FCS) intervjuades, 31 gårdar medlemsgårdar besöktes totalt; 16 på LL och 15 på HL. Under gårdsbesöken intervjuades lantbrukare om generella gårdsrutiner och mjölkningsrutiner observerades. Mjölkprover på heljuver och juverfjärdedelar samlades in och mjölkmängd registrerades (kg). Totalt inkluderades 114 kor i studien. Somatiskt celltal (SCC) mättes i alla mjölkprover och pH bestämdes i mjölkproverna på heljuvermjölk. Inga tydliga skillnader hittades i mjölkningsrutiner, juverhälsa eller mjölkmängd mellan HL och LL. Den genomsnittliga beräknade mjölkmängden var 6.58 kg per ko och dag och SCC i mjölk varierade kraftigt mellan gårdar, kor och juverfjärdedelar. Medianvärdet för SCC i heljuvermjölk var lågt med 139 000 celler/ml, men 25% av korna hade ≥ 400 000 celler/ml i deras heljuverprover och 38% av korna hade minst en juverfjärdedel med ≥ 1 000 000 celler/ml. Mjölkningsintervallen var ojämna på många gårdar och intervallen var ≤ 6 or ≥ 18 timmar på 32% av gårdarna. Indikationer hittades även på en bättre juverhälsa på de gårdar där kalvarna fick dia korna, så kallad restriktiv digivning, vilket tyder på att det är viktigt att uppmuntra restriktiv digivning som förebyggande juverhälsoarbete. Att förbättra vatten- och fodertillgången, i vissa regioner öka antalet dagliga mjölkleveranser från bönder till FCS, förbättra kontrakt mellan FCS och mejerier och att hitta sätt att hantera konkurrensen med handlare som köper och säljer mjölk på informella marknader, är aspekter som troligen skulle bidra med en ökad mjölkproduktion i Baringo.

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Abbreviations

AI	Artificial insemination
BAMSCOS	Baringo Agricultural Marketing Services Cooperative Societies Limited
DCC	Dairy cell counter
FAO	Food and Agricultural Organisation
FCS	Farmer cooperative society
FG	Free-grazing
GDP	Gross Domestic Product
HL	Highlands
IDF	International Dairy Federation
IQR	Inter quartile range
KCC	Kenya Cooperative Creameries
KDB	Kenyan Dairy Board
LL	Lowlands
LN	Natural logarithm
MCC	Milk chilling centres
SCC	Somatic cell count
SD	Standard deviation
SE	Standard error
SZ&ZG	Semi-zero- & zero-grazing

1 Introduction

The production of food in Kenya must increase to satisfy the substantial increase in demand for agricultural products that is anticipated in the coming years. The Kenyan population is expected to reach 96 million in 2050, from today's 46 million people. This rapid increase in population, along with increased incomes, urbanisation, and preferences for animal sourced products, is predicted to lead to a considerable increase in demand for products such as beef and milk. The demand for milk for instance, has been estimated to have increased by 175% from 2010 until 2050 (FAO & USAID, 2017). Agriculture and forestry has a great economic importance for Kenya and contributed with 35.6% of its gross domestic product (GDP) in 2016 (Worldbank, 2017). Kenya's dairy sector contributes to the livelihood of 700 000 households and it is predominantly women and children who carry out the work in this sector. The dairy sector is primarily characterized by smallholders and farmers owning one to three dairy cows and produce 80% of the total milk in the country (Makoni *et al.*, 2014). Livestock has a significant role for poverty alleviation in Kenya (Ton *et al.*, 2016). According to FAO and USAID (2017) an estimated 75% of the households keeping livestock have low incomes, and could benefit from the rapid increase in demand for livestock products that is expected.

The Rift Valley region in the south-western parts of Kenya has the highest density of dairy farms in the country (Muriuki, 2011). Baringo is one of Kenya's 47 counties and is situated in the Rift Valley region, where altitudes range between 700 to 3000 m above sea level. This vast variation in altitudes result in large differences in climatic conditions with humid weather in the highlands and arid- to semi-arid climate in the lowlands (CGB, 2013). This difference could presumably have resulted in different management routines between the regions which consequently affect milk yield and quality.

Milk losses (at farm or dairy chain level), poor hygiene and milk quality problems have been identified as the main weaknesses of the dairy sector in Kenya (Makoni *et al*., 2014). Milk yield is influenced by many management factors on farms and by udder health (Hagnestam-Nielsen *et al.*, 2009). Factors such as milking routines, breeding, and hygiene influence milk yield and could also influence udder health and food safety. Optimizing routines on farms are thus important in order to develop the dairy sector.

1.1 Aim

The aim of the project was to investigate possible differences in milking routines, milk yield and udder health between smallholder dairy farms in the highlands (HL) or lowlands (LL) of the Baringo county in Kenya and identify aspects that could be improved to increase milk yield. The objective was further to study milk handling practices of primary dairy cooperatives in Baringo and to assess which challenges they are facing.

2 Literature review

2.1 The dairy sector in Kenya

2.1.1 Market

The dairy sector has undergone extensive changes in Kenya, during the last decades. The Kenyan Dairy Board (KDB) was formed to develop efficient dairy production and marketing chains in 1958 (Muriuki, 2003). Some of the work performed by KDB was gradually taken over by the dairy processor Kenya cooperative creameries (KCC) which eventually handled most of the dairy marketing and processing in Kenya. However, the Kenyan dairy industry underwent a liberization and a decontrol of market prices in the beginning of the nineties, causing KCC and KDB to lose their market share. This was beneficial for small traders selling raw milk directly to consumers or for dairy cooperatives (Mbogoh, 1995). The liberization also caused a withdrawal of extension services from the government, which led to a challenge in terms of training of, and knowledge transfer to dairy farmers (Makoni *et al.*, 2014).

Since the liberalization of the market, the number of dairy processors in Kenya have increased from 3 to about 30 (Muriuki, 2011), but most of the milk is still processed by five major processors, with Brookside Dairy Ltd. processing the largest quantities in the country (Ton *et al.*, 2016). This affects milk prices since bargaining with major processers reduces the power of the producers. About 60-70% of the milk is sold on informal markets without being processed which poses a great food safety hazard (Makoni *et al.*, 2014). The primary reasons for the high consumer demand for milk sold on local markets are that the milk is easily accessible and has a low price (Omore *et al.*, 2000). Cooperatives that mainly act on the official market struggle to compete with milk sold on the informal market where much lower prices are offered (Ton *et al.*, 2016), by for example itinerant vendors referred to as hawkers (Muriuki, 2003).

2.1.2 Milk chilling centres (MCCs)

A common situation for smallholder dairy farmers in Kenya is to transport milk to MCCs from which processors collect the milk (Makoni *et al.*, 2014). It is common that the MCCs are operated by dairy cooperatives and there are 13 000 dairy cooperatives in Kenya, serving 1.5 million dairy farmers. The cooperative's offer services such as milk marketing, cooling, and bulking of milk from their members. Processors thereafter collect milk from the cooperatives and transport it to their facilities (Ton *et al.*, 2016). Establishing a cold chain for milk before collection has been described as a challenge. Morning milk is often marketed while evening milk is used within the household and for feeding of calves. The expression "forced consumption" refers to this situation when milk, that cannot be collected shortly after milking, exceeds the actual needs of the household and is regarded as waste (Muriuki, 2003). Efforts have therefore been made to establish local cooling centres as satellites to the MCCs from where processors collect the milk. However, challenges still exist and costs for transporting milk to MCCs are still high due to limitations such as non-functioning infrastructure (Makoni *et al.*, 2014).

Adding water to the milk has been a way for farmers to increase their income from the milk since it increases volume (Muriuki, 2003). At MCCs, milk is commonly tested for adulteration using a lactometer which determines milk density and can be used as an indirect measure of dilution by water. Milk pH is commonly also tested at the MCC (Ton *et al.*, 2016), which provides an indication of milk quality since pH drops when bacteria converts lactose in milk to lactate (Lu *et al.*, 2013). Efforts have been made to establish quality-based payment for the milk (Foreman & De Leeuw, 2013), but much work remains before this can be realised (Ton *et al.*, 2016).

2.1.3 Increasing demand

An increased population, income, and urbanisation will contribute to a substantial increase in the demand for animal derived foods such as meat, eggs and dairy products (FAO & USAID, 2017). Conditions such as the high number of smallholders with limited access to land (Makoni, *et al.*, 2014), and limited water sources (Makoni, *et al.*, 2014; FAO & USAID, 2017) are factors that challenges the potential to satisfy the increasing demand for dairy products in the close future. An uncontrolled intensification of the dairy production could result in an unsustainable use of environmental resources, and could result in greater risks of zoonotic disease outbreaks such as brucellosis or Rift Valley fever unless focus is put on preventive disease management such as vaccination programs (FAO & USAID, 2017).

Milk yield varies between different counties in Kenya, and Wambugu *et al.* (2011) collected data on milk productivity in different regions in Kenya between year 2000 and 2010 and found average yearly production per cow was 1344 litres across the country in 2010. The processing capacity of the registered milk processors has been described to be more than twice as high than what is being utilized, which suggests that there is a potential to increase milk delivery to the processors (Makoni *et al.*, 2014). There is however, a great variation in milk supply between the dry- and rain season since the level of the production reflects the availability of feed. Ways to prevent seasonal fluctuations in milk supply include providing dairy cows with nutritious feed throughout the year or developing processing methods to convert fresh milk into long lasting milk products such as milk powder or ultra-high temperature (UHT) milk (Muriuki, 2003).

2.1.4 Baringo

The Baringo county is situated in the western parts of Kenya in the Rift valley region. Dense agricultural productions are primarily found in the HL of the southern part of the county, in the subcounty of Koibatek. The area lacks a well-established road network, which affects the potential to effectively market agricultural products, especially during rainy seasons when supply exceeds demand. Apart from products derived from animal production, maize and coffee are two valuable agricultural products in the region. The East African Zebu is the most common dairy breed in the region, although exotic breeds are the most common in the HL where the most intensive agriculture is found. Water shortages have challenged the development of animal production in the county and most households have a long distance to the nearest water source (CGB, 2013).

2.1.5 WeEffect & BAMSCOS

WeEffect is an aid organisation developed in 1958, working with long-term strategies to strengthen people to escape poverty. They work to improve farmers' abilities to perform and engage in sustainable agriculture, which contributes to food security and livelihoods. In Kenya, WeEffect works for developing smallholder coffee, dairy and forestry production to increase farmer's incomes. They further offer financial services, form housing cooperatives and promote gender equality (WeEffect, 2017).

