ASSESSING FARM LEVEL PRACTICES AFFECTING MILK PRODUCTION, QUALITY AND POSTHARVEST LOSSES IN SMALLHOLDER DAIRY AND PASTORAL CAMEL HERDS OF KENYA

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A Research Thesis Submitted to the Graduate School in Fulfillment for the Requirements for the Award of the Degree of Doctor of Philosophy in Animal Science

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DECLARATION AND RECOMMENDATION

DECLARATION

This research thesis is my original work and to the best of my knowledge has not been presented for award of a degree at any other university.

Olivier Basole Kashongwe

Signature ................... Date ....

RECOMMENDATION

This research thesis has been prepared with our supervision and submitted to graduate school for examination with our approval as university supervisors

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DEDICATION

I dedicate this work to:

My wife Emmanuelle Furaha Nkaba, my daughters Ohanna and Shukria Kashongwe

My parents Prof. Zacharie Munogolo Kashongwe and Prof. Josephine Cishala Kashongwe;

My brothers Jean Paul, Innocent, Hervé, Prince and Jonathan, and to my sister Princesse;

For the far He has taken us from, may all the glory be to God.

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ABSTRACT

Farm level post harvest milk losses (PHL) in smallholder and pastoral milking herds that occur at milking, pooling, evening storage or at the farm gate delivery may be associated with many farm practices. This study tested the hypotheses that PHL results from milk hygiene practices, that feeding practices influence production and quality of milk, and that milk market outlets influence milk hygiene and PHL. Data was obtained in cross sectional survey, on-farm milk and feed sampling for quality and microbiological tests and targeted on-farm interventions to improve feeding and milk quality. Hypotheses were tested with Chi-square tests, analysis of variance and logistic regression. Mastitis prevalence within smallholder dairy herds was 1.69 times more in rural than in peri-urban farms while prevalence within pastoral camel herds was 1.56 times more in rangelands than in peri-urban herds. Mastitis positive milk samples had higher incidences of *Staphylococcus aureus* than of *Streptococcus* species, both in smallholder (57.9% vs 23.7%) and pastoral (41.6%vs 36.5%) herds. High SCC was associated with high prevalence of mastitis and *Staphylococcus aureus.* High SCC (≥4x 10^5cells/ml) was associated with PHL in pastoral (58.8%), in smallholder rural (27%) and in smallholder peri-urban (7%) herds. Feed diversity, quantity and quality (energy and crude protein) offered were better in rural than in peri-urban smallholder herds but had little influence on milk yields. Feeding green forages with crop residues and concentrates attained higher milk yields (10 kg to 14 kg per cow/day) in smallholder herds. Feeding in pastoral herds included *Euphorbia tirucalli* in the peri-urban where nutritional quality was better than in rangelands and feeds had influence on SCC and milk composition. Targeted intervention to improve feeding and milk quality in smallholder herds enabled the intervention group to produce 19.9 -19.2% more milk relative to control group, but intervention did not influence change in milk quality. Smallholders participating in both formal and informal markets produced more milk (21.9 kg/day) than those participating only in formal (≤14.7 kg/day) or informal (≤11.3 kg/day) market outlets. Milk quality was generally higher in informal compared to formal market outlets and milk price less than KES 28 a litre discouraged participation in formal markets (p=0.032). These results show that substantial PHL results from milk handling hygiene practices and that feeding practices influence volume and quality of milk produced while markets where farmers sell milk has influence on milk handling hygiene and PHL experienced.

Keywords: Milk hygiene, Mastitis, Feeding, Action research, Market outlets, Cows, Camels

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CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background

Over 75% of the domestic milk production in Kenya is from smallholder herds (Muriuki, 2003) while pastoral cattle and camel herds account for 24% of total supply but only a small quantity is marketed (Davies, 2007). Milk production in smallholder herds has characteristic features. Firstly, it is small scale utilizing 1 to 3 cows producing on average less than 10kg per farm per day (Bebe, 2003) and a quarter of that production is retained for home consumption (Muriuki, 2003). Secondly, there is marked unstable milk price attributable to poor rural infrastructures (Staal *et al.*, 2003). Each additional kilometre of poor feeder road separating a farm from the main road does reduce milk selling price by about 3 percent (Muriuki, 2003). Thirdly, the informal markets predominate and tends to be (Leksmono *et al.*, 2006) more competitive than the formal markets in prices to consumers (48% lower) and to farmers (22% higher). In the informal markets, raw milk is more attractive to low-to-middle income consumers because of low price as well as the taste (Muriuki, 2003). There are concerns however that trading large volumes of raw milk in the informal market outlets impacts on the hygiene and shelf life with available evidence indicating that over 50% of milk has unacceptable high total bacteria and coliform counts (Omore *et al.*, 2000).

Fourthly, postharvest milk losses (PHL) are of substantial volume (spillage) and quality (spoilage) and forced consumption, which Lore *et al.* (2005) estimates at 1.3 to 6.4% of the value of milk at the farm level. They estimated milk losses of 54.2 million litres worth about 23.9 million US$ and that the losses are significantly higher in the informal dairy market outlets. These magnitudes of milk postharvest losses contribute to less milk available to consumers and loss of income for producers, traders and/or processors and are likely to be even higher in the pastoral camel milk production herds. Interventions targeted to milk PHL in smallholder and pastoral herds are therefore of developmental relevance to realizing no poverty, zero hunger, good health and wellbeing because of direct impacts on income and food security.

At the farm level, the causes of postharvest losses are attributable to multiple causes including milking practices, storage and cooling facilities, infrastructure and marketing systems (Gustavsson *et al.*, 2011). Although milk spillage and spoilage are reported to be the major milk post-harvest losses, spoilage and losses in nutritive value could be more important, because they account for about 67% of total post-harvest milk losses (Lore *et al.*, 2005).

Spoilage may be due to contamination with foreign substances and harmful microorganisms that can cause illness to consumers (Younan, 2004). The status of the animal, unhygienic milking and poor farmers' practices negatively impact on the quality of milk produced (Lore *et al.,* 2006). These practices include cleanliness of animals (udder), milking environment, milking person and milk storage containers. Mixing of evening and morning milk can also contribute to milk spoilage depending on the preservation of evening milk (Younan, 2004; Lore *et al.,* 2006). External factors can also influence post-harvest milk losses at farm level as well as distribution and preservation of milk (Lore *et al.,* 2005). They consist of inadequate market due to failure to access the market or to market rejection; poor roads, lack of cooling facilities and unreliable electricity supply.

Milk postharvest losses reported in Kenya have ignored the seasonality effects and have been limited in geographical coverage (Muriuki, 2003; Lore *et al.,* 2005), suggesting that the magnitude of loss could even be higher, yet there is knowledge gap to inform areas to target for intervention. Building scientific knowledge on the efficient strategies to reduce milk post-harvest losses at farm level would therefore be valuable in contributing to improved income, food and nutrition security of smallholders and pastoral households who are the highly vulnerable groups in rural areas.

1.2 Statement of the problem

In smallholder and pastoral herds, milk postharvest losses (PHL) in quantity (spillage), quality (spoilage) and in economic value can occur from udder to the farm gate at milking, bulking, evening storage or at the farm gate delivery. At each of these spots, the PHL can result from many causes including seasonal effects, poor housing, feeding practices, and unhygienic practices in milking, milk handling and transportation, insufficient access to cooling facilities and market access. However, there are knowledge gaps on the extent of losses and the associated effects of the specific causes of PHL at the farm level to inform targeted interventions with which to secure more milk for sale, food and nutrition security in smallholder and pastoral herds.

1.3 Objectives

The overall objective of the study was to quantify farm-level milk post-harvest losses (PHL) with their determinants in smallholder dairy and pastoral camel herds to inform reduction of PHL for improved food and nutrition security. The specific objectives were to:

i. Determine relationship between milking practices, mastitis infections and somatic cell counts, and their effects on pre-and postharvest milk losses
ii. Determine influence of feeding practices on milk yield and quality
iii. Determine influence of improved feeding and milk hygiene on production and quality of milk
iv. Determine influence of market-outlets on hygienic practices and milk postharvest losses.

1.4 Research hypotheses

i. There is no significant association between milking practices, mastitis infections and somatic cell counts with pre-and postharvest milk losses
ii. Feeding practices have no significant influence on milk yields and quality
iii. Improving feeding and milk hygiene practices will not significantly influence production and quality of milk
iv. Milk handling practices, production, quality and postharvest losses are not significantly different between the milk market outlets.

1.5 Justification

In sub-Saharan Africa, 23% of food is lost at production level (Lipinski *et al.,* 2013) which contributes to deepening (Gustavsson *et al.,* 2011) hunger, lost income opportunities and food insecurity. In Kenya, quantities of food losses are not well documented, but the per capita food losses are high, between 120-170 kg/year for a total of 460 kg/year yet a large population is living in the margins of food insecurity (Lipinski *et al.,* 2013). In particular, smallholders and pastoral households are more vulnerable when losing milk due to spillage, spoilage or forced consumption. Additionally, food losses represent a waste of resources used in production such as land, water, energy and inputs. Producing food that will not be consumed leads to unnecessary CO_2 emissions in addition to loss of economic value of the food produced. Therefore interventions that help reduce PHL will contribute to more milk at the farm and in the market thereby supporting a secure food and nutrition, health and wealth for smallholder and pastoral households.

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CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In developing countries, dairy farmers earn a living from diversified subsistence activities ranging from the informal ones outside the cash economy, through more commercial production in the formal cash economy, to specialized peri-urban pockets of dairying similar to highly-capitalized production in developed countries (Dugdill *et al.,* 2013). Raw milk quality remains, however, an important component in assessing the performance of dairy chains (Srairi *et al.,* 2009). In Kenya, the dairy sector is vital for the livelihoods and food security of millions of people. Population growth and urbanization are increasing the demand for milk, hence putting pressure on the dairy sector to continuously increase production (WSPA, 2012).

Milk, in Kenya, is predominantly produced from cattle, camels and goats. Indeed, they contribute 84, 12 and 4 percent, respectively (Muriuki, 2003). More than half of total milk production originates from the central districts of the Rift-Valley and Central Province mainly from exotic and cross-bred dairy cattle (80%) (Omore *et al.,* 1999).Post-harvest losses due to spillage and spoilage significantly affect smallholder farmers' production and threaten their food security.

2.2 Post harvest milk losses at farm level

Food losses refer to the decrease in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption. It takes place at different stages of the supply chain: production, post-harvest and processing (Parfitt *et al.,* 2010). Post-harvest losses in the dairy industry can be described as losses at the farm level after milking and through the market chain up to the consumption. The latest figures about post-harvest losses in Sub-Sahara Africa food value chain show approximately 27% in milk production (Gustavsson *et al.,* 2011). In Kenya, lack of scientific follow-up and expert knowledge on post-harvest losses is apparent (Muriuki, 2003).

Losses can either be through spillage or spoilage. The spillage losses at farm level can occur during milking, storage or transportation. They are assumed to be minimal (less than 1%). But detailed information about their nature and value at farm level is not widely reported in the literature.

2.2.1. Milking and on farm milk handling practices

At farm level, milk quality is directly related to the farmer's capacity to apply handling practices that reduce exposure to pathogens and eliminate their transmission during milking (Ruegg, 2004). These practices include the animal factor which can, due to latent diseases (e.g. mastitis) contaminate the milk and unhygienic milk handling practices. These hygienic practices include cleanliness of animals (udder), milking environment, milking person and milk storage containers (Lore *et al.*, 2006). Mixing of evening and morning milk can also contribute to milk spoilage depending on the preservation of evening milk. (Younan, 2004; Lore *et al.*, 2006).

Exposure to pathogens occurs when large numbers of bacteria successfully colonize the teat end (Ruegg, 2004). The contamination can occur through colonization of the teat canal, an infected udder, or contaminants (Younan, 2004). These factors lead to mastitis (clinical or subclinical) which constitutes the main reason for spoilage of milk. The most common pathogens causing mastitis are *Staphylococcus aureus, Streptococcus agalatiae*, and *Mycoplasma bovis* (Ruegg, 2004; Gitau *et al.*, 2013). *Staphylococcus aureus* has been isolated from noses and hands of dairy workers which could serve as sources of mastitis infections for cows and heifers (Jones, 2006).

Mastitis is most commonly associated with physical and chemical changes in the milk. These changes are mainly caused by bacteria colonization of the milk. As a result there is an increase in the concentration of chloride and sodium, an increase in the pH, a decrease in the dry matter content as well as a decrease in casein concentration and a negative effect on the coagulation of milk casein (Abdurahman and Younan, 2004). The subclinical nature of these organisms results in costly infections of long duration. The udder of infected cows is the primary reservoir for contagious pathogens. Uninfected cows are exposed to organisms present in milk that originated from infected udders of other cows (Ruegg, 2004). Also exposure to environmental pathogens often occurs in areas outside the milking facility (housing areas, pastures, walkways). Manure handling, type of bedding and maintenance of cow beds all have significant influences on exposure to environmental pathogens (Keffe *et al*., 1997).

Effective implementation of a milking routine includes fore stripping, pre-dipping, adequate drying and effective post-milking teat disinfection. Fore stripping 4-5 squirts of milk from each quarter is beneficial because it allows you to detect early stages of clinical mastitis, removes foremilk which may have high bacteria counts, may serve as the primary stimulus for milk let-down, and assists in reducing mastitis (Jones, 2006).

Teat pre-dipping destroys microorganisms which contaminate the teat skin between milkings (Jones, 2006). Pre-dipping using iodine has been demonstrated to reduce standard plate counts and coliform counts in raw milk by 5 and 6fold, respectively as compared to other methods of pre-milking udder preparation (Ruegg, 2004). Sufficient time (approximately 30 seconds) and contact of the disinfectant with the teat is necessary for effective reduction in bacterial numbers (Ruegg, 2004; Jones, 2006). Effective drying of teats has been reported to lower somatic cell count and bacteria count in milk (Jones, 2006).

Post-milking teat dipping is one of the most important practices in dairy farming and it is the final hygienic defense against infection after milking is completed(Jones, 2006).This practice has been reported to contribute to the reduction of somatic cell count values in many studies (Ruegg, 2004; Jones, 2006). While teat dipping is universally recognized as a useful practice, effective implementation of teat dipping is often variable.

2.2.2 Factors contributing to post-harvest milk losses in Kenya

Cow milk is currently Kenya’s most important agricultural commodity, both in terms of quantity produced and in terms of value (FAO, 2011). Different studies report between 80 and 95% of all milk being produced by smallholders (Omore, 1999, FAO 2011). Milk is thus a major food item that is produced predominantly by smallholders and the national smallholder dairy herd has the potential to meet the market’s demand. Besides this formal dairy value chain, the informal channel is of high importance. Various studies estimate over 80% of marketed milk being sold as loose unprocessed “fresh” milk (Omore *et al.*2000, FAO 2011), which is usually boiled before consumption by the buyer. The informal channel often out-competes the formal channel by charging up to 48% lower consumer prices and paying up to 22% higher farm-gate prices (Leksmono *et al.*, 2006). Unpacked milk is often preferred by low-to-middle income consumers for its price, taste, and the possibility to test the quality at purchase. This, however, raises concerns about milk hygiene as milk and dairy products are highly perishable and pose a potential health hazard (Omore *et al.* 2000).

Milk losses can also vary with seasons with rejections of farmers’ milk by either the co-operatives or the processors being negligible during the dry season but can climb to very high levels during the wet season. For example, Muriuki (2003) estimated milk losses within the co-operative milk chain to be at 1 to 5 % on average, but this can go up to over 10 percent in the wet season when delivery rejections are common.

Despite the lack of interest on the post-harvest milk losses, there has been concern over the health risk to the consumers from unprocessed milk. It is estimated that over 80 percent of milk sold in Kenya does not pass through processors. This is the proportion that is either sold directly from farms to the consumer (neighbors and others), through itinerant traders (hawkers or small traders) or through co-operatives, milk bars and shops (Leksmono *et al.,* 2006). The quality of this raw milk will deteriorate faster with time especially where chilling facilities are not in use. Similarly, bacterial counts in milk reflect the temperature of milk; time elapsed since milking and the level of hygiene (Omore *et al.,* 2000).

Due to the characteristics of the milk production systems in Kenya (dominated by smallholder farmers), milk quality assessment at farm level may not be feasible. At market level, quality assessment showed that high proportions of milk from urban areas had unacceptable total plate (TPC) count and coliform plate count (CPC) of 61 – 84% and 39 – 69% respectively (Omore *et al.*, 2001). These results are meaningful to demonstrate that raw milk in the market (informal channel), generally very high in proportion (80% of total milk produced), does not meet the standards. And if those standards were to be enforced, probably over 50 percent of the raw milk in the market would convert to losses.

Among other contributing factors to milk post-harvest losses, lack of cold chain leading to microbiological and biochemical alteration of milk, may be considered one of the most critical (Omore *et al.*, 2001). Other contributing factors include poor harvesting methods, packaging and handling; overload postharvest circuits which also contribute to alter milk. These factors are dependent on the environment that can stimulate or inhibit them. Rural infrastructures, especially the roads which are very poor in rural areas negatively affect milk price and profitability in Kenya (Muriuki, 2003).

2.2.3 Estimation of post-harvest milk losses in Kenya

Food losses are economically avoidable. They have a direct and negative impact on the income of farmers. Given that many smallholders live on the margins of food insecurity, a reduction in food losses could have an immediate and significant impact on their livelihoods (Gustavsson *et al.,* 2011).

Postharvest handling losses include losses due to spillage and degradation during handling; storage and transportation between farm and distribution (Gustavsson *et al.,* 2011).For milk, post-harvest losses refer to spillage and degradation during transportation between farm and distribution. In Kenya, the annual milk production from all dairy species is estimated at about 3 billion kg.

Various methods have been used to estimate post-harvest losses in Kenya. Muriuki (2003) estimated post-harvest milk losses (food losses) during dry season along the milk value chain and found that losses were highest at the farm level (Muriuki, 2003). Lore *et al.* (2005), in a similar effort, found that the total value loss ranged from approximately 10 to 24 million US dollars per year They used descriptive statistics (percentages) with some assumptions to capture the losses due to forced consumption. Both authors reported spillage and spoilage as the major causes of milk losses. Lack of market and rejection at market are major factors related with milk losses (Muriuki, 2003; Lore *et al.*, 2005). Rejection at market, which is higher in wet season when production is high, is a result of poor handling and the time taken to reach markets (long distances and bad roads) (FAO, 2011).

Authors have reported forced consumption as a major component of milk post-harvest losses at farm level but its value is still to be determined. While FAO (2011) indicate the value of forced consumption losses to be notably low (less than 1% of total value loss), others like Lore *et al.* (2005) cite forced consumption as major portion of the milk post-harvest losses in milk production. The difference between these authors can be attributed to the period when the study was carried out (dry or wet season) and the method of estimation

2.3 Conceptual framework

The framework describing milk PHL is conceived as resulting from the interactions between factors influencing quality of milk and farm level post-harvest milk losses (Figure 1). Feeding practices though not directly influencing postharvest losses, affect milk composition and ability of animals to resist mastitis infections as well fed animals show lower prevalence of mastitis. The study is focused on smallholder dairy cow and pastoral camel milk production systems. Both have rural and peri-urban distinct system of production, depending on proximity to urban consumption centres. The rural pastoral herds are referred to as rangelands in this study. The rural and peri-urban herds may practice feeding, milk handling and marketing differently because of variations in production objectives, water source and quality requirements demanded in the market. Consequently, these influence magnitude of postharvest milk losses (spillage, spoilage and forced consumption) that occur in each of these milk production systems. The volume and quality of milk may influence choice of marketing channels, hence post-harvest losses. Thus improving management practices at the key points of production will have a positive impact on quality of milk production and sale.

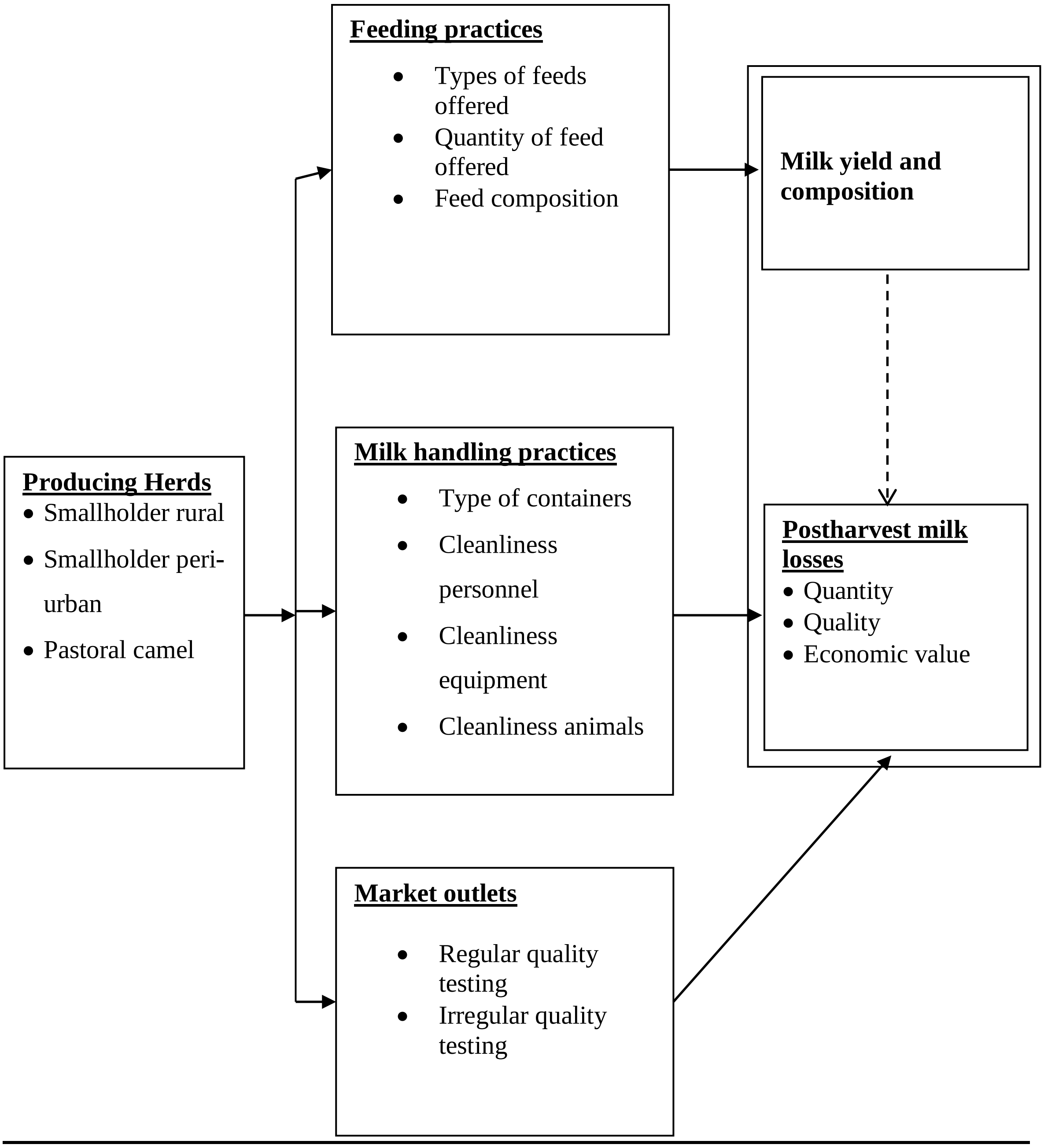

Figure 1: Conceptual framework (Source: Adapted from Aulak *et al.*, 2013)

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CHAPTER THREE

ASSOCIATIONS BETWEEN MILKING PRACTICES, SOMATIC CELL COUNTS (SCC) AND MILK POSTHARVEST LOSSES IN SMALLHOLDER DAIRY AND PASTORAL CAMEL HERDS IN KENYA

Abstract

This study investigated: (i) the relationship among milking practices, intra mammary infections and milk somatic cell counts (SCC) and (ii) the effects of high SCC on milk production and post-harvest losses in a sample of smallholder dairy and pastoral camel herds. Milking practices were recorded and milk samples from udder quarters were tested for mastitis, direct microscopic SCC and detection of *Staphylococcus aureus* and *Streptococcus species*. Estimates for production losses were computed as a proportion of cows and herds with SCC (> 200,000 cells/ml) and for milk post-harvest losses (PHL) as quantity of milk exceeding $400x10^3$cells/ml. Milking practices associated with production herds included hands washing, udder washing with warm water and milk let down stimulation either manually or with calves suckling. Udder drying was only applied in peri-urban herds and individual towel for drying only in farms milking one cow. Pastoralists did not apply any hygienic milking practice. Pre and post milking teat dipping were not practiced in all sample herds. Incidences of mastitis were higher in smallholder (60.7%) than in pastoral (57.6%) herds. The prevalence risk of mastitis in smallholder herds was 1.69 times higher in rural than in peri-urban and in pastoral, 1.56 times higher in the rangelands than in peri-urban herds. Mastitis positive milk samples had higher incidences of *Staphylococcus aureus* than the incidences of *Streptococcus species* in both smallholder (57.9% vs 23.7%) and pastoral (41.6% vs 36.5%) herds. Milking practices and animal factors (age, parity, and lactation stage) had no significant influence on SCC in both smallholder and pastoral herds. The herds with high SCC ($>4.10^5$ cells/ml) was 40% among rural and 35% among peri-urban, which respectively was associated with 10.6% and 11.6% of pre-harvest milk loss, but milk PHL from high SCC was higher in pastoral than in smallholder herds (59% vs 19%). Results indicate that high prevalence of mastitis, *Staphylococcus aureus* and *Streptococcus species* cause substantial pre- and postharvest milk losses in smallholder and pastoral herds. This could be managed with pre- and post milking teat dipping, and adopting dry cow period to improve milk quality and reduce milk PHL.

Key words: Milk handling, Mastitis, Teat dipping.

3.1 Introduction

In order of importance, milk consumed in Kenya is from cattle, camels and goats reared in smallholder or pastoral herds (Muriuki, 2003; Noor 2013). On-farm hygienic practices are important in assuring quality and safety of milk for consumers and for reducing losses at production and at post-harvest. Hygiene practices of importance include cleanliness of animals (udder), milking environment, milking person and milk harvesting and storage containers (Younan, 2004), especially for control of mastitis infections.

Mastitis is a complex disease characterized by inflammation of the mammary glands with heavy economic losses related to medication and veterinary services, microbiological diagnostic and additional management inputs, culling and replacement of the infected animals (Tyler *et al*., 1989). Significant reduction in milk yield has been associated with intra-mammary infection (Hortet and Seegers, 1998, Tyler *et al*., 1989). The inflammation severity depends on the causative agent and the host response whose somatic cells together play an essential role in immediate defense against local infection (Carrillo-Casas and Miranda-Morales, 2012). Somatic cells are cells of the immune system and are part of the natural defense mechanisms, including lymphocytes, macrophages, polymorpho nuclear and some epithelial cells (Ruegg and Pantoja, 2013). Somatic cell counts (SCC) provide good indications of infected and uninfected quarters, the former identified by increased SCC as a result of the inflammatory response to the infection (Carrillo-Casas and Miranda-Morales, 2012; Ruegg and Pantoja, 2013). The assessment of udder inflammation has therefore been based on detection of elevation of SCC either in individual quarter milk or in bulk milk from farms (Cervinkova *et al*., 2013; Pantoja *et al*., 2009).

Animal characteristics and hygienic milking practices have influence on udder health, for which Ahmed *et al*. (2011) observed that age, parity number, stage of lactation, breed, production system, hygiene of milking process, and presence of lesion on udder/teat have an influence on the prevalence of mastitis in camels. Mastitis infection contributes to changes in milk composition, in an increase in leukocyte counts, leakage of plasma proteins into the milk. The cell damage results in leakage of intracellular constituents into milk, change in ion composition and decrease in milk production (Korhonen and Kaartinen, 1995). Therefore, lower lactose concentration, higher protein concentration and lower casein/protein ratio are observed (Coulon *et al*., 2002). These changes in milk composition are mainly caused by bacteria colonization of the milk. The subclinical nature of these organisms results in costly infections of long duration. The udder of infected animals is the primary reservoir for contagious pathogens. Uninfected animals are exposed to organisms present in milk that originated from infected udders of other animals (Ruegg and Pantoja, 2013).