Before 2012, dairy farmers in the Baringo county were struggling to bargain for prices individually. This caused primary cooperative leaders to join to find ways to improve marketing conditions for their products and to improve the genetic material of the local animals. In 2012 the primary cooperatives formed BAMSCOS which is a union of cooperatives serving 19 primary cooperatives in the Baringo region. BAMSCOS is a democratic union with 9 board members elected annually by BAMSCOS' members. The union has about 17 000 members and approximately 12 000 of them are active. The rest are subsidence farmers which do not sell any of the farm products but might have the intention to do so eventually. BAMSCOS does not process any milk at the moment, but a processing facility is currently being built in Ravine, which is estimated to be functioning by 2022. The key focus of the union is dairy production and 17 affiliates serve dairy farmers, 1 serves dairy/coffee farmers and 1 serves honey farmers. BAMSCOS market about 40 000 litres of milk every day. The 17 dairy cooperatives, also called Farmer Cooperative Societies (FCSs), of the union collect, bulk and sometimes cool milk, and assist their member to access different services.

BAMSCOS work to improve the access to profitable markets for farmers and help them to negotiate for better prices. They further work with value addition to farm products and to facilitate access to a number of services such as AI-semen and extension services. BAMSCOS has received financial support from WeEffect since it was founded in 2014 and this has enabled them to accomplish a rapid progress in reaching some of their objectives (Changwony, personal communication, 2017).

2.2 Factors influencing total milk production in Baringo

The expectancy of rapidly increasing demands for dairy products in Kenya suggests that production must increase to meet the demand. With a daily production of 4,4 litres per cow and year (305 day lactation period) (Wambugu *et al.*, 2011), there is a large development potential. A number of management factors on dairy farms influence milk yield. Feed and water access are very important aspects which greatly influence milk yield. However, aspects relating to feeding will be addressed in a partnering study performed on the same farms (Möller, 2018). The factors that will be addressed in this paper are the management factors; hygiene, milking routines and breeding. A special emphasis will be put on udder health and the potential for milk production.

2.2.1 Udder health

The somatic cell count (SCC) is a measure of leukocytes which are drastically increased in milk when the udder is exposed to irritants causing inflammation, such as bacteria or tissue damage (Sandholm, 1995a). Elevated SCC causes a reduction in milk yield, between 0.7-3.7 kg per day depending on parity and lactation stage (Hagnestam-Nielsen *et al.*, 2009). An elevated SCC is correlated with a reduced milk quality as the lactose content is reduced and the composition of fat and protein is altered (Ali-Vehmas & Sandholm, 1995). Enzymes with proteolytic and lipolytic effects are elevated when SCC increases, causing a reduced milk quality and milk shelf life (Barbano *et al.*, 2006). The change in milk composition caused by for example hydrolytic enzymes, makes mastitic milk a better growth media for bacteria than healthy milk (Ali-Vehmas & Sandholm, 1995). Since lactose has a high importance for the osmotic balance in milk, the reduced lactose content cause sodium and chlorine to diffuse from the blood to milk, making the level of trace elements higher in mastitic compared to healthy milk (Korhonen & Kaartinen, 1995).

The SCC in milk could reflect the milking routines on farms and measuring SCC in the field using a portable instrument such as the Delaval cell counter is a well-established method to estimate udder health (Lam *et al.*, 2011). Healthy milk has a pH between 6.6-6.8 at 20 °C and varies considerably depending on temperature (Walstra *et al.*, 1999). The milk from a cow with subclinical mastitis has higher pH compared to healthy milk (Wielgosz-Groth & Groth, 2003; Batavani *et al.*, 2007), due to an influx of bicarbonate ions from blood to milk (Korhonen & Kaartinen, 1995). It is therefore possible to use milk pH as an indirect determination of elevated SCC (Batavani *et al.*, 2007) and poor udder health.

Hygiene

Poor hygiene can cause a bacterial infection of the udder which drastically increases SCC (Sandholm, 1995b). It is important for the milker to properly clean his/her hands before milking and to use clean water for cleaning of the udder (FAO & IDF, 2011) to prevent bacteria to enter the teats. It is also important to keep the cow's resting place clean to avoid bacteria from entering the teats while the cow is laying down. Cows' teat canals become dilated during milking and remain dilated for approximately two hours after milking. There are two common practices to avoid bacterial infection when the teat canal is open such as using disinfecting teat dip and to prevent the cow from lying down after milking by feeding the cow (Sandholm & Korhonen, 1995). Another method to improve udder health is to let the calf suckle for some period in connection to milking since suckling seems to have a positive effect on udder health (Krohn, 2001; Fröberg *et al.*, 2008).

Milking Frequency and Intervals

SCC has been found to fluctuate during the day (Riekerink *et al.*, 2007) and between days (Forsbäck *et al.*, 2010) and the fluctuation could partly be due to a dilution effect caused by changes in milk volume in the udder (Riekerink *et al.*, 2007). In accordance with this, Stelwagen and Lacy-Hulbert (1996) found that once a day milking result in a higher SCC than twice a day milking and Lakic *et al.* (2009) found an increase in SCC in response to an omitted milking. The researchers in the latter study explained that the increase in SCC seemed to be independent of the accumulation effect of milk in the udder (Lakic *et al.*, 2009). SCC in milk is thus influenced both by the milking frequency and milking intervals.

Parity and Lactation Stage

Both parity and lactation stage could have an influence on SCC. SCC is elevated after calving and thereafter drops in a healthy udder (Lacy-Hulbert *et al.*, 1996), and multiparous cows have a higher SCC than primiparous cows. The negative influence on SCC on milk yield has further a much higher impact on a cow in higher parity compared to lower and the effect is most pronounced in late lactation compared to early (Hagnestam-Nielsen *et al.*, 2009).

2.2.2 Milking routines

Milking technique

Most smallholder dairy farmers in Baringo practice hand-milking (Changwony, personal communication, 2017). The effect of milking technique on the condition of the teats and their ability to prevent pathogens from entering the udder has been well described in literature on machine milking (Hamann and Mein, 1990; Ambord and Bruckmaier, 2010; Ferneborg and Svennersten-Sjaunja, 2015) and may also be important in hand milking systems (Millogo *et al.*, 2012). The Food and Agricultural Organisation (FAO) and the International Dairy Federation (IDF) state in their recommendations that the full-hand grip preferably should be practised to minimize teat injury (2011).

Milk ejection

Milk ejection is necessary to optimize milk removal (Bruckmaier & Wellnitz, 2008) and fat composition (Ontsouka *et al.*, 2003) during milking and can be accomplished by tactile stimulation of the udder before milking. The stimulation can either be carried out by a calf or by massaging the udder and can also be elicited by smell, sound or visual input. In response to the stimulation, oxytocin is released from the pituitary into the blood. When oxytocin reaches the udder, it binds to myoepithelial cells surrounding the alveoli in the udder and causes them to contract. The contractions of the alveoli forces milk from the alveolar to the cisternal compartments of the udder and thereby making the milk available for removal by the calf suckling or by milking (Sjaastad *et al.*, 2010). Unless the milk ejection reflex is stimulated, only 20% of the milk stored in the cisternal parts of the udder can be collected as 80% of the milk is stored in the alveolar compartment. The time from stimulation to milk is ejected varies between 40 seconds to over 2 minutes and the time is influenced by udder fill and therefore also milking interval and stage of lactation (Bruckmaier & Wellnitz, 2008). The fat content of milk increases during milking and milk ejection is required to remove as much as possible of the milk fat during each milking (Ontsouka *et al.*, 2003).

Oxytocin release can be inhibited in situations where cows experience stress such as in novel surroundings and the inhibition seems to be associated with elevated levels of ß-endorphins during stressful situations (Bruckmaier *et al.*, 1993). Feeding during milking has also been found to stimulate oxytocin release (Svennersten *et al.*, 1995) and increase milk yield (Johansson *et al.*, 1999; Ferneborg *et al.*, 2016). However, it has been argued by Ferneborg (2016) that this affect is influenced by whether feeding during milking had been a common routine in the herds prior to the studies since the absence of feed can cause a stressful situation for a cow being used to be fed, which could lead to a drop in oxytocin and a reduction in milk yield (Bruckmaier *et al.*, 1993; Ferneborg, 2016).

Restricted suckling is common in pastoral and semi-intensive dairy systems and commonly implicates that the calf is separated from the cow during parts of the day and then used to stimulate milk ejection before milking and allowed to suckle after milking (Fielding & Mathewman, 2004). Suckling stimulates oxytocin release (Lupoli *et al.*, 2001) and furthermore milk ejection. It has been found that only having a calf present before hand-milking, results in the same amount of saleable milk as when the calf is allowed to suckle before hand-milking (Combellas *et al.*, 2003) suggesting that the calf's presence is enough to trigger oxytocin release and not just the actual suckling. Das *et al.* (1999) studied the effect of feed supplementation of the cow, and the use of restricted suckling in extensive dairy production systems in Tanzania. They found that restricted suckling resulted in a significantly higher daily live weight gain from birth to three months and that restricted suckling in combination with high feed supplementation resulted in improved lactation persistency in the cows.

Milking frequency

It is necessary to remove milk regularly to maximize the potential for milk synthesis and to prevent infection of the udder. When milk is accumulating in the udder, the intramammary pressure increases (Sjaastad *et al.*, 2010). Mammary blood flow decreases which reduces the nutrient uptake of the mammary gland and thereby reduces milk synthesis (Delamaire & Guinard-Flament, 2006). Accumulating milk in the udder further causes feedback inhibition by the milk on further milk secretion. Milk flow is another incentive to milk regularly, since it prevents bacterial colonization in the udder as milk has a wash-out effect during milking (Sandholm & Korhonen, 1995).

During suckling or milking, the galactopoietic hormone prolactin is released, which stimulates milk protein synthesis and metabolism in the epithelial cells. The hormone cortisol is also released which affects the secretory activity of epithelial cells and affects the general metabolism of the cow (Svennersten-Sjaunja & Olsson, 2005). The hormonal release stimulating milk synthesis has been found to be more pronounced during hand-milking than machine milking (Gorewit *et al.*, 1992).

Milking frequency and intervals are critical management factors that influence milk yield. Milk yield has been found to decrease when the milking frequency is reduced from twice to once per day milking (Stelwagen *et al.*, 1997; O'Brien *et al.*, 2002). Similarly, a milking frequency of three times daily results in more milk than two times daily (Klei *et al.*, 1997; Österman & Bertilsson, 2003; Hart *et al.*, 2013) . Milking intervals of over 18 hours have been found to induce leakage of the tight junctions, connecting the mammary epithelial cells where milk synthesis occurs, and this causes α-lactalalbumin and lactose to enter blood plasma. The tight junctions are thereafter open until 6 hours post milking (Stelwagen *et al.*, 1997). This elevated permeability of the mammary epithelial cells impairs milk synthesis and increase the risk of inflammatory cells entering the milk from the blood (Korhonen & Kaartinen, 1995). It is therefore important to milk cows on even intervals and not just as often as possible as this also could be damaging on the mammary epithelial cells. It is also important to adapt the number of daily milking times dependent on the production of the cow, to ensure optimal potential for milk synthesis.

2.2.3 Breeding

There are 12.8 million dairy cattle in Kenya out of which 9.3 million are of indigenous breeds (e.g. Zebus) and 3.5 million are of exotic breeds (e.g. Friesians, Ayrshires) or crosses. Even though indigenous breeds are more common, they only contribute with 30% of the total milk production per year (Firetail, 2013). Private AI-services has been available since 1993 and the use of AI is steadily increasing in the country. It has been reported that there is a problem with poor quality AI being sold at a high price which has slowed down the process of upgrading local zebus, especially for smallholders who alternatively might use bulls with unknown genetic values. The poor infrastructure also challenges the accessibility of AI services for farms located in remote areas (Muriuki, 2011).

Choice of Breed

The ability to produce milk differs between breeds and breed has a strong effect on total milk yield when cows are properly fed and are provided with water. Farmers in Kenya often introduce exotic breeds to their herds since these breeds have higher genetic potential for milk yield compared to local breeds. Other qualities of dairy cows that have been found to be valued by dairy producers in Kenya are adaptability to local conditions in terms of feed availability and disease resistance, and non-market values such as social roles (Bebe *et al.*, 2003). Indications have been found that exotic breeds (*Bos Taurus*) (Katsande *et al.*, 2013) and crossbred cows (*Bos Taurus* x *Bos Indicus*) between indigenous and exotic breeds (Shem *et al.*, 2002) have a higher incidence of mastitis and a higher SCC than pure indigenous breeds in studies performed in Zimbabwe and Tanzania respectively.

Calving interval

Calving intervals are generally long in Kenya, at an official estimate of 450 days (Muriuki, 2003). Kosgey *et al.* (2011) argue that one constraint for the development of dairy production in Kenya is that most smallholder farmers lack sufficient knowledge of breeding management and do not record production and reproductive performance of their animals. Some practices that could be implemented to obtain shorter calving intervals are to ensure proper feeding, improve heat detection routines and insemination timing, control reproduction disorders and cull cows that fail to conceive (Ilatsia *et al.*, 2007).

2.3 Food safety

2.3.1 Hygiene

Bacteria from within and around the udder and contaminated milk containers has been identified as the main sources of contamination in the milk chain from the farm to the consumer in a study performed in India (Colaco, 2011). A critical factor to prevent contamination of the udder and milk containers is that the water used for cleaning of both the udder and utensils is of good microbial quality (Amenu *et al.*, 2016). The udder shall be cleaned and dried and the foremilk may be checked for abnormalities before milking is initiated and should be discarded due to its poor quality. The milk containers should be of resistant materials which can be adequately cleaned and where bacteria cannot easily adhere. Furthermore, factors such as using heated water and detergent during washing are important to clean containers and to prevent the spread of bacteria (FAO & IDF, 2011).

Health risks when consuming milk sold on informal markets in Kenya was investigated by Omore *et al.* (2000) who found generally high counts of coliform bacteria in milk. Brucellosis, coliforms and bovine tuberculosis were the main zoonotic health risks (Omore *et al.*, 2000). It seems though, that most households in Kenya boil the milk before consumption which effectively destroys pathogens in the milk. Antibiotic residues in milk may be of concern if withdrawal times are not respected during treatment of animals. Antibiotic residues cannot be destroyed by pasteurization or boiling and consuming them could result in antibiotic resistance. It has been found that a small proportion of people ferment milk without boiling it beforehand and these people could risk illness from consuming milk pathogens (Omore *et al.*, 2005).

2.3.2 Milk storage

Soon after milking, milk from healthy cows contains low bacteria counts, which lasts for a few hours after milking. Thereafter, bacterial levels increase logarithmically in milk if it is improperly stored in warm temperatures. It is therefore important to not mix milk collected at different occasions since mixing evening milk with morning milk increase the risk of the bacterial growth entering log-phase faster than necessary. Milking into vessels that are improperly cleaned or mixing milk from different farms before delivery to the MCC is further a risk of increasing bacterial duplication (Ton *et al.*, 2016). pH is lowered due to an acidification caused by bacterial spoilage. This shift in pH might not be evident until after 24 hours of storage (Pesta *et al.*, 2007). However, factors such as poor udder health (Korhonen & Kaartinen, 1995; Ali-Vehmas & Sandholm, 1995), storage vessels of poor hygienic quality and mixing of milk (Ton *et al.*, 2016) could cause this shift to happen sooner.

3 Materials and methods

3.1 FCSs and selection of farms

The Baringo county is situated in the Rift Valley in Kenya where the climatic conditions vary considerably between different regions. The county varies between humid HL with higher annual rainfalls than the arid LL. In order to study principal differences between farms situated in different climatic conditions farms were chosen based on whether they were situated in the highlands (HL) or lowlands (LL). The altitudes ranged between approximately 1600 – 2000 metres in the LL and 2000-2600 metres above sea level in the HL. All farms were visited during late rainy season in September and October 2017.

Seven FCS (Mumberes, Torongo, Arama, Mogotio, Sabatia, Emining and Kiplombe), all members of the dairy cooperative umbrella organization BAMSCOS, were visited. During the FCS visits, representatives from the FCS were interviewed and arrangements were made for visits to farms from each FCS. The FCSs were asked to randomize the selection of farms to obtain a group of farms representative for the area. Among the seven cooperatives, three had members in the LL; Mogotio, Emining and Kiplombe; three in the HL: Mumberes, Torongo and Arama; and one had members in both on the HL and LL: Sabatia. In total, 31 farms were visited; 16 in the LL and 15 in the HL. The farms were evenly distributed between the different cooperatives (number of farms): Mumberes (4), Torongo (4), Arama (3), Mogotio (4), Emining (4), Kiplombe (4), Sabatia HL (4) and Sabatia LL (4).

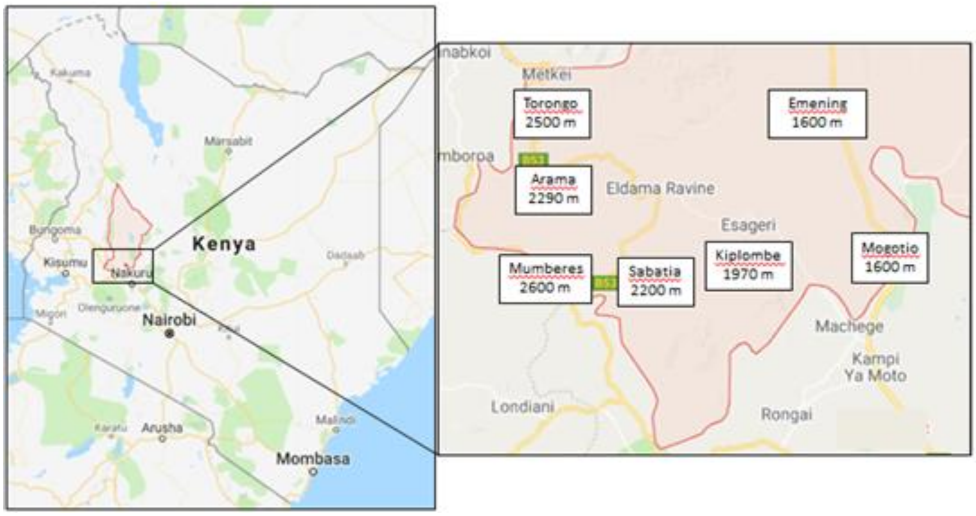

Figure 1. Location of Baringo county in Kenya to the left and the seven Farmer Cooperative Societies which were visited during September 2017 to the right (including height above sea level (m).

3.2 Data collection

3.2.1 Interviews

Interviews were performed with representatives from each FCS and with farmers from 31 farms. Questions were asked to FCS-representatives/farmers directly or with the help from an interpreter from BAMSCOS. The interviews were performed using semi-structured questionnaires, similar to the method of Zvinorova *et al*., (2013), to allow for questions in response to comments or reasoning which could generate important findings. The interviews held with the FCSs involved questions about the number of members, daily milk deliveries, which dairy processor the co-operative delivers to, cooling tank availability, milk quality testing, advisory or veterinarian services offered to members and aspects most important for the farmers to improve. Approximately 30-45 minutes were used for each interview. The full questionnaire can be found in appendix 1.

The farm level questionnaire was slightly adjusted after the first two farm visits based on local conditions and the resulting questionnaire used on the rest of the farms included 45 questions. Interviews were held either just before or after milking depending on milking times. The interviews lasted for 15-30 minutes. The person interviewed was generally the farm owner or the farm manager and sometimes more than one person were present to answer the questions. The questions included the farmer's background, milking routines, productivity, milk consumption, buildings, breeding, calf management, disease management, water access and feeding system, availability of services and aspects to improve with the production. The questionnaire can be found in appendix 2. The interviews further included questions about feed availability and feeding routines which was studied by another student visiting the same farms (Möller, 2018).

Short interviews were also held with a representative from KCC's milk cooling facility in Eldama Ravine and from one of Sabatia FCS's milk selling centres. These interviews were performed to provide a greater understanding of the milk chain in the region. The interview at the KCC milk cooling facility included questions regarding; which actors that deliver to the cooling plant, how milk is handled, where milk is transported further, the distance of milk collection, who provides the transport, storage capacity, time of storage and milk quality testing. The representative from the Sabatia cooperative's milk selling centre was mainly asked about the prices that farmers are offered for their milk, at which price they sell the milk, and how the prices fluctuate between the dry and wet season.

3.2.2 Observation of milking routines

A protocol was used to document milking routines. The protocol included the following aspects: hand and udder wash, pre-stimulation, calf presence during stimulation before milking or during the actual milking or both, fore-stripping, milking salve (lubricating cream) and teat-dip use, cleaning of milking equipment and type of container used during milking and for milk delivery. Hand-milking techniques were observed and related to the three different techniques: thumb in, pull down and full-hand grip (Illustrated by Cvek-Hopkins 2009 in: Millogo, 2012). The number of animals in each age category on the farm was determined with help from the farmer. The observation protocol can be found in appendix 3.

3.2.3 Measurements

On each farm, a maximum of 5 cows were included in the study and if there were ≤ 5 lactating cows on a farm, all of them were included in the study. In cases where there were ≥ 6 lactating cows, the cows included in the study were selected as randomly as possible. On a few farms, it was not possible to meet the criteria described above since either some cows already had been milked at our arrival or since only some cows were being milked in the afternoon. In total, 114 cows were included in the quantitative study, out of the 194 lactating cows in total on the visited farms. On 14 out of 31 farms, all lactating cows were included in the study. Whole udder and quarter milk samples were collected from each cow. Information regarding the specific animal was collected during the visit when milking was observed, and included: breed, lactation stage and lactation number for the selected animals included in the study. The milk yield (kg) was determined for all investigated animals after milking. The body condition score (BCS) was determined by the fellow student who performed a study on feeding routines, which was later used in the statistical analysis in this study.