The two most common mastitis pathogens identified in cow and camel milk and presenting risks of pathogenicity to humans are *Streptococcus agalactiae* and *Staphylococcus aureus* (Matofari *et al*., 2005; Younan, 2004). The latter has toxin producing activity which may cause food poisoning while the former is a known cause of human infections, particularly in newborn children. *Streptococcus agalactiae* isolates from camels seems more closely related to the human than to the bovine biotype and can survive for up to 7 days in souring camel milk and at pH of 4.5 (Younan, 2004).

California Mastitis Test (CMT) is an effective diagnostic tool for rapid approximate determination of the SCC in milk from udder quarters. The CMT reagent reacts with the DNA material of somatic cells to form a gel. The CMT is graded subjectively as Negative (O) when no thickening of the gel is observed meaning no mastitis infection is found; Trace (T) when slight thickening of the mixture is observed suggesting possible mastitis infection. It is graded Positive (+ve) (1) when there is a distinct thickening of the mixture but no tendency to form a gel, meaning quarters are infected. Positive (2) is when immediate thickening is observed with slight gel formation meaning infection of udder quarters, Positive (3) is when gel is formed and surface of the mixture becomes elevated suggesting mastitis infection (Plate1).

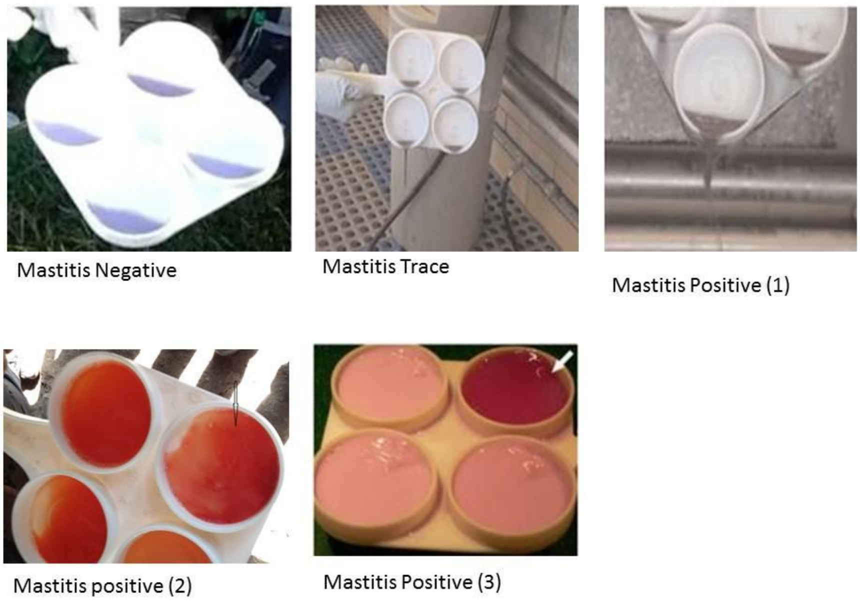

Plate 1: California Mastitis test interpretation

Best results are obtained when CMT is conducted just before milking after stimulation of let down and discarding foremilk (Shivairo *et al*., 2013). This study determined the: (i)relationship between milking practices, intra mammary infections and milk somatic cell counts (SCC) and (ii) effects of high SCC on milk production and post-harvest losses in a sample of smallholder dairy and pastoral camel herds.

3.2 Methodology

Sampling procedure

Sample milk was obtained from lactating cows and camels in smallholder dairy and pastoral herds respectively in Nakuru and Isiolo Counties. Smallholder dairy herds were randomly stratified into rural and peri-urban while camel herds could only be sampled from those with willingness to allow access and ease of accessing grazing fields where the herds had been moved to. Local Country livestock and veterinary offices aided identification and access to the herds.

Data collection

Milk samples were collected from 32 smallholder rural and peri-urban herds each, and 15 pastoral camel herds. In the pastoral system, two distinct categories of herds were observed: rangeland browsing herds (n=11 herds) and peri-urban herds feeding on *Euphorbia* *tirucalli*(n=4 herds). Udder quarters of all milking animals were tested for mastitis using California Mastitis Test (CMT) (KENOTEST, Belgium). Individual quarter milk samples were collected when found positive for mastitis; otherwise a composite milk sample of the four quarters was collected in a sterile sampling bottle. Milk samples were kept in a cool box at a temperature of $6^{O}C$ and transported to the laboratory for further analysis within 6 hours from collection. Milk yield per animal was weighed and information on animals' characteristics recorded for each sample herd.

All collected milk samples taken to the laboratory were subjected to direct microscopic somatic cell count in accordance with the procedure outlined by Sarikaya, 2006.With this procedure, milk samples are thawed to $25^{o}C$ then thoroughly mixed. An aliquot of 0.05 ml of milk was then collected and diluted in 9.95 ml of distilled water. From this solution 0.05 ml was pipetted and mixed with 0.95ml of Turk's solution. This was pipetted and put on an improved Neubaeuer Chamber where somatic cells were counted as average number of cells in the 4 corner cells and the center cell for both the upper and lower chamber.

Milk samples were further subjected to microbiological identification of *Staphylococcus aureus* and *Streptococcus, being the* major contagious pathogenic mastitis causing organisms. Milk was diluted in peptone water to 10^{-1} then streaked using an inoculating loop on Baird Parker agar and KF streptococcal agar (HIMEDIA). The plates were incubated at 37 ^{o}C for 48 hours and growth observed on the plates was used to consider presence or absence of the organisms. Isolates were further identified on the basis of colony characteristics, gram stain and biochemical tests (catalase, hemolysis and CAMP- test).

Production (pre-harvest) losses in smallholder herds were estimated as a proportion (percentage) of sample herds with high somatic cell count in milk based on procedure of Tyler *et al.* (1989) to quantify milk yield losses (Table 1). Production loss refers to the amount of milk that is not produced due to high somatic cell counts. Milk post-harvest losses (PHL) were estimated as quantity of milk exceeding 4.10^{5} cells/ml, corresponding to the level of clinical mastitis. However most of the milk with high SCC reached the market since both milk failing and passing the tests were pooled, collected by transporters and delivered to the targeted market outlet (collection centers or informal outlets). In pastoral camel herds an assumption was made that all milk positive for mastitis was a postharvest loss because of the insufficient good postharvest handling practices to making '*suusa'* (traditionally fermented camel milk) on basis of observations of Mwangi *et al*., (2015). Therefore, the proportion of milk from camels positive for mastitis was used to estimate the PHL.

Table 1: Production losses estimation in relation to SCC

SCC (x1000 cells/ml)	Production loss (%)
0—20	00
21—30	0.47
31—55	0.99
56—90	0.05
91—148	-0.88
149—245	-4.47
246—403	-6.78
404—665	-7.82
667—1097	-7.85
1098—1808	-7.12
1809—2981	-12.44
>2981	-15.22

Source: Tyler *et al.*, 1989

Statistical analysis

Chi-square test of dependence was used to determine association of milking routine and handling practices within the herds. Logistic regression was used to determine the prevalence of mastitis, *Staph. aureus* and *Strep spp.* in cows and camel milk within the herds. Regression models with stepwise selection were run to assess the relationship between management practices, farm and animal characteristics and the SCC. From this analysis, regression models with R^2 above 0.15 were selected because they contributed to more than 70% of increase in SCC and showed significant difference between production herds. Subsequent analysis was done using the GLM procedure of SAS (SAS, 2008) to determine the effects of herd management, animal characteristics on SCC (Table 2). Means were separated using Tukey's test. Finally, milk scored according to the SCC threshold of less than $2x10^5$; $2x10^5$to $4x10^5$ and above $4x10^5$cells/ml was used to estimate production and post-harvest losses. Milk yield per cow within a herd was related to its somatic cells count score and yield loss correction factor to calculate the cow and herd milk production losses.

Table 2: List of variables with R^2 submitted to regression analysis.

Variable	R^2	Decision
Intra mammary infections	**0.456**	Included
Presence of *Staphylococcus aureus*	**0.206**	Included
Lactation stage	**0.165**	Included
Parity number	0.074	Excluded
Presence of Streptococcus species	0.048	Excluded
Calves suckling	0.021	Excluded
Bulking container type	0.013	Excluded
Udder washing	0.01	Excluded
Milking container type	0.009	Excluded
Presence of cow shed	0.009	Excluded
Hand washing	0.008	Excluded
Udder drying	0.008	Excluded

3.3 Results

The herd size was variable, from 2 cows in the smallholder herds to 17 camels in pastoral herds with parities from 2.8 to 3.5. The average number of days in lactation was 230 and 239 days in smallholder peri-urban and rural, respectively, but 12% and 37% of cows were milked beyond 305-days. Pastoral herds had an average of 399 days in milk with 37% of camels milked beyond the 305- days. The herd average milk production per day in smallholder farms was 9.1kg and 12.3kg for rural and peri-urban herds respectively and 26.2 kg/day for camel herds, but cow productivity was highest in the rural herds (6.0 kg/day) and lowest in the pastoral herds (Table 3).

Table 3: Herd characteristics in smallholder dairy cow (rural and peri-urban) and pastoral camel herds

Variable	Smallholder peri-urban(n=32)	Smallholder rural (n=32)	Pastoral (n=15)
Milking cows (n)	2.3±1.3	2.3±1.4	17.1±2.1
Milk production (kg/herd)	9.1±8.5	12.3±11.9	26.2±5.0
Milk yield (Kg/animal/day)	4.9±3.6	6.0±3.9	1.5±1.8
Age of cows (years)	8.8±8.8	5.9±3.8	9.5±4.2
Parity of cows (n)	2.8±1.7	3.2±2.1	3.5±1.8
Lactation stage (days)	230.5±157.8	239.6±119.9	399.1±278.6
Cows with lactation > 305 d(%)	11.9	36.7	37

Majority of smallholder farms in the peri-urban had a cowshed with concrete floor (58.3%) and covered with iron sheets (80%). In rural farms, cows were mostly kept in open grazing areas (69.2%) and a few with a cowshed (29.8%) of which those with majority had mud floor (68.4%) and iron sheets roofing (66.7%). Cleanliness of cowshed in peri-urban farms was average and generally clean in rural farms (Figure 2).

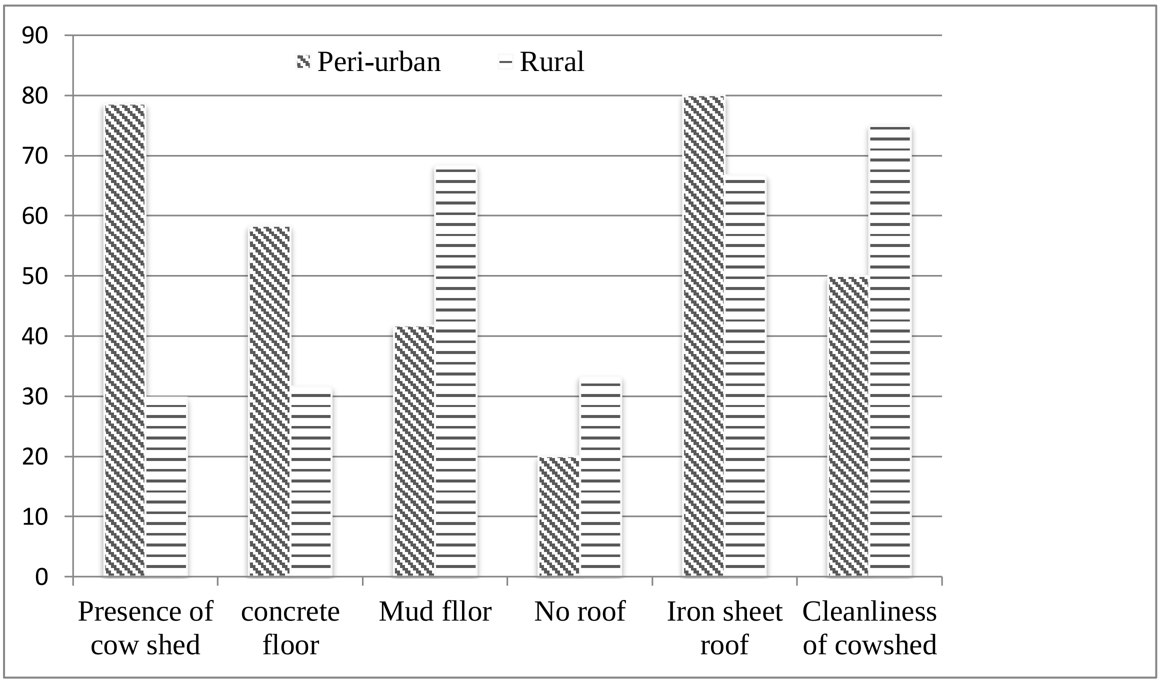

Figure 2: Cowsheds characteristics in smallholder peri-urban and rural farms

Milking was manual and routinely twice a day (morning and evening) in both smallholder and pastoral herds, but milking in pastoral herds were all in the morning (5:00 to 6:00 am and 9: 00 to 10:00 am) without a practice of pre-milking hygiene of hands and udder washing, unlike in smallholder herds.

In both rural and peri-urban smallholder herds, hand washing was a practice in the pre-milking hygiene routine (93.8 -100%) and udder washing a practice too (95 -98.8%). In contrast, hand and udder washing before milking was not a practice in pastoral herds. Teat drying before milking was a common practice in herds in the peri-urban but not in rural and pastoral herds. Pre-milking palpation to stimulate milk let down by allowing calves to suckle prior to milking (Table3) was a common practice in herds grazed in the smallholder rural (68.8%) and in pastoral rangelands (93.3%).