Milk yield

Milk yield was recorded in kg for each cow during afternoon milking using a digital fish weighing scale (art. no 26624, Biltema, Helsingborg, Sweden) (kg ± 0,01). 113 registrations of milk yield were obtained. Data was missing from one cow because her milk was lost since the bucket was tipped over. Milk yield was measured in volume during the first two farm visits before the method was adjusted to increase the accuracy and simplification of recordings. The milk yield in litres from the first two farms was converted directly into kg (1 litre = 1 kg). Daily milk yield was calculated using data from different publications where milk yield during milkings had been registered. The results from the studies provided an estimation of what proportion of the total daily milk yield that afternoon milking contributes with. The data published by Quist *et al.* (2008) was used to estimate daily milk yield on farms milking three times/day (daily milk yield = measured milk yield / 0.34), Chládek *et al.* (2011) was used to estimate milk yield from cows that were being milked two times daily in intervals close to 10 and 14 hours (daily milk yield = measured milk yield / 0.404), and Forsbäck *et al.* (2010) was used for cows being milked two times daily with more extreme milking intervals than 10 and 14 hours (daily milk yield = measured milk yield / 0.370).

SCC & pH

Milk samples were collected in the field during afternoon milking into 15 ml test tubes. Udder quarter milk samples (approximately 10 ml each) were collected immediately after milking in individual test tubes. The milkers were collecting the samples by hand-stripping into the different test tubes after/when being instructed about the milk sampling. Thereafter, a 10 ml composite whole udder milk sample was collected from the container used during milking, after stirring the milk gently for ten seconds using a metal ladle. The milk samples were stored in ambient temperature and analysed within 6 hours after collection (1-6 hours). Milk SCC was determined both on whole udder and udder quarter level using a DeLaval Dairy Cell Counter (DCC, DeLaval AB, Tumba, Sweden) which quantifies the SCC in milk using fluorescent technology. An individual disposable cassette was used for each SCC analysis in which the milk became mixed with a fluorescent dye to stain the somatic cell nuclei (DeLaval, 2003), before the cassette was inserted into the DCC. Cows that had recently calved (within one week) was not tested for SCC since those cows have elevated SCC in their milk compared to cows in later lactation (Lacy-Hulbert *et al.*, 1996). In total, 564 SCC tests were made. Six SCC samples on udder quarter milk were lost either due to cows being restless after milking on pasture, or because milk had leaked during transport or the cow only having three functioning udder quarters (because of having had mastitis). pH was determined on whole udder milk using a pH-meter (pH 1100H, VWR, Leuwen, Germany) which was calibrated before each use. The pH-determinations were performed within five hours (1-5 hours) after milk samples were collected to avoid reductions in pH due to bacterial spoilage (Pesta *et al.*, 2007). In total, 114 analyses of pH were made, but eight samples were analysed with an incorrect setting on the pH-meter resulting in the exclusion of those results and leaving 106 successful pH-readings. An overview of the distribution of the samples taken in the different research regions and in total can be found in Table 1.

Table 1. *Distribution of pH, whole udder and udder quarter SCC samples taken during 31 farm visits in 2017 where 114 cows were studied in the Baringo county, Kenya. The number of samples are presented in total and for the highlands (HL) and lowlands (LL) respectively.*

	Whole udder SCC	**Quarter SCC**	**pH**
HL	52	206	44
LL	62	244	62
Total	114	440	106

3.3 Statistical analyses

Descriptive information is provided about management practices on farms (proportions, means and medians). The data on milk yield, SCC, and pH, is presented both by descriptive and inferential statistics. An analysis of Variance (ANOVA) was performed using Minitab 18 (Minitab, 2017) to determine if there were any difference in SCC, pH and milk yield, between the production environments (HL;LL) and between feeding systems (free-grazing; semi-zero- and zero-grazing. The data sets of SCC readings were not normally distributed, and were therefore transformed using the natural logarithm (LN) before statistical testing was made. Milk yield and pH data were plotted in histograms which showed approximate normal distributions. The ANOVA was tested with the following hypotheses (with x being either milk yield, SCC or pH):

$H_0 = x_{HL} - x_{LL} = 0$
$H_1 = x_{HL} - x_{LL} \neq 0$

$H_0 = x_{FG} - x_{SZG\&ZG} = 0$
$H_1 = x_{FG} - x_{SZG\&ZG} \neq 0$

The response variables tested included; LNSCC, milk yield and pH. The factors that were tested to have an influence on the response variables (predictor variables) were: Production environment (HL; LL), restricted suckling (yes; no), feeding system (free-grazing; zero- & semi-zero-grazing), lactation stage (unknown; < 8 months; ≥ 8 months), lactation number (unknown; 1st; 2nd or 3rd; 4th or more), body condition score (<2.5; 2.5-3; ≥ 3.5), breed category (*Bos Taurus*; *Bos Indicus;* cross breed) and milk yield (continuous variable). The information about lactation stage was missing for nine of the cows and the lactation number was missing for 20 of the cows. Those missing values were categorized into groups named unknown, and were still included in the ANOVA.

A univariate General Linear Model analysis was performed by testing each predictor with each response variable. The variables which showed to have a significant influence on a response variable were included in the model. Moreover, some core variables and variables with documented influence/relevance were included in all models; production environment, herd, feeding system, lactation stage, lactation number, breed category and restricted suckling. Herd and cow were nested within production environment and feeding system. The interaction between research group and feeding system was tested for significance in all models, and was included if it had a significant effect. The final models included both fixed and random effects and were thus performed with the fit Mixed Effect Model which is used to test models with both fix and random variables.

Model 1:
Milk yield = production environment + herd (production environment; feeding system) + feeding system + restricted suckling + lactation stage + lactation number + body condition score + breed category + e

Model 2:
Whole udder LNSCC = production environment + herd (production environment; feeding system) + feeding system + restricted suckling + lactation stage + lactation number + breed category + milk yield + e

Model 3:
*Quarter LNSCC = production environment + cow (production environment; feeding system) + feeding system + restricted suckling + lactation stage + lactation number + breed category + milk yield + (feeding system * production environment) + e*

Model 4:
pH = production environment + herd (production environment; feeding system) + feeding system + restricted suckling + lactation stage + lactation number + body condition score + breed category + milk yield + e

Herd was included in three of the models as a random factor, while all the other factors were included as fixed. In the model for quarter LNSCC, the factor cow was included as a random factor, which compensated for the impact of herd. Milk yield was included as a fixed continuous covariate. Pairwise comparisons between research groups, feeding systems and predictor variables with significant effects was performed using the Tukey method.

4 Results

4.1 FCSs and the milk chain

4.1.1 The milk chain

The work of the FCSs that were included in this study was to collect and bulk their members' milk before delivering it to a dairy processor or a processor's partnering cooling facility. Three out of the seven visited FCS had cooling tanks at their facilities and two FCS had been promised cooling tanks by the county governments to be installed. Emining, Arama, Sabatia and Mogotio, who did not have functioning coolers at their facilities, transported their members' milk to KCC's cooling facility in Eldama Ravine. The KCC in Eldama Ravine was not a processing facility but collected and cooled milk before transporting it to its partner in Nyahururu. KCC collected milk from farmers who were not members of any cooperative or from small cooperatives without coolers. All of the FCSs delivered milk to either one of the processors KCC and Daima.

4.1.2 Local sales

Five FCS sold milk locally, either processed into products such as yoghurt, or fresh or pasteurized milk, and two FCSs sold unprocessed milk to end consumers. One cooperative reported selling all milk locally, from local milk selling points, during the dry season since milk yields are low, and demands are high during that season. During a short interview with a representative from one of Sabatia FCS's milk selling points in Eldama Ravine, it became clear that farmers could deliver their milk directly to this milk selling centre. This small milk selling centre therefore functioned as a milk collection centre, but the milk was not transported from there via a processor, but instead sold directly on site.

4.1.3 Seasonal fluctuations

One FCS reported having monthly contracts with processors since the offered prices varied greatly. Some of the FCSs also experienced problems with competition from hawkers who bought milk directly from the farmer and sold milk on the informal market, leading to FCSs losing active members. The number of members in each society ranged from 600 to 3000 in total and 300 to 1000 were active at the time of the interviews. The proportion of active members in relation to total members ranged from 28 to 55 %. One manager said the active membership of his cooperative had been less than 100 during the last drought, which constitutes 4% of the total number of members. The prices that farmers were offered for their milk fluctuated between the dry and wet season and could range from between 27 ksh (0.26 USD) in the wet season to 60 ksh (0.58 USD) in the dry season per kg, according to the interview at Sabatia FCS's milk selling centre. The consumer prices fluctuated correspondingly, between 40 (0.39 USD) and 70 ksh (0.68 USD) per kg.

4.1.4 Milk quality testing

All but one cooperative performed quality testing on the delivered milk. The most common properties that were tested included: acidity, density and sensory properties such as smell, taste and appearance (organoleptic test). The protein stability, which changes when lactic acid increases in milk (due to bacterial spoilage) (Foreman & De Leeuw, 2013), was tested using an alcohol test, and the density was tested using a lactometer. In addition to those tests, two of the cooperatives tested microbial activity in the milk by using a resazurin test.

When representatives from the FCSs were asked whether they experience problems with poor quality milk, three of them answered that they do, while four societies answered that it sometimes is a problem. The managers reported that the reasons for bad quality milk could be that farmers mix evening and morning milk, long time of storage before cooling the milk, use of plastic cans, and delivery of milk from cows with mastitis or from cows treated with antibiotics. When the representative from KCC's cooling facility was asked the same question, he answered that the most common indication of a milk quality problem was a positive alcohol test, probably resulting from the mixing of morning and evening milk.

4.2 Farms

4.2.1 Management

Feed and water

The distribution of feeding systems between the farms were; 42 % free-grazing, 32 % semi-zero-grazing and 26 % zero-grazing. The distribution of feeding systems in the different production environments can be found in figure 2. Feeding systems were defined during the study as follows:

- Free-grazing: freely grazing cows, both day and night with a potential supplementation of dairy meal (commercial concentrate)
- Semi-zero-grazing: part-time grazing cows in a prepared enclosure and the cows are fed part of their feed ratio by their owners
- Zero-grazing: permanent housing of cows in an enclosure/ unit with no access to pasture. The complete feed ratio is given in the enclosure.

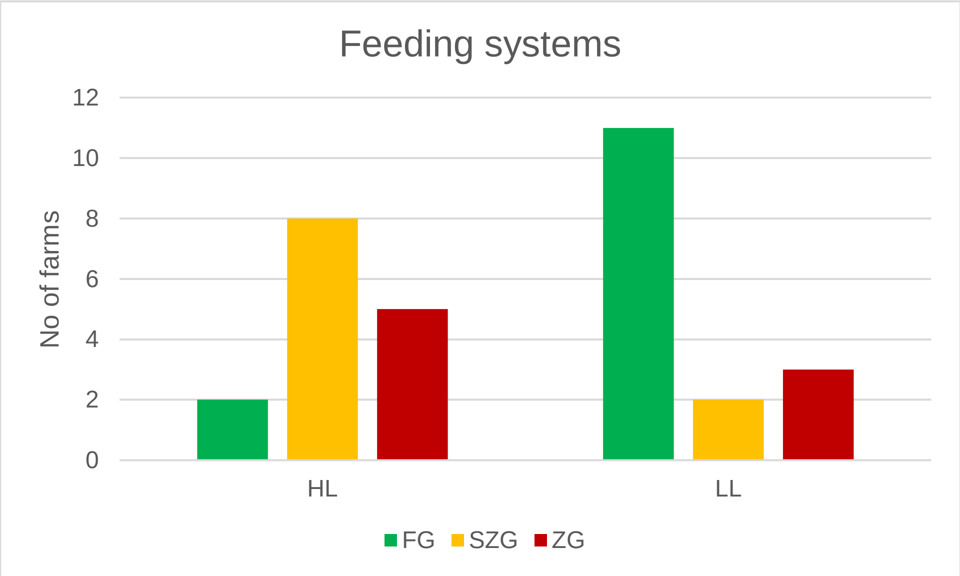

Figure 2. Distribution of feeding systems (free-grazing (FG), semi-zero-grazing (SZG) and zero-grazing (ZG) in the different production environments (highlands (HL) and lowlands (LL). The data is based on findings from 31 farm visits in the Baringo county, Kenya during late rainy season (September and October) in 2017.

Most of the farmers (94 %) answered that their cows had free access to water. The remaining farmers allowed their cows to drink either two or three times daily. The different water sources used at the studied farms were: river, bore-hole, tap, dam, and water harvesting.

Breeding

Artificial insemination (AI) was widely used in the region; 77 % used AI or AI in combination with a bull, while 23 % of the farmers used bulls to serve their cows. It was more common to use AI in the HL (100 %) than in the LL (56 %). Among the 114 cows included in the study, 75 % were of *Bos Taurus* breeds, 12 % of *Bos Indicus* breeds, and 12 % were crosses between *Bos Taurus* and *Bos Indicus* breeds. Four farmers mentioned that they had a strategy for when to inseminate the cows, and two farmers planned for calvings during the wet season while two farmers planned for their cows to calve during the dry season. The lactation stages of cows included in the study on each farm were estimated by the farmers, and were ≥ 12 months for 30% of the cows and ≥ 18 months for 7% of the cows (n=105).

When the farmers were asked whether there were any aspects of their production they would like to improve, 42 % answered breeding. Some also added that they wanted to use more semen from exotic breeds (Friesians and Ayrshires) to improve their animals and some mentioned that they wanted to improve heat detection. 40 % of the farmers did not keep any records on performance such as productive or reproductive characteristics.

Milking routines

Most of the visited farms (65 %), milked their cows in milking parlours or cubicles, while some milked freely on pasture or in enclosures (36 %). It was more common to milk in parlours in the HL; 87 % and 44 % of the farms were milking in milking parlours in the HL and LL respectively. Most of the farmers milked two times per day (84 %) and some milked three times per day (16 %). Among those who milked twice per day, three of the farmers noted that some cows were milked only in the morning, while others were milked also in the afternoon. The milking intervals were generally uneven and milking intervals were ≤ 6 hours or ≥ 18 hours on 32 % of the farms

The milking routines were similar on the farms visited during the study. An overview of the percentage of farmers in each research group and in total who practice different milking routines, can be found in Appendix 4. It was most common to start by cleaning the hands and teats with water (which was warm on 58 % of the farms), without using a cloth (84 %). Water was collected from the cows' water drinking trough on 19 % of the farms, which often appeared dirty and brown in colour. Most did not wipe the teats dry after washing (74 %) and it was instead a common practise to stroke the teats with the hands to remove dripping water. No farmers used individual cloths to clean or to dry the teats. Restricted suckling was used on 45 % of the farms; 27 and 63 % in the HL and LL respectively. One farmer had high producing cows, with an average daily milk yield (of the studied cows) of 15.4 kg. He experienced a high incidence of mastitis in his herd and believed that the most likely reason for the high prevalence of the disease was incomplete udder emptying. Lubricating ointments marketed for dairy cows (milking salve) were used during milking on all but one farm (97 %), and were of the brands Cooper's, High Chem, Norbrook and Arimi's. Pictures of different milking environments can be found in Appendix 5. A few farmers answered that they wanted to invest in milking machines when they were asked if there were any aspects of their production they wanted to improve. The reason for this was the inefficient use of time with hand-milking and the unreliability of employed workers.

Feeding during milking was more common in the HL (67%) than in the LL (38%) and was practiced on 52 % of the farms in total. The full-hand grip was the milking technique most commonly used by the farmers (74 %), followed by the pull-down grip (26 %). 65 % of the farmers milked into metal containers while the rest milked into plastic containers. When asked whether they deliver milk to the FCS in metal or plastic containers, 84 % answered that they deliver in metal, 10 % in plastic, and 6 % answered that they deliver in both metal and plastic containers.

4.2.2 Milk yield

Descriptive statistics

The average milk yield recorded during afternoon milking on all the 31 farms was 2.38 kg in total; 2.52 kg in the HL and 2.27 kg in the LL. The median for the registered milk yields were 2.03 kg (interquartile range (iqr) 1.29) in the HL and 2.26 kg (iqr 1.68) in the LL.

After converting the data into daily milk yield, by accounting for number of milkings per day and milking intervals, the average daily milk yield was estimated to be 6.58 kg (median 5.45) in total and 6.93 kg (median 6.09) in the HL and 6.29 kg (median 5.24) in the LL. As illustrated in Figure 4, daily milk yields were higher for *Bos Taurus* breeds (mean 7.29 kg) compared to *Bos Indicus* breeds (mean 3.53 kg) and crossbreeds (mean 5.23 kg). The results further show that daily milk yields were highest in zero-grazing systems (mean 9.13 kg) followed by semi-zero systems (mean 6.96 kg) and free-grazing systems (mean 4.71 kg).

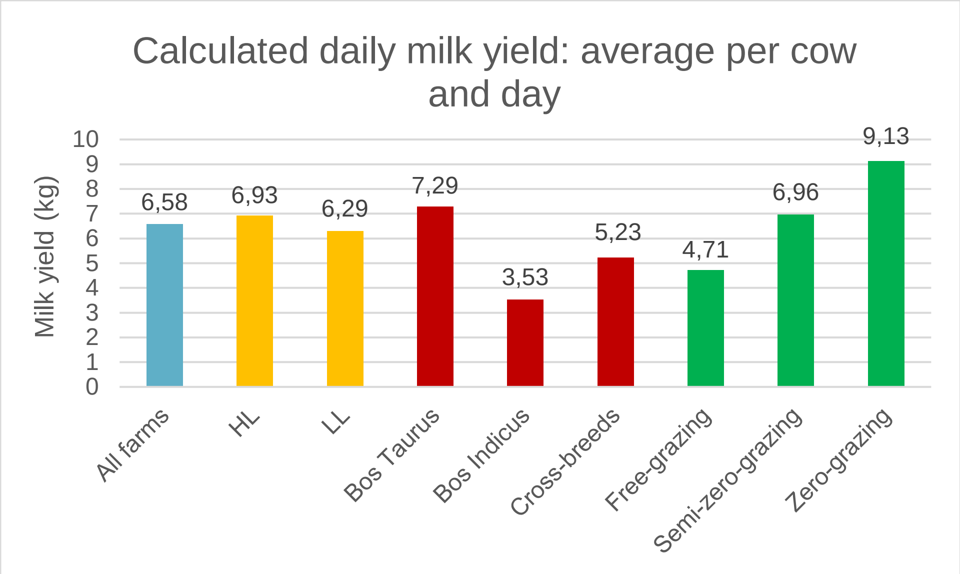

Figure 4. Calculated average daily milk yield per cow and day (kg); presented in total (blue) and for the different production environments (highlands (HL) and (LL) (yellow), breed categories (red), and feeding systems (green). The estimations are based on milk yield recordings made during 31 farm visits in the Baringo county, Kenya during late rainy season (September and October) in 2017.

Inferential statistics: Difference in milk yield between production environments and feeding systems

There was no significant statistical difference in milk yield between the HL and LL or between free-grazing systems compared to semi-zero- or zero-grazing systems ($p > 0.05$) (Table 2). The difference between the corrected means for production environments was 1.30 kg (SE 1.29), and feeding systems 1.54 kg daily milk yield per cow (SE 1.55) (Table 3). Cows with lactation stages < 8 months had 3.16 kg (SE 0.77) higher daily milk yields compared to cows in lactation stages of ≥ 8 months ($p < 0.001$). Cows with body condition scores of ≥ 3.5 had 3.39 kg (SE 1.34) higher daily milk yields than cows with BCSs of < 2.5 ($p < 0.05$).

Table 2. *P-values of predictor variables, obtained from the ANOVA performed on model 1 (milk yield) using the fit mixed effect model. The statistics is based on registrations made during or after 31 dairy farm visits in the Baringo county, Kenya, in late rainy season (September and October) in 2017.*

	P-value
Production environment	0.322
Herd	0.007***
Feeding system	0.329
Restricted suckling	0.121
Lactation stage	0.000***
Lactation number	0.870
Body condition score	0.042*
Breed	0.462

95% (*) and 99.9% (***) confidence intervals

Table 3. *Data from Tukey's pairwise comparisons, showing the number (n) of readings, corrected mean values and mean differences of milk yield (kg). Numbers are presented for the different production environments (highlands (HL) and lowlands (LL) and feeding systems (free-grazing (FG) and semi-zero & zero-grazing (SZ&ZG). The statistics is based on registrations made during or after 31 dairy farm visits in the Baringo county, Kenya, in late rainy season (September and October) in 2017.*

Variables	**Categories**	**n**	**Corrected mean (kg)**	**Difference of means**	**SE of difference**	**P-value**
Production environment	**HL**	52	5.15	1.30	1.29	0.322
	LL	62	6.46			
Feeding system	**FG**	48	5.04	1.54	1.55	0.329
	SZ&ZG	66	6.57			

4.2.3 SCC

Descriptive statistics

The average whole udder SCC values were 352 000 cells/ml from the total number of cows and 329 000 and 381 000 cells/ml from cows in the HL and LL respectively. The average SCC values were higher in udder quarters than in whole udder samples and there was a great variation in SCC, ranging from 9 000 to 4 242 000 cells/ml (Table 4).