Milking was shorter in pastoral herds than in smallholder herds (5 vs 10 minutes). In all the sample herds, post milking hygiene was not a practice and mostly used plastic containers for milking. Bulking of milk in pastoral herds was (Table 4) in plastic containers but aluminum containers were common (62.5%) in peri-urban while either of the containers was used in rural farms (50%). Among pastoral camel herds, milk from first and second milking were in some cases mixed in the same container and kept under a shade from where it was later transported using motorbikes to urban collection centers owned by women groups.

Table 4: Milking routine and milk handling practices (% herds) in the sample herds

Variable		**Smallholder peri-urban herds** (n=32)	**Smallholder rural herds** (n=82)	**Pastoral herds** (n=15)	**Chi-Sq significance**
Hand washing	Yes	100.0	93.8	0.0	67.9***
	No	0.0	6.3	100.0	
Udder washing	Use cold water	0.0	12.5	0.0	73.5***
	Use warm water	100.0	81.3	0.0	-
	No water used	0.0	6.3	100.0	
Pre-milking palpation	Yes	100.0	100	100.0	-
	No	0.0	0.0	0.0	
Calves suckling prior to milking	Yes	0	68.8	93.3	113.7***
	No	100	31.3	6.7	
Dry teat prior to milking	Yes	100	0	0	79.0***
	No	0	100	100	
Post-milking treatment	Yes	0	0	0	-
	No	100	100	100	
Type of milking containers	Aluminum	0	31.3	0	16.8***
	Plastic	100	68.8	100	
Bulking container	Aluminum	50	62.5	0	21.3***
	Plastic	50	37.5	100	
Sample (n)		32	82	15	

***P<0.0001

Udder quarters tested in smallholder peri-urban herds had high mastitis prevalence (11.1%) corresponding to 36.2% of cows tested with at least one quarter infected compared to samples from smallholder rural herds where mastitis prevalence was7.0% of infected quarters corresponding to 23.5% of cows with at least one quarter mastitis infected. Prevalence risk of mastitis for cows in smallholder rural herds was 1.57 times lower than in smallholder peri-urban herds. The odds of finding cow positive for mastitis were 1.48 times higher in pastoral rangeland camel than in peri-urban camels (Table 5).

Table 5: Prevalence of mastitis in smallholder dairy cow and pastoral camel herds

Herds	Mastitis positive cases (%)	Odds ratio	95% C.I.	P-value
Udder quarters by herds				
Smallholder herds				
Peri-urban (n=172)	11.1	1.68	1.4 - 2.0	0.0001
Rural (n=204)	6.9	Ref		
Total smallholder herds (n= 376)	8.8			
Pastoral herds				
Rangelands (n= 666)	31.1	1.56	1.5 – 1.7	0.0001
Peri-urban (n= 184)	34.8	Ref		
Total pastoral herds (n= 860)	31.5			
Cows with ≥ 1 quarter infected				
Smallholder herds				
Peri-urban (n= 43)	32.6	1.57	1.2- 2.0	0.0005
Rural (n= 51)	23.5	Ref		
Total smallholder herds (n= 94)	27.7			
Pastoral herds				
Rangelands (n= 175)	34.3	1.48	1.2 – 1.9	0.001
Peri-urban (n= 47)	36.2	Ref		
Total pastoral herds (n= 222)	34.7			

*Mastitis positive= CMT ≥+1;
Prevalence risk computed for the odds of finding mastitis positive

At the herd level, incidence of mastitis was higher in rural (70.8%) compared to peri-urban (53.1%) smallholder herds. Figure 3 illustrates a higher prevalence of mastitis causing pathogens (*Staphylococcus aureus* and *Streptococcus species*) in smallholder rural compared to peri-urban herds. *Staphylococcus aureus* was more prevalent in mastitis positive samples from rural (60%) than from peri-urban (56.5%) herds. Regardless of the smallholder dairy herd, mastitis positive milk samples had lower cases *Streptococcus species* (23.7%) than *Staphylococcus aureus* (57.9%).

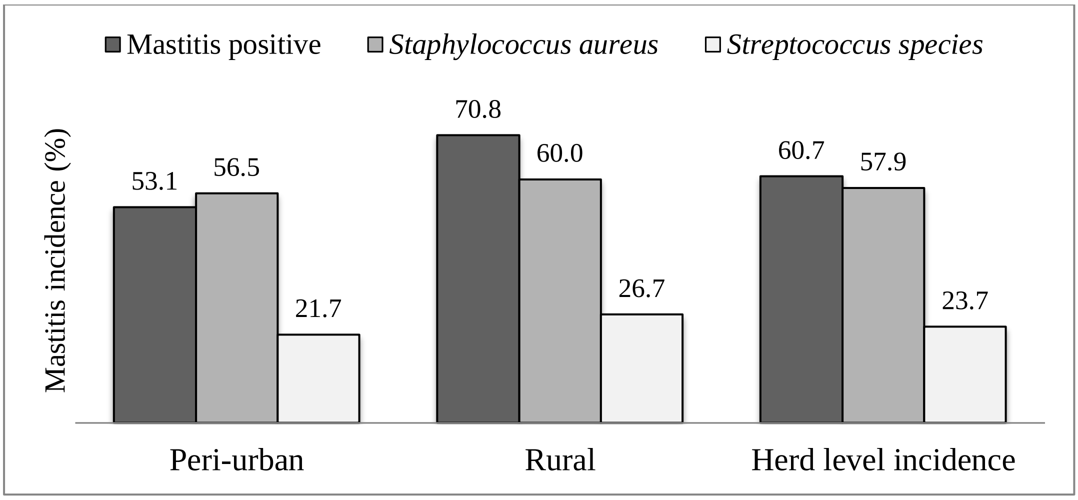

Figure 3: Prevalence of mastitis, *Staphylococcus aureus* and *Streptococcus species* in smallholder dairy herds.

Figure 4 is an illustration of the prevalence of mastitis and *Staphylococcus* and *Streptococcus* genera in pastoral camel herds. The prevalence of mastitis (CMT $\geq +1$) in the pastoral herds was 93.3% of the sample herds with at least one camel positive. It was higher in peri-urban herds (100%) than in the rangelands (90.9%). Prevalence of *Staphylococcus* in mastitis positive milk samples was higher (40.6%) than of *Streptococcus species* (34.6%). Milk positive for mastitis from camels in rangeland had an incidence of 40% of *Staphylococcus* which was lower than peri-urban camels (48.4%). Prevalence of *Streptococcus species* was high in milk from rangelands camels (41.5%) than in peri-urban (12.9%).

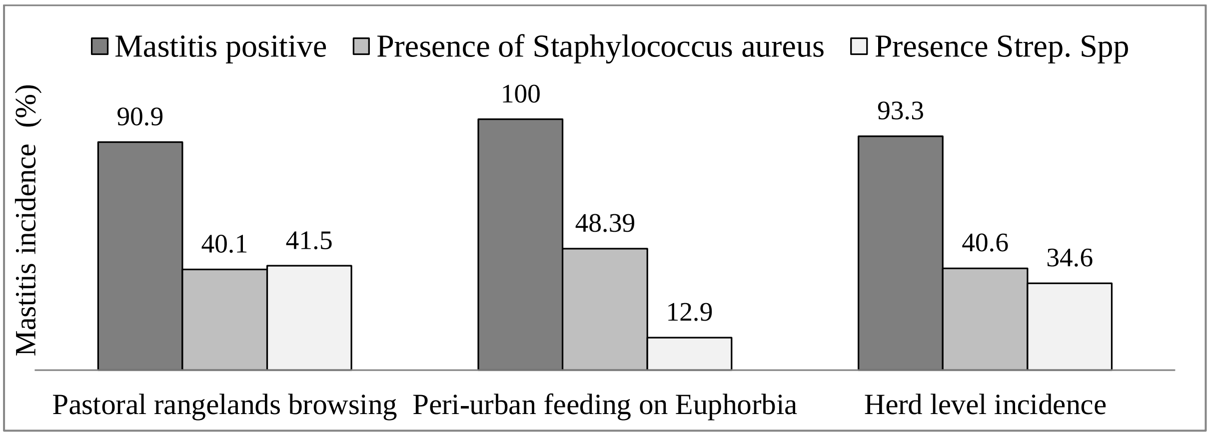

Figure 4: Prevalence of mastitis, *Staphylococcus aureus* and *Streptococcus species*.in pastoral camel herds.

Results in Table 6 are somatic cell counts converted to log_{10}. There was no significant difference in $Log_{10}SCC$ of cows' milk between smallholder rural and peri-urban herds. The difference was significant difference between infected and uninfected quarters tested with 4.9vs 5.8log_{10}cells/mlin mastitis negative and positive respectively, in peri-urban herds and 5.0 vs 5.6 cells/ml in rural herds. Camels' positive for mastitis in rangelands herds had higher $log_{10}SCC$ (7.5 cells/ml) than those found negative (7.2 cells/ml). In pastoral peri-urban herds there was no difference in SCC between camels' positive and negative for mastitis. Log_{10} SCC was significantly ($p<0.05$) higher in milk samples positive for *Staph. aureus* (5.6 and 5.7cells/ml in peri-urban and rural smallholder herds respectively) than in negative samples (5.1 and 5.2cells/ml). There was however no significant difference between smallholders' herds (peri-urban and rural). In pastoral herds, camel milk samples negative for *Staph aureus* tended to be higher in log_{10} SCC than positive samples but the difference was not significant.

Table 6: Effects of animal characteristics on $Log_{10}SCC$ in smallholder dairy cow and pastoral camel herds

Variable	**Smallholder dairy herds**		**Pastoral camel herds**	
	Peri-urban	**Rural**	**Peri-urban**	**Rangelands**
Overall	5.4 ±0.1	5.3 ±0.1	7.4±0.0	7.4±0.1
Lactation stage				
Early/mid	5.3±0.2	5.2±0.1	7.4±0.1	7.5±0.1
Late	5.1±0.1	5.5±0.2	7.3±0.4	7.5±0.1
Udder inflammation				
Mastitis negative	4.9±0.1[a]	5.0±0.1[a]	7.4±0.2	7.2±0.1[a]
Mastitis positive	5.8±0.1[b]	5.6±0.1[b]	7.4±0.2	7.5±0.0[b]
Occurrence of Staph. aureus				
Absent	5.1±0.1[a]	5.2±0.1[a]	7.3±0.3	7.7±0.1
Present	5.6±0.1[b]	5.7±0.1[b]	7.2±0.4	7.5±0.1

Means with different letter in superscript within a column differ ($p<0.05$).

Estimation of production losses due to high somatic cells in milk are summarized in Table 7.For smallholder herds, estimated milk production losses within the threshold of $200x10^3$ to $400x10^3$ cells/ml is higher in rural (11.4%/cow/day) than in peri-urban(10.6%/cow/day). In rural and peri urban farms respectively, this loss corresponds to145.8 Kg and 273.9 Kg of milk yield losses per cow during a 305d lactation period. Cows with milk SCC >400 x 10^3 had an estimated production loss of 10.6% and 11.6%/ day in rural and peri-urban herds respectively.

Table 7: Estimated production losses (%) in smallholder dairy cow and pastoral camel herds

Herds	SCC threshold (1000 cells/ml)	Herds within the threshold (%)	Average milk yield (cow/day)	Production losses (%)
Rural (n=32)	< 200	36.4	5.7	1.8
	200 to 400	22.7	4.4	11.4
	> 400	40.9	8.5	10.6
Peri urban (n=32)	< 200	41.2	6.0	1.7
	200 to 400	23.5	8.5	10.6
	> 400	35.3	4.3	11.6

Milk from cows with clinical mastitis (scoring SCC >400 $x10^3$ cells/ml) was considered a postharvest loss. Results of milk PHL are presented in Table 8. They show overall milk PHL of 18.96% of the milk produced per day. Rural herds were found with higher daily milk PHL (27.3%) than peri-urban herds (7.4%).

Table 8: Estimated milk PHL based on SCC levels in smallholder and pastoral herds

Smallholder herds	**N**	**Cows clinical mastitis** [a] (%)	**Milk PHL** (Kg/day)	**Total milk** (Kg/day/herd)	**Milk PHL (%)**
Rural	32	21.6	43.5	159.5	27.3
Peri-urban	32	35.3	8.5	114.7	7.4
All smallholder herds	64	27.0	52.0	274.2	19.0
Pastoral herds					
Pastoral rangelands	185	75.7	210.3	277.7	75.7
Peri-urban	53	80.6	121.8	151.1	80.6
All pastoral herds	222	58.8	311.6	529.9	58.8

[a]Cows with SCC> 400,000 cells/ml considered having clinical mastitis.
[b]Estimation of PHL in pastoral camel system is based on mastitis, all sample camel milk had SCC beyond 400,000 cells/ml pathogenic microorganisms causing mastitis.

3.4 Discussion

In smallholder herds, 1.69 times higher mastitis prevalence risk of peri-urban herds than in rural was reflected in slightly higher log_{10}SCC (5.4 vs 5.3 cells/ml). Higher hygienic constraints in zero grazing units may explain the difference because overall cleanliness of cowshed in most smallholder peri-urban farmer (78.6%) is just average. Indeed Barnouin *et al*. (2005) and Chassagne *et al*. (2005) have highlighted importance of clean cows housing for higher milk quality. The levels of SCC are, however, high in both herds probably because inadequate hygienic milking practices led to mastitis occurrence of 71% in rural and 53% peri-urban. Although most farmers practiced hand washing and udder washing with warm water prior to milking, there was no pre- or post-milking teat dipping. The use of warm water (55 to 60^{o}C) and drying udder with individual towel prior to milking has been demonstrated to reduce microbial loads in milk (Hubaety *et al*., 2013). However, drying of teats prior to milking was only practiced in peri-urban herds and individual towels for drying teats were only used in farms with one milking cow. Also, no farmer used cleaning agent for udder washing, yet it has proven more efficient in reducing microbial loads on teat surface than warm water only (Gleeson *et al*., 2009). However, in free grazing systems such as in majority of rural farms, use of cleaning agents for udder washing may not be economical in dry seasons when cows' udders are relatively clean and dry. They are of more importance in rainy seasons in rural herds and throughout the year in zero grazed herds, such as peri-urban herds were teats are heavily soiled and incidence of mastitis is high (Morton *et al*., 2014).