Table 4. *Data on the number of recordings, mean values and ranges of whole udder and udder quarter SCC. Numbers (n) are presented both in total, and for the different production environments (highlands (HL) and lowlands (LL) and feeding systems. Samples were collected during 31 farm visits in the Baringo county, Kenya in the late rainy season (September and October) in 2017.*

Group	**Whole udder SCC**			**Quarter SCC**		
	n	**Mean (cells/ml)**	**Range (cells/ml)**	**n**	**Mean (cells/ml)**	**Range (cells/ml)**
Total	114	352 000	9 000 - 4 242 000	440	526 000	11 000-4 220 000
HL	62	329 000	9 000 - 1 445 000	206	521 000	16 000-3 648 000
LL	52	381 000	19 000 - 4 242 000*	244	530 000	11 000-4 220 000*
Free-grazing	48	351 000	20 000 - 1 306 000	189	559 000	11 000-3 648 000
Semi-zero-grazing	37	387 000	12 000 - 4 242 000*	147	482 000	16 000-4 220 000*
Zero-grazing	29	307 000	9 000 - 1 901 000	115	528 000	26 000-3 734 000

** The (upper limit) SCC was higher in the whole udder samples than the udder quarter samples. This irregularity is due to milk samples not always being obtained from all udder quarters (See Material and Methods 3.2.3).*

The distribution of SCC data is presented in a box plot in figure 3. The median values ranged from 118 000 cells/ml in whole udder samples from all cows to 198 000 cells/ml in udder quarter samples from the LL. The plot shows a high variation in SCC values and the interquartile ranges varied from 385 000 to 470 000 cells/ml.

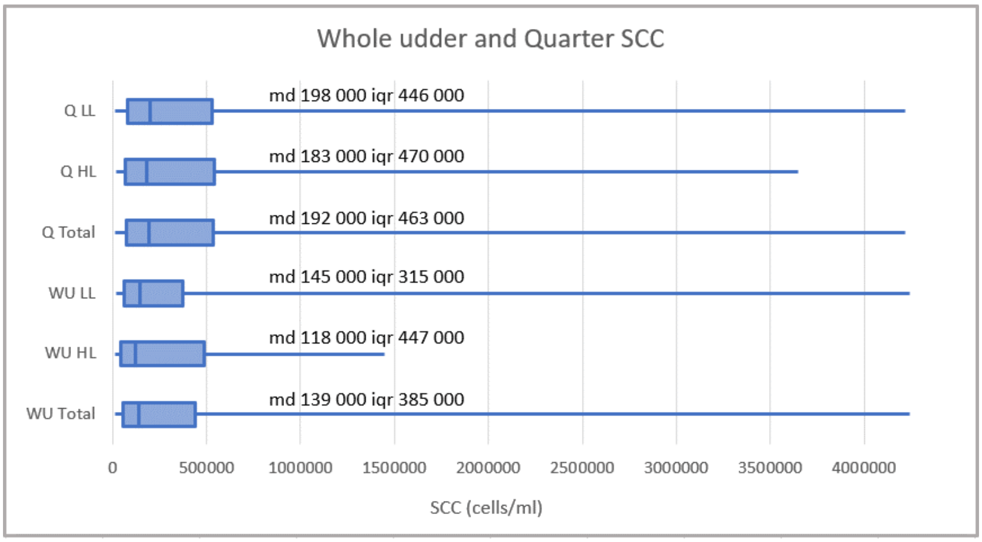

Figure 3. Box-plot illustrating the distribution of whole udder and udder quarter SCC values in total and for the different production environments (HL and LL). Median values (md), and interquartile ranges (iqr) for each data-set is clarified in numbers for each box. Samples were collected during 31 farm visits in the Baringo county, Kenya, during late rainy season (September and October) in 2017.

The proportion of cows with elevated SCC values are presented in Table 5. 58 % of the herds, and 43 % of the cows included in the study had an average SCC value of ≥ 200 000 cells/ml. The percentages of cows with SCCs of ≥ 400 000 and 600 000 cells /ml were 31 and 21 % for the HL, and 21 and 16 % for the LL.

Table 5. *Percentage of herds, cows and udder quarters (Q SCC) with SCCs ≥ 200 000, 400 000 or 600 000 cells/ml in the milk, both in total and for the highlands (HL) and lowlands (LL) respectively. Samples were collected during 31 farm visits in the Baringo county, Kenya during late rainy season (September and October) in 2017.*

	SCC ≥ 200 000 cells /ml (%)			**SCC ≥ 400 000 cells /ml (%)**			**SCC ≥ 600 000 cells /ml (%)**		
	Total	**HL**	**LL**	**Total**	**HL**	**LL**	**Total**	**HL**	**LL**
Herd SCC	58	60	56	35	40	31	16	13	19
Cow SCC	43	40	45	25	31	21	18	21	16
Q SCC	49	49	50	30	31	30	23	24	23

The SCC measurements of quarter milk showed that many of the cows in the study had elevated SCC in one or more of the udder quarters. 38 % of all the cows included in the study had ≥ 1000 000 cells/ml in at least one of its udder quarters, and these cows were evenly spread between the two production environments, with 38 and 37 % in the HL and LL respectively (Table 6).

Table 6. *Number and percentage of cows with at least one udder quarter with ≥ 1000 000 cells/ml, in total and in the highlands (HL) and lowlands (LL) respectively. Samples were collected during 31 farm visits in the Baringo county, Kenya, during late rainy season (September and October) in 2017.*

Cows with at least one udder quarter with ≥ 1000 000 cells /ml		
	No.	**%**
HL	37	38
LL	42	37
Total	79	38

Inferential statistics: Difference in whole udder SCC between production environments and feeding systems

Production environment and feeding system did not significantly affect whole udder LNSCC ($p > 0.05$). Among the predictor variables in model 1, herd was the one with the greatest effect on whole udder LNSCC ($p < 0.05$) (Table 7). The difference in corrected mean values were 0.258 SE 0.483 (LNSCC cells/µl) (= SCC 1 294 SE 1 621 cells/ml) for production environments and 1.060 SE 0.573 (LNSCC cells/µl) (= SCC 2 886 SE 1 774 cells/ml) for feeding systems (Table 8).

Table 7. *P-values of predictor variables, obtained from the ANOVA performed on model 2 (whole udder LNSCC) using the mixed effect model. The statistics is based on registrations made during or after 31 dairy farm visits in the Baringo county, Kenya, in late rainy season (September and October) in 2017.*

	P-value
Production environment	0.599
Herd	0.027*
Feeding system (2 groups)	0.080
Daily milk yield	0.482
Restricted suckling	0.095
Lactation stage	0.232
Lactation number	0.288
Breed	0.821

95% (*) confidence interval

Table 8. *Data from Tukey's pairwise comparisons, showing the number (n) of readings, corrected mean values and mean differences of whole udder LNSCC. Numbers are presented for the different production environments (highlands (HL) and lowlands (LL) and feeding systems (free-grazing (FG) and semi-and semi-zero-grazing (SZ&ZG). The statistics is based on registrations made during or after 31 dairy farm visits in the Baringo county, Kenya, in late rainy season (September and October) in 2017.*

Variables	**Categories**	**n**	**Corrected mean (ln cells/µl)**	**Difference of means**	**SE of difference**	**P-value**
Production environment	HL	52	5.024	0.258	0.483	0.599
	LL	62	5.282			
Feeding system	FG	48	5.683	1.060	0.573	0.080
	SZ&ZG	66	4.623			

Inferential statistics: Difference in udder quarter SCC between production environments and feeding systems

There was no significant difference in udder quarter LNSCC between production environments ($p > 0.05$), but there was a significant difference between feeding systems ($p < 0.05$) (Table 9). However, since there was a significant correlation between feeding system and production environment ($p < 0.05$) on udder quarter LNSCC, it was necessary to compare quarter LNSCC values for the different feeding systems within each production environment. Average udder quarter values were 1.214 (LNSCC cells/µl) (= SCC 3 367 SE 1 503 cells/ml) higher in free-grazing systems compared to semi-zero- or zero-grazing systems in the HL ($p < 0.05$) (Table 10). In addition to these results, cow had a significant effect on udder quarter LNSCC ($p < 0.001$) (Table 9).

Table 9. *P-values of predictor variables, obtained from the ANOVA (mixed effect model) performed on model 3 (udder quarter LNSCC). The statistics is based on registrations made during or after 31 dairy farm visits in the Baringo county, Kenya, in late rainy season (September and October) in 2017.*

	P-value
Production environment	0.314
Cow ID	0.000***
Feeding system (2 groups)	0.029*
Daily milk yield	0.814
Restricted suckling	0.055
Lactation stage	0.916
Lactation number	0.652
Breed	0.394
Production environment * feeding system	0.041*

95% (*) and 99.9%(***) confidence interval

Table 10. *Data from Tukey's pairwise comparisons, showing the number (n) of readings, corrected mean values udder quarter LNSCC. Numbers are presented for the different feeding systems (free-grazing (FG) and semi-and semi-zero-grazing (SZ&ZG) within each production environment (highlands (HL) and lowlands (LL). The statistics is based on registrations made during or after 31 dairy farm visits in the Baringo county, Kenya, in late rainy season (September and October) in 2017.*

Production environment	**Feeding system**	**n**	**Corrected mean (ln cells/µl)**	**Groupings**	**Difference of means**	**SE of difference**	**p-value**
HL	FG	40	6.422	A	1.214	0.408	0.019*
	SZ&ZG	166	5.208	B			
LL	FG	133	5.579	AB	0.079	0.393	0.997
	SZ&ZG	107	5.500	AB			

95% (*) confidence interval. Groupings (A, B and AB) shows for which groups the difference of means is significant (groups that do not share a letter are significantly different).

4.2.4 Milk pH

Descriptive statistics

Milk pH ranged from 6.44 (SD 0.09) in free-grazing systems to 6.53 (SD 0.09) in zero-grazing systems and from 6.46 (SD 0.10) in the LL to 6.52 (SD 0.11) in the HL (Table 11).

Table 11. *Data on the number of recordings, mean values and SD values of milk pH. Numbers are presented both in total, and for the different production environments (highlands (HL) and lowlands (LL) and feeding systems. The data was collected during and after 31 dairy farm visits in the Baringo county, Kenya, in late rainy season (September and October) in 2017.*

	N	Mean	SD
Total	106	6.49	0.10
HL	44	6.52	0.11
LL	62	6.46	0.10
Free-grazing	48	6.44	0.09
Semi-zero-grazing	29	6.51	0.11
Zero-grazing	29	6.53	0.09

Inferential statistics: Difference in pH between production environments and feeding systems

Neither production environment nor feeding system influenced pH in milk ($p > 0.05$) (Table 12) and the difference of corrected mean values were 0.016 (SE 0.032) for production environments and 0.022 (SE 0.038) for feeding systems. Cows that were restrictedly suckled had 0.08 (SE 0.04) units lower milk pH than cows that were not restrictedly suckled ($p < 0.05$) (Table 13). Calculated daily milk yield was negatively correlated with milk pH ($p < 0.05$) (Table 12), with a correlation coefficient of -0.0068, indicating a decrease in pH with 0.0068 units, for every increase in milk yield with 1 kg.

Table 12. *P-values of predictor variables, obtained from the ANOVA performed on model 4 (milk pH) using the fit mixed effect model. The statistics is based on registrations made during or after 31 dairy farm visits in the Baringo county, Kenya, in late rainy season (September and October) in 2017.*

	P-value
Production environment	0.621
Herd	0.020*
Feeding system	0.564
Daily milk yield	0.022*
Restricted suckling	0.040*
Lactation stage	0.165
Lactation number	0.443
BCS	0.308

95% (*) confidence interval

Table 13. *Data from Tukey's pairwise comparisons performed after ANOVA, showing the number (n) of readings, corrected mean values and mean differences of milk pH. Numbers are presented for the different production environments (highlands (HL) and lowlands (LL) and feeding systems (free-grazing (FG) and semi-and semi-zero-grazing (SZ&ZG). The statistics is based on registrations made during or after 31 dairy farm visits in the Baringo county, Kenya, in late rainy season (September and October) in 2017.*

Variables	**Categories**	**N**	**Corrected mean**	**Difference of means**	**SE of difference**	**P-value**
Production environment	**HL**	62	6.47	0.016	0.032	0.621
	LL	42	6.49			
Feeding system	**FG**	48	6.47	0.022	0.038	0.564
	SZ&ZG	56	6.49			

5 Discussion

5.1 Management routines on farms

Management routines did not vary considerably between the different production environments. The high use of AI in the region and high proportion of *Bos Taurus breed* indicate that much emphasise likely has been put on introducing exotic breeds in the region. Kosgey *et al*., (2011) wrote that many smallholder farmers lack sufficient knowledge of breeding management and record keeping. In the present study, 60 % of the farmers answered that they keep records of some kind which suggests a high awareness of the importance of record keeping and could indicate that efforts also have been made to improve breeding management even though many farmers have not yet adopted this practice. Increasing the use of record keeping would enable farmers to make management decisions more easily (Kosgey *et al*., 2011) such as knowing which the most limiting aspects are in the production to increase milk yield. Another aspect which gives an idea about breeding practises on farms, other than record keeping, is calving intervals. Many farmers did not know what to answer when they were asked what the average calving interval was on their farms, which made it difficult to draw any conclusions from that information since all farmers did not keep records of that information. However, the high lactation stages on some cows included in the study, provided indirect information about long calving intervals on some of the farms. The long calving intervals on some farms are not necessarily a result from insufficient knowledge of breeding management, since it is very much influenced by feeding (Bebe, 2004). However, reducing calving intervals is of great importance for some farmers in the studied region to increase productivity.

Restricted suckling has in previous studies been found to be an efficient way to stimulate milk let down. The calf's presence stimulates oxytocin release (Lupoli *et al*., 2001), even when it is only standing close to the cow prior to milking, and not just when it suckles (Combellas *et al*., 2002). It has also been suggested that practicing restricted suckling could improve lactation persistency (Das *et al*., 1998). Indications have also been found, that letting a calf suckle in connection to milking could have a positive effect on udder health (Fröberg *et al*., 2008; Krohn, 2001). One farmer that was visited during the study, experienced big problems with mastitis in his herd and he believed his biggest challenge was to achieve full udder emptying. This farmer would probably benefit from letting calves suckle after finished milking, instead of separating the calves from their mothers soon after birth, since it is not possible to empty the udder completely by hand and probably would be beneficial for the growth and well-being of the calves. It sometimes seemed that many progressive farmers were reluctant to go back to practicing restricted suckling since it to them was associated with a low producing production system. The same attitude seemed to exist towards feeding systems; zero-grazing systems were promoted by most extension officers even in situations when pasture resources were abundant.

The practice to feed cows during milking, found in 52% of the farms, may have contributed to an increased oxytocin release (Svennersten *et al.*, 1995) and consequently an increased milk yield (Johansson *et al.*, 1999; Ferneborg *et al.*, 2016). The daily milking intervals were very uneven on most farms visited during this study. It is necessary to milk regularly to prevent the inhibition of milk synthesis that happens when milk volume increases in the udder which causes FIL to accumulate (Sjaastad *et al.*, 2010) and mammary blood flow to be reduced (Delamaire & Guinard-Flament, 2006). This highlights the importance of maintaining even milking intervals to prevent these physiological responses to happen when milk accumulates in the udder. Stelwagen *et al*. (1997) found that tight junctions open when the time since milking had exceeded 18 hours and the junctions remain open for 6 hours post milking. The milking intervals were either < 6 or ≥ 18 hours on 32 % of the farms. These uneven milking intervals have a negative influence on milk yield and could also increase the risk of mammary inflammation since the permeability of the mammary epithelial cells is increased which increase the risk of inflammatory cells entering the milk (Korhonen & Kaartinen, 1995). Changing the routine from milking with uneven, to even, intervals is easy to accomplish practically, and would benefit the productivity of farmers and health of the animals. It would therefore be beneficial to provide farmers with training regarding the impacts of milking intervals on production.

Milking two times instead of once daily has a positive influence both on milk yield (Stelwagen *et al*., 1997) and SCC (Stelwagen & Lacy Hulbert, 1996) and it reduces the risk of bacterial colonisation of the udder (Sandholm & Korhonen, 1995). 84 %

of the farms participating in this study practised twice daily milking while 16 % milked three times per day. Although milking three times a day could have a positive influence on milk yield and udder health, it is important to maintain a sufficient milking interval to prevent the udder from becoming damaged (Korhonen & Kaartinen, 1995; Stelwagen *et al*., 1997). Furthermore, hand-milking technique is something which could impact teat condition (Millogo, 2012) and the full-hand grip is preferable to prevent teat damage (FAO & IDF, 2011). The full-hand grip or techniques similar to the full-hand grip was practices on 74 % of the farms while the pull-down technique was used on 26 % of the farms. These results suggest that the hand-milking technique was favourable on most farms practicing the full-hand grip, but that milkers using the pull-down technique should aim to develop their technique to prevent teat damage.

In FAO & IDF's guide to good dairy farming practice, it is described that milking equipment which will be in contact with milk and detergents, such as milk containers, should be of resistant materials. Most farmers in this study answered that they use metal containers for delivery of milk but only 65 % of the farmers used buckets in metal during milking. This emphasize that there is a development potential among the farmers to change milk equipment in plastic to metal since metal is a much more resistant material which is easier to clean. Milking into a vessel that is improperly cleaned increases the risk of the milk becoming spoiled (Ton *et al*., 2016).

5.2 Udder health

The udder health status varied among the farms in the study, but the ANOVA analysis resulted in no significant difference in whole udder LNSCC, udder quarter LNSCC or milk pH between the production environments (HL or LL). One could have expected that the different production environments could have influenced udder health due to the expected differences in management routines, feed and water availability and environmental conditions. This was however not the case for the present study. The management routines contrasted, were generally similar in the different production environments.

There are several factors which could have influenced the milk SCC values and that were not accounted for during the analysis. For instance, SCC fluctuate over the day and is influenced by the number of hours since the last milking (Riekerink, 2007) and by how many times the cows are milked per day (Stelwagen & Lacy Hulbert, 1996). SCC is higher after milking compared to before and during milking (Riekerink *et al.*, 2007). In accordance with this, the udder quarter milk samples collected in the present study had higher SCCs than the whole udder samples since they were collected after milking while the whole udder samples were collected from milk from complete milkings. The variations were very high in the datasets which could have influenced the results from the analyses. The median SCC values (whole udder 139 000; udder quarter 198 000 cells/ml) were for instance much lower than the mean SCC values (whole udder 352 000; udder quarter 526 000 cells/ml) and 38% of the cows had at least one udder quarter with ≥ 1 000 000 cells/ml. Additionally, farms that were to be included in the study were chosen by representatives from the FCS, they had to milk in the afternoon, and had to be located within a practical distance to enable two farm visits within one afternoon. The selection of farms was thus influenced by the human factor and by practical conditions. An increased number of cows in the study and a controlled selection procedure for choosing farms to be included in the study are aspects that could be improved to increase the credibility of the results.

The results from the mixed effect model analysis of udder quarter LNSCC showed a significantly higher LNSCC in free-grazing systems compared to semi-zero-systems in the HL. It is questionable however, whether this difference is worth noting since the number of farms with free-grazing systems in the HL only were two and the results may have been influenced by such a different number of readings in the contrasted groups.

The mean pH-value was 6.49 which is low compared to the values presented in previous literature, where pH in healthy milk is reported to range between 6.6-6.8 (Walstra *et al.*, 1999). However, those pH-values were found at a temperature of 20 °C in the milk and the milk samples of the present study were not cooled after collection. Since milk pH to a high degree is influenced by temperature, this may be the explanation for the comparably low pH-values in this study compared to literature.

The higher milk pH in systems where restricted suckling systems was not used may be a sign of high SCC, as in agreement with previous studies (Batavani *et al.*, 2007; Wielgosz-Groth & Groth, 2003). It may be suspected that the restricted suckling could have had a positive influence on udder health, as have been suggested previously (Fröberg *et al.*, 2008; Krohn, 2001). However, restricted suckling did not have a significant effect on neither whole udder ($p = 0.095$) or udder quarter LNSCC ($p = 0.055$). The effect of restricted suckling on quarter LNSCC is almost significant, with a p-value of 0.055, which makes it possible to suspect that the significantly lower pH-values on farms that use restricted suckling, could be due to the positive effects of suckling on udder health. It should be noted though, that the pH-values of this study must be interpreted with caution due to a possible contamination of buffer solutions.

Hagnestam-Nielsen *et al.* (2009) investigated the influence of elevated SCC on milk yield in primiparous and multiparous cows. They found that cows with > 500 000 cells/ml in their milk (whole udder), compared to healthy cows, had decreased milk yields of 1.7-2.0 and 1.1-3.7 kg for primiparous and multiparous cows respectively. The results in the present study showed that 25 % of cows had ≥ 400 000 cells/ml and 18 % of the cows had ≥ 600 000 cells/ml in their milk. This indicate a vast production loss for some of the farms that participated in this study, especially for farms with cows in high parities since this has a greater effect on reduced milk yield. Many of the studied cows were in late lactation stages. Hagnestam-Nielsen *et al.* (2009) found that the effect of elevated SCC on milk yield is more pronounced in later lactation compared to early, which emphasize the importance of reducing calving intervals.

5.3 FCSs

The absence of coolers at some FCSs likely resulted in longer durations from milk collection until the milk entered a cooler. Due to poor infrastructure and limitations in the vehicles, it was not always possible to deliver all milk in one delivery, so it could take an entire day before the morning milk reached a cooler. However, the milk chain was not studied in detail in this study and extensive conclusions regarding the cold chain can therefore not be drawn based on these findings. One area of interest for a further study could be to investigate which part of the dairy chain that is the most critical in terms of affecting milk quality.

Some FCS also practiced local sales of milk without processing it and without cooling the milk at any stage. Omore *et al*. (2000) investigated public health risks from consuming raw milk and found a high variation in detected brucellosis in milk. The researchers emphasized the risk of mixing milk from different farms since it increases the risk of bacterial spread, and further argued that the long storage times of the milk further cause the bacteria to rise in numbers. However, Omore *et al.* (2000) also claimed that the overall health risks are low, provided that the consumer boils the milk before consumption. The lacking ability to maintain a cold chain and the extensive time span from collection until marketing of the milk, increase the risk of milk spoilage (Ton *et al*., 2016).