There was no significant difference in SCC in milk from pastoral rangelands and peri-urban herds and the level of SCC in camels was high (7.4 cells/ml) in both of these pastoral herds. Hygienic milking practices may have contributed to increase of SCC in camel milk. Pastoralists did not apply any hygienic practice due to lack of water in the rangelands.

Staphylococcus aureus and *streptococcus species* had a high prevalence of 40.6% vs 34.6 % in pastoral and 57.9% vs 23.7% in smallholder herds, confirming findings from Matofari *et al*., 2005 and Younan, 2004.They reported relationships between occurrences of mastitis pathogen hygienic milking practices. The spread of mastitis pathogens in camel herds might even be higher because only one of the 15 sample herds did not have a case of mastitis. Since unidentified infected animals constitute the reservoir for *Staphylococcus aureus* and *streptococcus species*, transmission is done from an animal to the other during milking through milker's hands (Carillo-casa and Morales, 2012). Additionally, lack of water to wash hands and udders in pastoral herds, non-application of udder drying with individual towels in smallholder rural and unclean cowsheds in peri-urban herds may have contributed to spreading and maintaining the pathogens in the herds. Practices such as teat dipping and herd level therapy can reduce infections (Keefe, 1997) but they were not applied in herds sampled and mastitis treatment was directed to t quarter level rather than to the herd level

A relatively high proportion of camels in pastoral (37%) and cows in rural (36.7%) herds were milked continuously without a dry off period. The dry off period is important because it contributes to cell turnover in the mammary gland and optimization of milk production in the next lactation (Hou *et al*., 2016; Steeneveld *et al*., 2013 and Pezeshki *et al*., 2010). It is also used to eliminate existing and preventing new intra-mammary infections with appropriate antibiotic treatment at the end of lactation (Leelahapongsathon *et al*., 2016). However, chronic infection of *Staphylococcus aureus* can be lingering lifelong and success in curing chronic *Streptococcus species* infection is low (Keefe, 1997).

Public health concerns may be raised if the milk is not properly handled along the marketing chain. Also, improper handling with heat treatment may not limit the action of spoilage and pathogenic microorganisms in milk (Rebelein, 2010;Hassan *et al*., 2009).Risks are higher with milk from pastoral camel herds because a reasonable amount is fermented into '*suusa*' along the marketing channel without boiling (Mwangi, 2015).

The variation in Log_{10}SCC with lactation stage may not be attributed to udder infection of the animals but rather to the animal's immune response in preparation for calving and to increase the mammary gland defense mechanism at calving time (Sharma *et al*., 2011; Ruegg and Pantoja, 2013). Herds in smallholder dairy farms and pastoral herds had low daily milk production of 5 to 6 kg and 1.5 kg respectively. Feeding practices (Njarui *et al*., 2010) and hygienic situation of these herds may have contributed to this low production and postharvest losses may further reduce. High somatic cell counts, an indicator of milk quality, have been reported to affect milk yield in dairy cows (Tyler *et al*., 1989). In smallholder herds, high SCC contributed substantially to milk yield losses of145.8 kg and 273.9 kg per cow in 305 d lactation in rural and peri-urban respectively. Milk yield losses constituted therefore a critical loss to farmers whose low average daily milk yield already limits bargaining power and ability to reach better outlets for their milk (Bebe *et al*., 2003; Muriuki, 2003).Daily milk PHL was estimated at 19.0% and 58.8% in smallholder and pastoral herds respectively. These losses in smallholder were higher than previously reported levels of 6% at farm level (Lore *et al*., 2005; Muriuki, 2003). While previous researchers reported losses based on surveys data, the current research used actual production measurements, farm tests and laboratory analyses to estimate postharvest losses which may explain the difference.

3.5 Conclusion and recommendations

Somatic cell counts were not affected by milking practices but by intra-mammary infections. Milking practices such as hand washing, udder washing and udder drying were strongly associated with production herds and may have influenced contributed to high mastitis prevalence in herds. Prevalence of *Staphylococcus aureus* and *Streptococcus species* was high in both smallholder and pastoral herds. Since these pathogens are hardly eradicated from the herds, pre- and post milking teat dipping, using of cleaning agents to wash the udder, keeping cowsheds clean and a dry off cow period (35 to 60 days) are recommended. Milk postharvest losses were high in both smallholder and pastoral herds because of high mastitis prevalence which further reduced milk production by 11% in smallholder herds. This coupled with observed low milk production as result of management challenges, especially in feeding, reduces income security of smallholder and pastoralists. Training and participatory action research is of relevance in targeting to increase milk production, reduction of mastitis cases and postharvest milk losses.

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CHAPTER FOUR

ASSOCIATIONS BETWEEN FEEDING PRACTICES, MILK YIELD AND COMPOSITION IN SMALLHOLDER DAIRY AND PASTORAL HERDS IN KENYA

Abstract

Associations between feeding practices and milk quality was assessed in a sample of smallholder peri-urban (n= 32) and rural (n= 82) herds and pastoral camel (n=15) herds where cross sectional survey data was obtained. Rural smallholder herds were free grazed mostly on pastures (87.7%) and supplemented with Napier grass (89.4%) or dairy meal (93.9%) while peri-urban smallholder herds were fed mostly on Napier grass (68.4%) supplemented with dairy meal (100%), oats forage (42.9%) and sometimes, crop residues (28.6%). Pastoral camel herds were on three distinct feeding practices: shrub browsing, rangeland pasture grazing and *Euphorbia tirucalli* feeding in peri-urban herds. External sourcing of pasture and forage feeds was important in peri-urban herds (31.6%) where over half of the herds (52.6%) were either semi zero-grazed or zero-grazed. Feeding in rural compared to peri-urban smallholder herds had on average more feeds offered (11 vs 9 kg feeds/day) and consequently rations of higher net energy for lactation (N.E.$_L$) (1.4 vs 1.3 MCal/kg) and crude protein (10 vs 12%) contributing to higher milk yields (6 vs 4 kg/cow/day). Milk yield in smallholder herds generally higher with forage to concentrate ratio (FCR) of 7 to 7.5 (14kg to 10.5 kg per cow/day) when feeding Napier with hay and oats forage to supplement silage and pastures. Feeding practices in pastoral herds were better in peri-urban than in rangelands herds and were associated with influence on SCC and milk composition, unlike in smallholder dairy herds. These results reflect a need for intervention in feeds management and formulation of balanced rations to improve milk production in both smallholder and pastoral herds.

Keywords: Feed resource, Net energy for lactation, Somatic Cell Counts, Dairy cows, Camels

4.1 Introduction

Both smallholder and pastoral herds suffer inadequate feed supply and handling to support good quality milk production indicators of fat, protein and solid contents and Somatic Cell Counts (SCC) (Goff, 2006; Njarui *et al*., 2010). The level of SCC is indicative of animal health status and quality of milk and nutrition has influence through immune boosting against pathogens including those causing mastitis (Goff, 2006). Feeding recommendations for dairy cows include an optimum ratio of forage to concentrates of 60 to 40% with concentrates levels not exceeding 45% for efficient rumen function (Coppock *et al*., 1971). The levels of inclusion of concentrates will influence milk yield, fat, and protein. Pandey and Voskuil, 2011have recommended a daily dry matter intake of 3.6 to 4% of bodyweight for milking cows. They further suggest 0.2% to 0.3% of daily feeds to be proteins. The fibrous feeding material, important for ruminant nutrition are needed in adequate amounts between 40 to 50% of the diet for crude fibre with 19-21% of ADF and 26-28% of NDF (Pandey and Voskuil, 2011).

In chapter three of this thesis, average milk yield per cow in all sample herds was low (4.1 Kg, 1.5kg to 6.0 Kg) suggesting challenges with feeding practices in smallholder and pastoral herds. Feeding practices is therefore likely to influence milk yield and quality in these herds. Smallholder herds are fed on on-farm grown fodder and crop residues with some supplementation using externally sourced forages and limited commercial dairy meal while pastoral milking herds are fed on shrubs, dry grasses in rangelands or on *Euphorbia* depending on the locality of the herd (Noor *et al*., 2013).The objective of this study was therefore to determine the effects on milk yield and quality of feeding practices in smallholder (peri-urban, rural) and pastoral herds on rangeland shrubs browsing, rangelands grass feeding, and peri-urban feeding on *Euphorbia*.

4.2 Materials and methods

Study area

The study areas in Nakuru County for the sample rural and peri-urban smallholder herds and in Isiolo County for the sample pastoral camel herds have been described in chapter three of this thesis. Briefly, Nakuru County has a large population of typical rural and peri-urban smallholder dairy farms. The representative rural dairy farms were obtained in a remote area of County with less developed milk marketing infrastructure while representative peri-urban farms were obtained in peri-urban areas of Nakuru town. Milk samples were collected from 82 rural farms, 32 peri-urban farms keeping crossbreds of Friesian and Ayrshire cattle breeds.

The pastoral camel herds were sampled in Isiolo County, which is a typical ASAL area in northern Kenya but with flourishing urban traded camel milk from both peri-urban and pastoral rangeland herds (Noor *et al*., 2013). Herds sampling was within in a radius of about 40 km from Isiolo town and captured three distinct feeding practices: (i) shrub browsing (8 herds with 139 camels), (ii) rangeland pasture grazing (3 herds with 53 camels) and (iii) *Euphorbia tirucalli* feeding (4 herds with 53 camels) for herds grazed within the peri-urban areas.

Data collection and laboratory analysis

Data on individual camels (age, breed, parity, and lactation stage) and feeding practices was recorded. All lactating animals in the herd were tested for mastitis using the California Mastitis test (CMT) on all udder quarters. Milk samples from individual quarters (when found mastitis positive) or composite of all four quarters (when found mastitis negative) were then collected and transported in a cool box to the laboratory within 3 hours for testing somatic cell count (SCC) and milk composition. Milk production of all cows or camels in the sampled herds was weighed and recorded. Quantity of feed offered was weighed where possible and estimated where animals were free-grazed. Feed samples were collected for proximate analysis.

Laboratory somatic cell count used direct microscopy following the procedure outlined by Sarikaya (2006) in which milk samples are thawed to 25^{o}C then thoroughly mixed. An aliquot of 0.02 ml of milk was then collected and diluted in 44.48 ml of distilled water. From this solution 0.05 ml was pipetted and mixed with 0.95ml of Turk's solution. This was pipetted and put on an improved Neubaeuer Chamber where somatic cells were counted as average number of cells in the 4 corner cells and the center cell for both the upper and lower chambers. Milk composition was determined following standard methods. Feeds analysis included dry matter and crude protein following standard methods (Galyean, 2010). Net energy for lactation values were obtained from the NRC tables (2001).The C.P. and N.E.$_{L}$ content of the samples were adjusted with the quantity offered to obtain the contribution of these feeds (basal forages, supplementary forages and concentrates) to the nutrients of ration using formulas adapted from Yan *et al*. 2016. This was then adjusted to the total DM offered to obtain proportional contribution of feeds to the ration.

N.E.$_{L}$ = N.E.$_{L}$. of a given feed (e.g. Napier grass) * DM of the feed * quantity offered (1)

CP = CP % of given feed * DM* quantity (2)

Statistical analysis

Data was subjected to descriptive statistics (frequencies and means) to explore the differences within the production herds. Correlations (PROC CORR) analysis was used for associations between milk yield and quantities of basal, supplementary forage and concentrates offered. Analysis of variance (PROC GLM) was used to determine differences in feeding practices between and within smallholder production herds. It was also used to determine differences in milk composition (fat, protein and solids) within smallholder dairy cow and pastoral camel herds. Mean separation tool was Tukey's test. Data was analysed using SAS (SAS, 2008).

4.3 Results

4.3.1Feeding practices in smallholder dairy and pastoral camel herds

Feeding practices in pastoral camel herds presented in Table 9 reflect that feeding practices were based locally available feed resources because there was shrubs browsing (53.3%) or pasture grazing (20%) in the rangelands and *Euphorbia tirucalli* (26.7%) in the peri-urban herds.

Table 9: Feeding practices in pastoral system

Feeding	Major feed	Frequency
Traditional pastoral extensive	Shrubs	53.3
Pastoral grazing	Dry grass	20.0
Peri-urban	*Euphorbia tirucalli*	26.7

Feeding practices in smallholder and pastoral herds (Table 10) suggest a diversity of feeding with free grazing predominant in rural smallholder herds (87.7%) and in pastoral herds (100 %)while intensive feeding (semi zero-grazing and zero-grazing) practiced more in the peri-urban (52.6%). Napier grass (*Pennisetum purpureum*) fodder was a common basal feed for peri-urban herds (68.42%) and was supplemented with Oats (42.9%) o sometimes fed with crop residues (28.6%).On farm produced feed was common in smallholder rural (68.4%) and in peri-urban (92.3%) herds and were supplemented with commercial dairy meal twice a day at morning and evening milking. External sourcing of pasture and forage feeds was important in peri-urban herds (31.6%) where over half of the herds (52.6%) were either semi zero-grazed or zero-grazed. Land size was 1 and 5.2 acres on average, of which 12.5% and 40% were used for fodder production in peri-urban and rural farms respectively.

Table 10: Feeding practices in smallholder peri-urban and rural herds

Preferential feeds		Peri-urban herds (n=32)	Rural herds (n=65)	Overall
Basal feed	Grass pastures	21.1	87.7	66.0
	Napier grass fodder	68.4	10.8	29.9
	Maize stovers	10.5	1.6	4.1
Forage supplement	Napier grass fodder	28.6	89.4	69.1
	Crop residues	28.6	6.4	13.4
	Oats	42.9	2.1	15.5
	Nandi setaria grass	-	2.1	1.0
Concentrate offered	Commercial dairy meal	100	93.9	95.9
	Mixed meals*	0	4.6	3.1
	Homemade meals	0	1.5	1.0
Source of forages	On-farm	68.4	92.3	84.4
	Off-farm	10.5	3.1	5.5
	On and off-farm	21.1	4.6	10.0
Farming system	Free-grazing	47.4	87.7	74.4
	Semi zero-grazing	26.3	6.2	12.8
	Zero-grazing	26.3	6.2	12.8

4.3.2 Influence of feeding practices on milk yield and quality

Smallholders offered more feed in rural (9kg DM/day) than in peri-urban (8.5 kg DM/ day) herds and energy and protein content also higher in rural (1.36 MCal/kg and 12.04% y) than in peri-urban (1.33 MCal/ kg and 9.99%). Nutrients supply was from basal feeds (7.0 and 7.5 kg in rural and peri-urban, respectively),forage supplements (6.1 and 5.8 kg) and concentrates (3 and 1.9 kg).Feeding was predominantly on forage and limited on concentrates with the Forage to concentrate ratio slightly lower in rural (8:2) than in the peri-urban herds (9:1) (Table 12).

Table 11: Diets composition in smallholder rural and peri-urban herds

Herd	Feed types	Quantity offered (Kg)	$N.E_l$ (MCal/Kg)	CP (%)
Smallholder rural	Basal feed	7.0±0.3	1.0±0.4	9.4±3.7
	Forage supplement	6.1±0.4	0.3±0.2	1.9±1.5
	Concentrates	3.0±2.9	0.1±0.0	0.8±1.7
	Total quantity	16.1±3.9	1.4±0.1	12.0±2.0
	Dry matter content[a]	9.0±3.1	-	-
	FCR[d]	**8: 2**		
Smallholder peri-urban	Basal	7.5±0.5	0.9±0.3	7.3±3.4
	Forage supplement	5.9±1.8	0.3±0.2	1.9±1.6
	Concentrates	1.9±0.2	0.1±0.1	0.8±1.3
	Total quantity	15.3±6.1	1.3±0.1	10.0±2.6
	Dry matter content	8.5±4.3	-	-
	FCR	**9:1**		

[a]Refers to the dry matter content of the feed mixture,[d] Forage to concentrate ratio

Peri-urban smallholder herds feeding maize stalks as basal diet attained the highest milk yield (12 kg/ cow/ day). This was achieved with beans husks as forage supplement and concentrates for a FCR (Forage to concentrate ratio) of 7.0. Maize stalks as basal diet had 4.3 kg/cow/day when fed with Napier grass and concentrates for FCR 7.0. Farmers allowing cows to graze produced 10kg of milk /cow/day, when using crop residues (mostly maize stalks) as supplement, for FCR of 3.5. Farmers using Napier grass as supplement for grazing had lowest production (3.1 kg/cow/day) and highest FCR (9.3). But those feeding Napier grass without forage supplement and concentrates had milk yield of 5.6 kg/cow/day. Pasture without forage supplement but with concentrate (FCR 3.5) had milk yield of 6 (Figure 5).

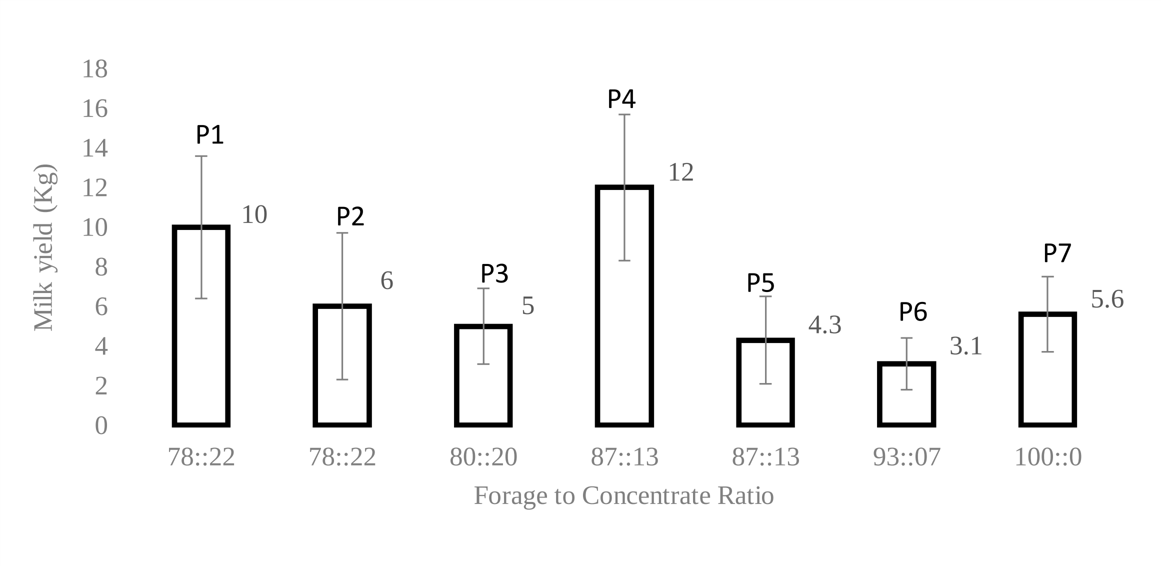

Figure 5: Effects of feeding practices on milk yield in smallholder peri-urban herds. P1= pasture, crop residues and Dairy meal (Dm); P2= pasture and Dm; P3=Maize stalks and Dm; P4= Maize stalks, beans husks and Dm; P5=maize stalks Napier and Dm; P6=pasture, Napier and Dm; P7= Napier.

In smallholder rural herds, three basal diets were used: Napier grass, pasture and silage each attaining milk production above 10 kg /cow/day. Napier grass diets attained milk production of 10.7 kg/cow/day when fed with crop residues and high quantity of concentrates for FCR 2.5. Pasture based diet produced 10.5 kg/cow/day when fed with Napier grass and oats for FCR 7.9, while silage fed with hay attained 14 kg/cow/day for FCR 7. Practices attaining lower milk yields used Napier grass or no forage supplements for 5.4 and 6 kg/cow/day respectively. Pasture and crop residues resulted in lowest milk yield (2 kg/cow/day) (Figure 6).

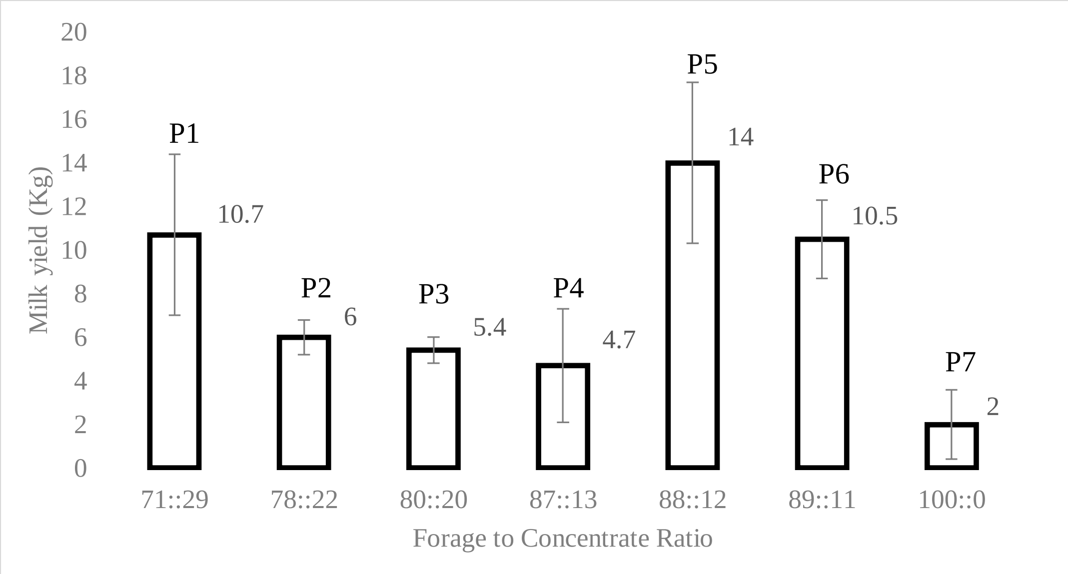

Figure 6: Effects of feeding practices on milk yield in smallholder rural herds. P1 = feeding practice of Napier, crop residues and Dm, P2 = Pastures and Dm, P3= Pasture, Napier and Dm, P4= Napier, Nandi setaria and Dm, P5= Silage, hay and Dm; P6=Pasture, Napier, oats and Dm; P7=Pasture and crop residues.

Milk yield had a strong positive correlation with quantity of concentrate feeds offered (r=0.78; p=0.009) but not with the amount of basal and supplementary forages (r=0.01 and r= 0.15 respectively) while correlation between quantity of basal forage and the quantity of supplementary forage was negative and low (r= -0.39) (Table 12).

Table 12: Correlation coefficient of relationship between milk yield and quantity of feeds offered to dairy cows in smallholder dairy herds

	Milk yield	Quantity of basal diet offered	Quantity of forage supplement offered	Quantity of concentrates
Milk yield	__	0.01 (0.97)	0.15 (0.08)	0.78 (0.009)
Quantity of basal diet offered		__	-0.39(0.027)	0.07 (0.19)
Quantity of forage supplement offered			__	0.14 (0.15)

Feeding practice in pastoral herds had influence on milk composition (Table 13). Milk from camels grazing pastures compared to those browsing shrubs or Euphorbia was lower in: fat (2.64% vs 3.53% -4.65%), protein (2.77%; vs 2.79% -3.61%) and density (1027.5 vs 1029 -1030g/ml)

Milk butter fat was slightly higher in smallholder herds feeding on Napier grass basal diets (in peri-urban herds) than those feeding on pasture basal diets (in rural herds) but proteinand density were similar. Feeding had influence on SCC in pastoral herds but not in smallholder herds. SCC was lower in pastoral herds grazing on pastures compared to those browsing shrubs (Table 13).

Table 13: Effects of feeding practices on milk quality in smallholder dairy cow and pastoral camel herds

Feeding practice	Yield/ herd (Kg)	Yield/ animal (Kg)	Fat (%)	Protein (%)	Density (g/ml)
Pastoral camels' herds					
Shrubs browsing	35.0±20.4	1.4±1.3	4.2±0.4^{a}	3.0±0.1^{a}	1029.0±1.0^{a}
Grass pasture grazing	22.8±15.5	2.0±0.8	2.6±0.3^{b}	2.7±0.1^{a}	1027.5±0.6^{a}
Euphorbia tirucalli	62.9±26.0	2.8±0.8	4.7±0.3^{a}	3.6±0.1^{b}	1035.1±0.6^{b}
Overall pastoral herds	36.9±24.8	2.1±1.0	3.7±0.2	3.2±0.1	1030.9±0.6
Smallholder dairy cows' herds					
Rural	12.3±11.9	6.1±3.8	3.9±1.0^{a}	2.8±0.1^{a}	1026.7±4.1^{a}
Peri-urban	9.1±8.5	4.9±3.4	4.3±1.6^{a}	2.8±0.4^{a}	1026.9±1.7^{a}
Overall smallholder herds	10.7±10.2	5.5±3.6	3.9±1.2	2.8±0.2	1026.8±2.5

Within herd category means with different letter superscript in a column differ $p<0.05$

4.4 Discussion

At system level, cows in peri-urban smallholder herds were offered, on average, less feed compared to those in rural herds (16.1 vs 15.3 kg/day). This is partly influenced by their small farm holding (1.1 vs 5.2 acres) in which fodder and food crops compete for land allocation with rural farms owning larger farms able to allocate more to fodder production (12.5% vs 40%). Faced with limited on-farm feed production, peri-urban smallholders source feeds off-farm to supplement on-farm feeds but the cost is a limitation in hiring land, hiring casual labour or accessing cash readily to purchase feeds. Consequently, peri-urban smallholders feed more crop residues (39.1%) high in dry matter (>83%) as basal feed or as forage supplement (FAO, 2002) while rural farmers mostly feed natural pastures (87.7%) as basal feed supplemented with Napier grass (89.4%). The small difference in rations dry matter (8.5 kg/cow/day vs 9 kg/cow/day) content between the two production herds is a consequence of feeds used because rural farmers feed mostly pastures and Napier grass in large amounts but with low dry matter content. Peri-urban farmers on the other hand incorporate Napier grass in their diets but feed less quantity, hence the small difference between the two systems. Therefore, improving nutritive value of crop residues in peri-urban feed rations and introduction of legume forages in rural farms may improve value and production (Devendra, 1992; Kashongwe *et al*., 2014).

Compared to diets fed in smallholder peri-urban herds, the diets fed in rural herds had higher $N.E_l$ (1.4 vs 1.3 MCal/kg) and CP (12% vs 10%) and attained higher milk yield on average (12.3 vs 9.1 kg/ herd/ day). This is probably because the positive relationship between energy, crude protein intake and milk yield suggest an increase in milk yield with increased level of intake, energy, and protein (Bannink *et al*. 2008). The dry matter, energy and crude protein levels observed in smallholder feeding diets interestingly are closer to the NRC (2001) recommendations of a minimum of 11 Kg DM, 1.5 MCal/Kg and 13% crude protein. However, the 1.5 to 2.3 FCR for optimum rumen function (Coppock *et al*., 1971) is far from being met, whether in rural (19% concentrates) or peri-urban (12% concentrates) herds feeding diets. This can be explained by high costs of concentrates in the markets with 16% VAT charged on animal feeds in Kenya besides rampant trade malpractices with regards to quality and quantity labels in the packages (Njagi *et al*., 2013).