The problems with competition with milk vendors mentioned by some FCSs were similar to findings documented by Ton *et al*. (2016). They described that dairy co-operatives in Kenya struggle with the competition from hawkers who offer higher prices than the dairy cooperatives, require lower quality of the milk and pay the farmer directly in cash. Common coping strategies mentioned in literature were that FCSs have adopted to deal with the competition of the hawkers. These included; shortening of payment periods, offerings of additional services to their members such as buying things on check-off, and increasing the involvement of the members by for instance promoting leadership (Ton *et al*., 2016).

Feed and water access varied considerably between the dry and wet season in the area and is further discussed by Möller (2018). One FCS only had an active membership of 4% during the dry season which emphasizes the vulnerability of farmers to drought in some regions of Baringo. Another FCS reported that they do not deliver any milk to the processor during the dry season when demand is high, and the milk is instead sold raw locally. Some FCS also experiences challenges with short contracts with processors and one person explained that contracts with processors change monthly, depending on the price that is offered. This fluctuation in milk supply was discussed by Muriuki (2003) who describes that processors are more likely to reject milk in the wet season when supply is high compared to the dry season, and that the imbalance in milk supply over the seasons cause big milk losses. The researcher explained the reasons for milk becoming spoiled being; the challenge of maintaining a cold chain, the availability of water and power, and the poor infrastructure in the milk chain. The fluctuation in milk supply over seasons in this study was further evident in the prices that farmers were offered. Farmers could get as little as 27 ksh (0.26 USD) in the wet season, while they could be offered 60 ksh (0.58 USD) in the dry season.

Most of the FCS reported that they perform quality testing of the milk, and the most common tests are the organoleptic-, alcohol- and the lactometer test. Similar milk quality testing procedures by dairy cooperatives were reported by Ton *et al*. (2016) who described that organoleptic testing usually is performed during collection of the milk, on farm level, while density and pH-testing is performed at the cooling facility. Quality testing of milk in Sweden involve testing fat and protein content, bacterial count, SCC, antibiotics in milk, freezing point and appearance (LRF, 2014). These additional tests, allow for detection of elevated SCC and bacterial counts; which affect the cheese making process negatively (Foreman & De Leeuw, 2013; Ali-Vehmas & Sandholm, 1995). Increasing the number of quality tests performed and developing a quality based payment system for milk would strengthen the Kenyan dairy sector, improve food safety and product quality (Foreman & De

Leeuw, 2013) and would be an incentive for all actors along the milk chain to improve the handling of milk.

Some of the representatives from the FCSs and the KCC's cooling facility, described that rejection of milk often could be caused by the mixing of morning and evening milk. This suggests a wish by farmers to deliver evening milk, but that the possibility to cool the milk or to deliver twice per day is lacking. This could cause farmers to risk contamination the fresh morning milk to gain an extra income. Muriuki (2003) discussed the problem with forced consumption, which refers to the situation when the actual needs of the household are exceeded since all intended milk cannot be delivered. Since some cooperatives had experienced mixing of milk to have been a problem among their members, this suggest that the problem of forced consumption, which Muriuki describes, could have a problem also in Baringo.

6 Conclusion

No clear differences were found between management practices, milking routines, udder health or milk yield between the HL and LL. The calculated average milk yield was 6.58 kg per cow and day and the milk SCC varied greatly between farms, cows and udder quarters. The median milk SCC was low in whole udder samples with 139 000 cells/ml, but 25% of the whole udder samples had ≥ 400 000 cells/ml and 38% of the cows had at least one udder quarter with ≥ 1 000 000 cells/ml. The results further indicate that milking intervals were uneven on many farms, with ≤ 6 or ≥ 18 hours on 32% of the farms and should be improved to increase milk yield Additionally, indications of a beneficial effect of restricted suckling on udder health were found and should be seen as an important practice to promote good udder health.

Quality testing of milk was practiced by most FCS, but poor infrastructure and lack of coolers in some regions poses a risk of milk spoilage. The low and fluctuating active memberships of the FCS, vulnerability to climate seasons, and the imbalance of supply and demand of dairy products suggest a development potential in the region. Improving the availability of feed and water, increasing the number of daily milk deliveries from farmers to FCS in some regions, improving contracts with processors and finding ways of coping with the competition of informal milk vendors are aspects which likely would contribute to increased milk production in the Baringo area.

7 References

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7.1 Personal communication

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Appendix 1

Questionnaire: primary cooperatives

Co-operative:
Date:
Name:

How many farmers are members of your co-operative?	
How many of them are active?	
How much milk is delivered to the co-operative each day?	
How often do you collect milk at and at which times?	
Do you have access to a cooler?	
Do you process any of the milk yourself? If so, which products?	
Which processor do you deliver to?	
Do you analyse the milk? If so, for which parameters?	
Is it a frequent problem with bad quality milk?	
Do you have a warning system for farmers with rejected/adulterated milk?	
Do you offer extension services?	
How many employees do you have?	
Are your staff trained in any way?	
Do you offer AI-services?	
Do you have an available veterinarian?	

Do you have any vaccination program?	
Do you have problem with any particular diseases?	
What do you believe is the most important aspect farmers need to improve?	

Appendix 2

Questionnaire: farms

Farm number:
Co-operative:
Date:
Name:

What is your age?	
Do you have an educational back-ground?	
Have you grown up on a farm?	
If not, have you started the agricultural business yourself?	

Milking routines

How many lactating cows do you have?	
How often do you milk the cows, and at what time?	
Who performs the milking, hired la-bour or family members?	
How often do you deliver to the MCC?	
If milk is only delivered in the morn-ing: Do you have a problem with ex-cess milk from evening milking?	
Can you cool milk until delivery the following day?	
For what period of time is milk stored after milking until pick-up?	

Productivity

How much milk does each cow yield per day on average?	
Is there a difference between dry and wet season?	
How much milk do you deliver to the co-operative each month?	
Is dairy production the main source of income for your household?	
If not, what other income sources do you have?	

Milk consumption

How much milk is consumed within the household each day?	
Is the milk boiled or processed in any way before consumption?	

Buildings

How are your cattle housed?	
Are they housed differently during the day and night?	
How do you handle the manure?	
Do the cattle have access to shade during the daytime?	

Breeding

What breeds do you have?	
Do you prefer specific breeds or crosses of breeds? Why?	
Do you have a strategy for breeding? Do you keep records on performance?	

What is the calving interval? (Time between when the cow delivers one calf until the next)	
How long is the dry period for your cows? (How long time before the cow gets her new calf is she dried off)	
When do you serve/inseminate the cows? (For how long into milking)	
Do you use natural or artificial insemination?	

Calf management

How long do you keep the calf together with the cow after calving?	
How often and how much milk do you feed the calves every day?	
Do you sell the bull calves?	
If so, at what age?	

Disease management

Do you have any problems with diseases?	
Are veterinary services easily available?	
Are you currently treating any animals with antibiotics?	
Are you vaccinating your cows for any disease?	

Water access and feeding system

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?	

How far is it to the nearest waterpoint?	
What type of feeding system do you have?	

Summarizing questions

Are there aspects you would like to improve with your production? If so, how?	
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 3

Observation protocol

Farm number:
Co-operative:
Date:
Name:

Animal categories

Lactating cows	
Dry cows	
Heifers	
Growing stock (for meat production)	
Breeding bulls	
Calves	

Hand wash

No wash	Wash with water	Wash with soap and water	Warm water	
			No	Yes

Comments:

Cow cleanliness

Whole cow	Clean	Moderate	Dirty
Udder	Clean	Moderate	Dirty

Udder cleaning

	No	Yes
Wash of the udder		
• With cloth		
Wipe dry teats		
• Dry cloth		
• Wet cloth		
Individual cloths		

Comments:

Hand wash between cows

Yes	No

Pre-stimulation

No pre-stimulation	Massage	Calf-stimulation

Lag-time

No	Yes

Calf presence during milking

	No	Yes
Calf present		
Allowed to suckle		
• Before milking		
• After milking		

Comments:

Fore-stripping

No	Yes	Yes + inspecting the milk

Feeding during milking

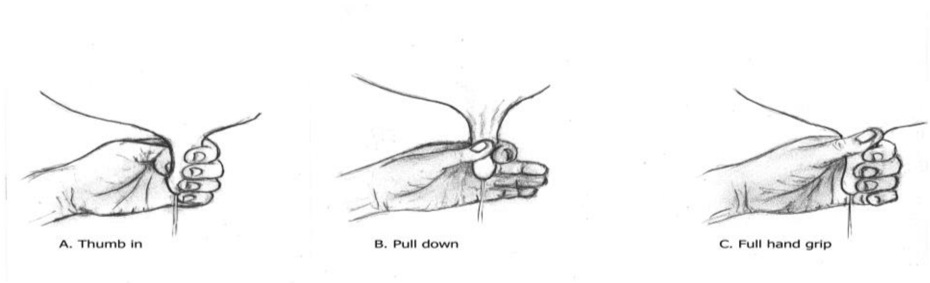
No	Yes

Milking method

Hand-milking	Machine-milking

Hand-milking technique

Thumb in	Pull down	Full hand grip



Comments:

Milking salve

During milking	After milking	No

Milking salve brand:

Teat-dip after milking

No	Yes

Cleaning of milk containers and milking equipment

Wash with water	Wash with detergent and water	Warm water	
		Yes	No

Type of container for milk delivery

Plastic	Metal

Milk yield

Cow	Milk yield (kg)	Lactation stage (M)	Lactation number	Breed
1				
2				
3				
4				
5				

Appendix 4

Overview of the percentage of farmers in each research group and in total who practice different milking routines. Based on 31 farms; 15 in the HL and 16 in the LL.

		HL	LL	Total
Hand-wash	**Water**	87	94	90
	Soap and water	13	0	7
	No	0	6	3
Hand-wash between cows		50	73	62
Warm water		93	25	58
Wash of udder	**Without cloth**	80	88	84
	With cloth	20	0	10
	No	0	13	6
Wipe dry	**With dry cloth**	13	19	16
	With wet cloth	20	0	10
	No	67	81	74
Individual cloths		0	0	0
Pre-stimulation	**Calf**	20	56	39
	Massage	80	44	61
	No	0	0	0
Restricted suckling		45	63	27
Feeding during milking		67	38	52
Milking technique	**Thumb in**	0	0	0
	Pull down	27	25	26
	Full hand grip	73	75	74
Teat dip after milking		0	13	6
Milking salve		100	94	97
Vessel to milk in	**Plastic**	40	31	35
	Metal	60	69	65

Appendix 5

Selection of pictures of taken during milking in different environments on farm visits in Baringo 2017.