Feeding practices in smallholder herds depicted use of diverse feed resources, predominantly Napier grass, pastures and crop residues. The practice has been reported elsewhere, for instance by Lukuyu *et al*. (2011) and by Njarui *et al*. (2010). Napier grass and pastures are low in dry matter (DM) content (20-25%) (Pandey and Voskuil, 2011) and farmers often wilt the fodder prior to feeding (Lukuyu *et al*., 2012; Manyawu *et al*., 2003), which still hardly exceeds 50% dry matter content (Manyawu *et al*., 2003) and insufficient for providing nutrients to support high milk production. Smallholder peri-urban feeds were crop residues and Napier grass based, although pasture based feeding was also observed. These were associated with higher milk yield (≥ 10 kg/ cow/ day) when maize stalks were used as basal feed or forage supplement for FCR 7 and 3.5. This level of production is higher than has been reported for smallholder farmers (Ngongoni *et al*., 2006; Kavoi *et al*., 2010; Chagwiza *et al*., 2016). These authors reported 7.6 kg, 4.7 kg and 6.3 kg /cow/day respectively in Zambia, Kenya and Ethiopia. The high production of these practices may be explained by nutritive value of the diets. Bean husks provide more crude protein (8%) than cereal crop residues (< 3%) and slightly lower energy (7.6 vs 8.2 MJ/ kg DM) than forages such as Napier grass (Lopez *et al*., 2005 and Manyawu *et al*., 2003). Milk yield was lower when no forage supplement was added to the basal forage, suggesting the importance of forage supplements to improve on nutritive value of rations for higher production (Devendra, 1992). These feeding practices resulted in milk production comparable to reports of other studies (Ngongoni *et al*., 2006; Kavoi *et al*., 2010; Chagwiza *et al*., 2016), which indicates that the practice is common to smallholder dairy farmers. The lowest production was observed when Napier grass was used as forage supplement of maize stalks and pasture with 4.3 and 3.1 kg/ cow/ day. This was mainly because, due to small land dedicated to fodder production (12.5% of 1 acre), Napier grass fed in limited quantity could not support more milk production.

Practices attaining highest milk yield in smallholder rural herds used green forage basal diets with dry forage as supplement and concentrates. Among those, the Napier grass based practice resulted in 10.7 kg milk / cow/ day probably because of high concentrate level in that ration (FCR 2.5). Herds feeding pastures and silage basal diets produced 10.5 and 14 kg milk/ cow /day respectively. Forage supplement combination of Napier grass with oats and use of hay may have contributed to improve nutritive value of these rations for FCR 7.9 and 7. The other feeding practices led to lower milk yield because of no forage supplementation to natural pastures (FCR 3.5 for 6 kg milk /cow/day); quantity of forage supplement (FCR 4 for 5.4 kg milk/ cow/day). The lowest production (2 kg/cow/day) was probably due to no concentrate supplementation. These results imply that crop residues represent important feed resources and their value is increasing bulkiness of the feed rations, efficient rumen function and reducing cost of purchasing off-farm feeds for farms with limited land to grow fodder. They can successfully be used as forage supplements and contribute to improve on the low DM (9 and 8.5 kg DM in rural and peri-urban, respectively) of green forage based smallholder feeds. Application of physical, biological and chemical treatment to crop residues can improve on their low degradability values and nutrient content (FAO, 2002). Low quantities of concentrates were used leading to high FCR for most of the 14 feeding practices in both peri-urban and rural herds. Only 1 herd had FCR 2.5 which gave 10.7 kg milk/ cow/day. Concentrates supply readily available nutrients to dairy cows; therefore, higher quantities should be included in rations for higher production. Studies have shown that increase in concentrate levels in dairy rations contribute to more milk production with FCR 1.5 (6:4) providing better results (Hernandez *et al*., 1976). However, the high cost of concentrates with the new 16% VAT imposed by the government on animal feeds and their uncertain quality limit their use by most smallholder farmers (Njagi *et al*., 2013).

Leguminous protein sources were not used to supplement basal forages (Napier or pastures) yet they may improve on nutritive value of rations (Nnadi and Hanque, 1986). Introduction of fodder crops such as lucerne, or fodder trees such as *Luceana leucocephala* can have been interventions for improving quality of feed rations and production. Napier grass and pastures on the other hand are a good basal diet with 5.6 kg milk/cow/day when fed alone, and can be used as basis for feeding improvement strategies together with concentrates (FAO, 2006). This was observed for practice with Napier grass supplemented with crop residues and concentrates (10.7 kg/cow/day).

Milk fat was slightly higher with Napier grass based feeding system compared to pasture based system probably because crop residues feeding increase the dry matter content of feeds, which is associated with higher acetate levels, hence higher milk fat (Palmquist and Conrad 1978; Kashongwe *et al*., 2014).

Feeding practices in pastoral herds corresponded with the available local feeds, for instance those in the rangelands fed on shrubs (53.3%), or grass (20%) while those in peri-urban areas fed on *Euphorbia tirucalli* (26.7%), which affirms findings of Noor *et al*. (2013). The *Euphirbia tirucalli* diet attained higher milk yield (2.85 kg) compared to grazing grass (2.02 kg) or browsing shrubs (1.37 kg), possibly associated with nutritive value of *Euphobia* and less energy animals spend unlike when trekking over long distance over rangelands in search of pastures and water (Noor *et al*., 2013).

Camels from peri-urban herds which fed on *Euphorbia tirucalli* and offered mineral licks without trekking over long distance had higher milk yield and higher milk quality (fat, protein and solids) compared to those grazing or browsing. This feeding practice contrasts with those in the rangelands where grazing camels can only access very dry grass which supply insufficient nutrients unable to support high milk production. Camels browsing on shrubs had lower milk yield probably because they had limited access to water and had their energy spent trekking for feeds, water and mineral licks.

In smallholder herds, the SCC was higher in milk from peri-urban than from rural herds (5.4 vs 5.3 Log_{10}SCC) which may be attributed to unhygienic milking environments of zero-grazing units often with mud floored shed difficult to clean. Rural herds are mostly left on pastures and milked while standing in open areas, which reduces risks of microbial contamination from the environment, thus lower milk SCC (Sharma *et al*., 2011). Milk from pastoral herds was high in SCC which may be associated with prolonged and widespread infection of *Staphylococcus and Streptococcus* in camels (Sharma *et al*., 2011) resulting from scarcity of water needed to implement hygienic milking practices.

4.5 Conclusion and recommendations

Feeding practices were diverse in smallholder and pastoral herds. In smallholder herds, two feeding practices in peri-urban and three, in rural showed farmers' willingness to improve feeding for higher milk yield (>10 kg/cow/day). In pastoral herd browsing *Euphorbia tirucalli,* offering minerals and water was the better practice. These feeding interventions present opportunities for improved feeding in smallholder and pastoral herds. The options for feeding improvement include forage management, preservation by ensiling or hay making and value addition of crop residues. Use of concentrates is also recommended. Mixing grass and forage legume is a promising option to improve feed quality especially for cut and carry feeding. Implementing hygiene practices of the shed before milking, of animal and milking personnel and of milking equipment can enable farmers to reduce SCC. The wide variations of feeding practices within each production system points to the need of involving farmers in participatory action research to test on-farm contextualized feed formulations for progressive improvement of milk yield and quality.

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CHAPTER FIVE

INFLUENCE OF ON-FARM FEEDING AND HYGIENE INTERVENTIONS ONMILK QUALITY AND POSTHARVEST LOSSES IN SMALLHOLDER DAIRY HERDS

Abstract

This study deployed participatory action research with smallholder farmers to improve their feeding and milk hygiene practices in order to increase milk production and improve quality of milk. Identification of challenges revealed low milk prices, poor breeds and feed unavailability as priority challenges. Feeding intervention was selected by the platform because of feasibility and needs expressed by farmers to address low milk production. Milk quality was given low priority but was selected because of farmers' willingness to learn about recommended practices. Feeding intervention started with identification of fodder crops using the Feed Evaluation Assessment Tool (FEAST). Feed resources in peri-urban farms were sorghum, Napier grass, Lucerne and oats, while feed resources in the rural farms were Napier grass, oats, *Nandi setaria*, and *Calliandria.* In order of importance, peri-urban farms utilized purchased feeds, collected fodder and pasture grazing while rural farms utilized pasture grazing, purchased feed and cultivated fodder. Capacity building in utilization of these feed resources resulted in a change in milk production, by 19.9% in peri-urban and by 19.2% in rural farms after three months of intervention. Capacity building in milking hygiene however did not result in a noticeable change in milk quality, probably because milk was market access is not based on quality but on quantity. Therefore there is no incentive for farmers to produce high milk quality.

Key words: Feeding analysis; participatory research; smallholder farmers

5.1 Introduction

Milk production in smallholder farms in Kenya is characterized by low output and low quality (Bebe *et al*., 2003; Lore *et al*., 2005). Inadequate feeding explains low milk production while unhygienic milking and handling practices explain low milk quality from previous chapters (3 and4) with subsequent influence on postharvest losses. Feeding diet with insufficient dry matter, low energy and crude protein were important explanations for low milk production in smallholder farms (Chap 4) while inadequate milking hygiene practices and extended lactation were important explanations for low milk quality (Chap 3).

Researchers have found concurring results and recommended uptake of improved feeding and hygienic practices in smallholder farms (Lore *et al.,* 2005; Kurwijila 2006). However, uptake by farmers remains low, possibly related to limited innovation capacity in accessing information, technology or inability to invest on technology and information. Participatory action research together with collaborative learning could be an alternative to foster better understanding and contextualization of innovations to farmers' needs and priorities (Mahra *et al.,* 2015; Musvoto *et al.,* 2015; Restrepo *et al.,* 2016). Promoting innovations relevant in low agricultural input systems requires that the innovation be indigenously generated through research processes that harness and integrate knowledge and information in stakeholder interaction platform (Musvoto *et al.,* 2015). This study aimed at developing and testing contextualized feeding, hygienic milking and handling interventions for smallholder dairy farmers to bridge the knowledge gap in on-farm application of recommended practices to improve milk production and milk quality.

5.2 Methodology

Development of research agenda

The study was conducted in Nakuru County for the sample of rural and peri-urban smallholder herds described in Chapter 3. Two farmer groups were selected, one from rural (Olenguruone Dairy Farmers' Cooperative) and another from peri-urban (Mukinduri Self-Help Group).

A collaborative learning approach was used where researchers, facilitators and farmers from rural and peri-urban established a research platform. The platform initiated a learning process with focus group discussions and individual farmers' interviews to identify management problems related to dairy farming. These problems were prioritized and possible solutions were suggested to inform draft research agendas for implementation. Sequential on-farm training sessions were conducted by researchers. This was followed by on-farm experiments to fill knowledge gaps expressed by farmers and to assess applicability of suggested interventions in farmers' context. The choice of experimental design, units, variables and other measurements were made by the platform. Farmers selected volunteer members to participate in experiments with provision of animals, facilities and feeds and accessibility of the location by all farmers of the group. This pilot group formed the intervention sample while the rest of the beneficiaries formed the control group. Figure 7 summarizes the research process developed by researchers and adopted by the platform.

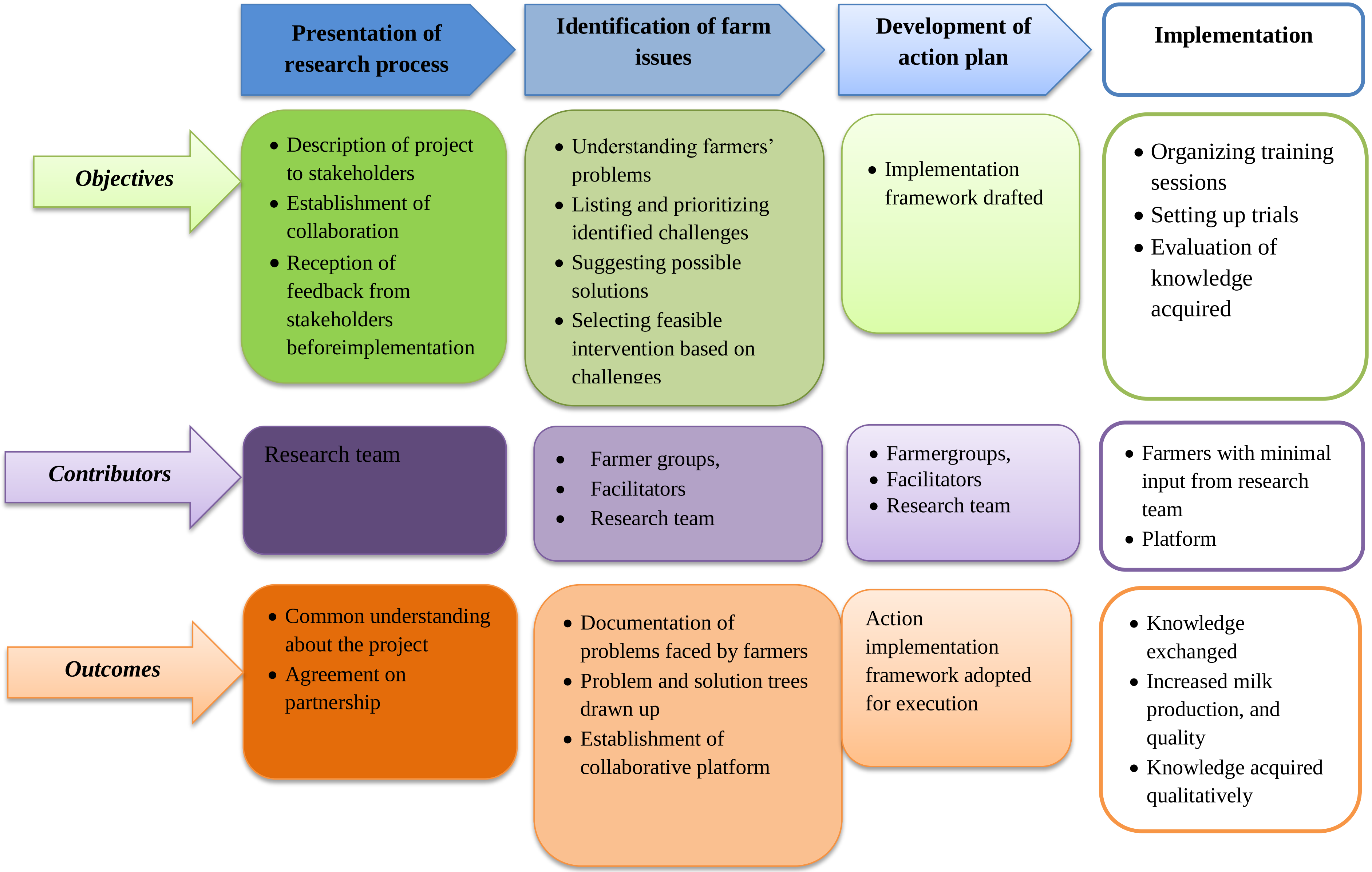

Figure 7 : Summary of the research process (Adapted from Musvoto *et al.*, 2015)

Feeding interventions

Two feeding interventions were designed in peri-urban and rural smallholder farms to improve nutritive value of identified available feed resources. The trial in peri-urban consisted of improving nutritive value of maize stalks to include in a forage mixture with Napier grass and Lucerne. Maize stalks were abundant in the area from previous planting season. They were chopped manually and spread on a polythene sheet, and then 400 g of urea diluted in 5 litres of water were sprinkled on it and mixed thoroughly. The mixture was put in a silage tube (1.5m x 3m) tied to avoid oxygen inclusion and left to incubate for 21 days. After 21 days, the silage tube was opened to allow excess ammonia to escape before mixing with little molasses (0.1 kg/L water). Then wilted Napier grass and lucerne were chopped and mixed with treated maize stalks ready for feeding (Figure 8).

Figure 8: Preparation of forage mixture in a peri-urban farm

The proportional composition of peri-urban feeding ration is presented in Table 14.

Table 14: Proportional contribution of feed ingredients used in peri-urban farms

Feed ingredient	Proportion (%)	N.E.l	C.P. (%/ proportion)
Urea treated maize stalks	28.57	0.41	2.29
Lucerne	21.43	0.26	4.11
Napier grass	21.43	0.50	2.14
Dairy meal	28.57	0.61	6.85
Total	100	1.77	15.40

Feeding intervention in rural consisted of silage making with Napier grass harvested early (1 m high) in order to preserve its' nutritive value before it decreases (Manyawu *et al*., 2003). Napier grass was chosen for silage making because it was the most common forage supplement in rural farms during the investigation and farmers mentioned willingness to learn the technique since some of them had tried but never succeeded to make good quality silage. Wilted Napier grass was chopped either manually or using a chaff cutter. Then 1 kg of molasses was diluted in 3 l of water and sprinkled on 10 kg of Napier grass spread on a plastic sheet. This was mixed thoroughly and put in a silage tube (1.5m x 3m) and tied in a way to exclude oxygen from the mixture. The ensiling process took 21 days, after what mature silage was ready for feeding (Figure 9).

From left to right: Chopping Napier grass, sealing silage tube, filling tube and compressing Napier, and mature silage after 21 days incubation.

Figure 9: Silage making process in rural farm

Feeding interventions were evaluated by dry matter intake, animal body condition, milk production and milk composition. Knowledge gained during sessions was also evaluated. An option for possible modification of interventions to suit farmers' context was also included.

Hygiene milking and handling intervention

Unlike feed intervention, milking and handling hygiene were not mentioned as priority challenges by farmers. They were included because farmers mentioned during focus group discussions, willingness to learn more about recommended practices. Training sessions focused on cleanliness of cowshed, milking person, recommended pre-milking practice, milking routine and post-milking handling of milk. Hygiene interventions were evaluated by knowledge gained and milk quality.

Data collection and analysis

Data from focus group discussions (FGDs) and individual interviews included feeds availability, milking routine and equipment used and challenges faced in feeding and hygienic milking and milk handling. Feeds availability and challenges where assessed using Feed Assessment Tool (FEAST) (ILRI, 2015). Knowledge acquired during training was assessed qualitatively between and within groups, and scored using a 1-5 scale with 1 being very low and 5 being very high. Data from trials included feed composition, milk yield, milk quality (composition, total viable counts, coliform counts, *Staphylococcus aureus* counts, *Streptococci* species counts and somatic cell counts).

Descriptive statistics was used to analyse data from FGDs and individual interviews. Farmers hosting the training sessions and trials were labeled pilot farmers and neighboring farmers attending the sessions or visiting site during experiment were labeled participating farmers. The analysis of variance with Generalized Linear Model (GLM) procedure of SAS was used to determine the change influenced interventions on milk yield and quality by herd category of participants.

5.3 Results and discussion

Prioritization of challenges and suggested solutions in the smallholder farms

Smallholder farmers ranked low milk price a first challenge in both rural and peri-urban farms for which their suggested intervention was better access to markets and to market information and milk value addition. Seasonal feed unavailability and poor breed were second and third challenges respectively in rural and peri-urban farms. Farmers suggested purchasing more feeds, growing fodder and feed conservation as solutions in rural farms.

Outsourcing information and accessing better quality semen were suggested solutions to improving quality of breeding stocks in the peri-urban farms while sensitization on the use of artificial insemination (A.I.) instead of bull service was suggested would be a solution to avoid inbreeding the in rural farms. High cost of concentrates and disease outbreak were fourth mentioned challenge in peri-urban and rural respectively. Peri-urban farmers suggested getting extra income from off farm jobs to purchase dairy meal and salt licks, while rural farmers mentioned vaccinations to face disease outbreaks. Low production and animal theft were last mentioned challenges in peri-urban and rural respectively (Table 15). Based on the challenges mentioned, the platform opted for feed interventions as feasible options for improvement. Value addition of maize stalks was selected in peri-urban, while preservation of Napier grass through silage making was selected in rural. Both feeds were abundant in the areas.

Table 15: Priority challenges and possible solutions in the smallholder farms

Smallholder peri-urban			**Smallholder rural**	
Priority	**Challenges**	**Possible solution**	**Challenges**	**Possible solution**
1	Low milk prices	Access better markets	Low milk prices	Better market information, Milk value addition
2	Poor breed/ inefficient A.I. services	Outsourcing information and access to better semen	Seasonal feed unavailability	Improve information and knowledge of feed conservation
3	Feed availability	Purchase feed Growing fodder	Poor breeds due to inbreeding	Farmers' sensitization to use A.I. services
4	High costs of salt lick and dairy meal	Get extra cash from off-farm jobs to purchase	Diseases outbreak	Vaccinations
5	Low milk production	Change breeds Improve feeding	Animal theft	Security improvements (better fences)

Description of available feed resources in rural and peri-urban farms

The main crops cultivated in peri-urban were common peas, maize, potatoes and common beans with fodder crops Napier grass, Lucerne, oats and sorghum on small land (0.6 ha and 10% of total farm holding). Dry matter intake was mostly from purchased feeds (50%) in peri-urban and grazing (80%) in rural farms. Collected fodder (35%) and cultivated fodder (8%) was common peri-urban and rural farms respectively (Figure 10). Land holding may be the reason for fodder preferences. Peri-urban farmers have to choose between food crop production and fodder production on the small available land. Rural farmers on the other hand have larger farm sizes (2.1 ha) which allow them to grow natural pastures and rely on Napier grass as forage supplement. Energy and crude protein intake followed the tendency and were mostly from grazing in rural and from purchased feed and collected fodder in peri-urban.

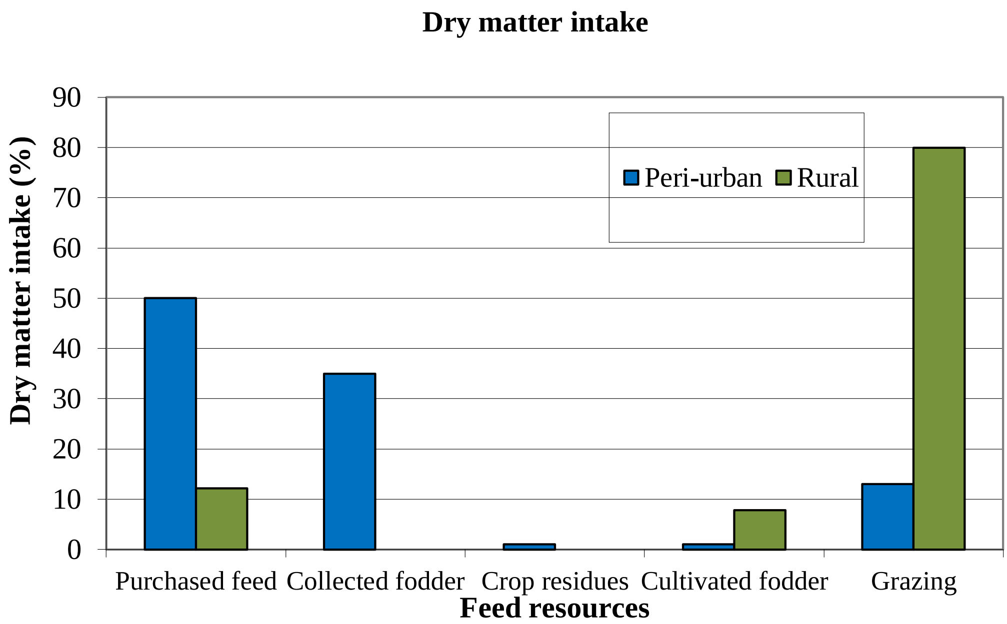

Figure 10: Contribution of available feed resources to dry matter intake in smallholder peri-urban and rural farms

Energy intake followed the same trend as dry matter intake and was mostly from purchased feeds in peri-urban, while grazing was the major contributor in rural farms (Figure 10)

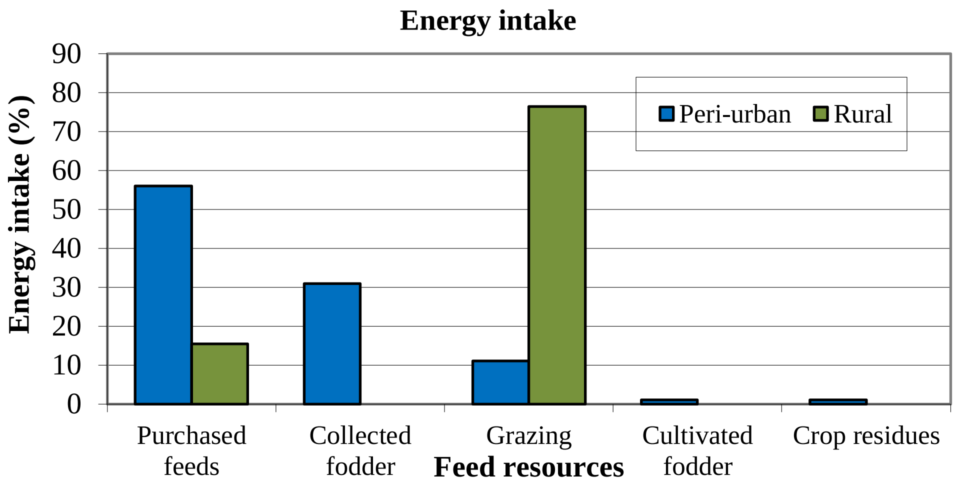

Figure 11 : Contribution of available feed resources to energy intake in smallholder peri-urban and rural farms

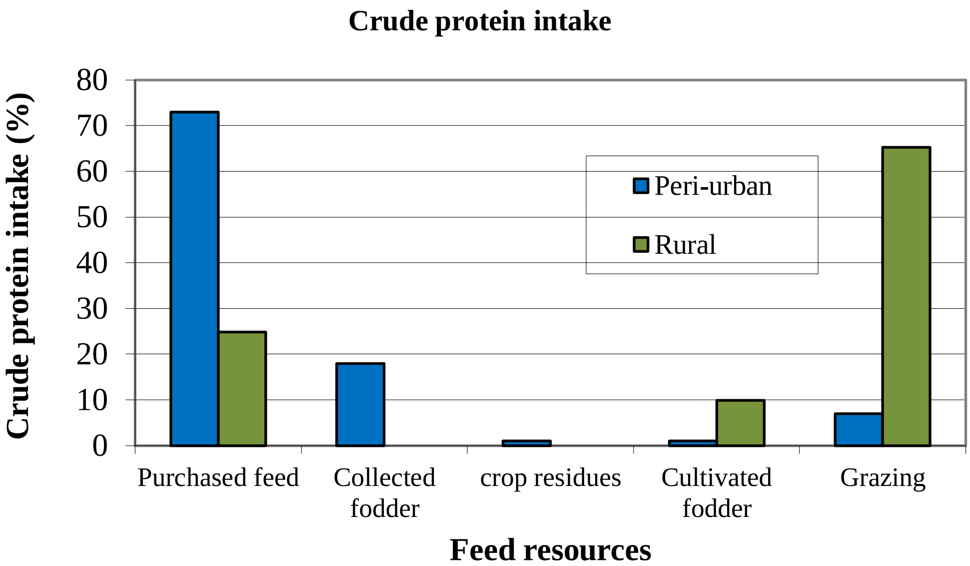

Figure 12: Contribution of available feed resources to crude protein intake in smallholder peri-urban and rural farms

Knowledge analysis

Before training, 67%of pilot farmers (intervention group) in rural showed good knowledge of planting and harvesting forages (natural pastures and Napier grass), although they mentioned poor performance of lucerne in the area. This may explain higher milk yield observed in rural farms compared to peri-urban in Chapter 4.Pilot farmers (67%) had low knowledge of forage preservation methods through silage making, but never succeeded in making it, hence the training. Feed formulation was not known by pilot farmers which may explain the non-utilization of forage legumes in dairy cows' rations in rural herds. Among participating farmers (control group), 33% showed good knowledge of forage planting, forage harvesting time and forage preservation through silage making. Knowledge on cows feed requirements and formulation was only expressed by 22% participating farmers but they showed below average knowledge of those. After training, knowledge assessment showed that both pilot and participating farmers had gained knowledge on feed management and rations formulation (Table 16).

Table 16: Knowledge level on feed management and rations formulation assessed before and after training in rural

	Pilot farmers (n=3)		Participating farmers (n=9)	
Training items	Before training	After training	Before training	After training
Planting and harvesting forages	67%	100%	33%	78%
Forage preservation and value addition	67%	100%	33%	55%
Cows' requirements	33%	67%	22%	55%
Feed formulation	0%	100%	22%	55%

Knowledge level from very low (light blue) to very high (dark blue). White colour = knowledge inexistent. Shape size = proportion of farmers with knowledge of the practice.

All pilot farmers and 23% of participating farmers in peri-urban had high prior knowledge of forage planting and harvesting time (Table17).Knowledge on forage value addition, cows feed requirements and feed formulation was low to not existent among pilot farmers, while it was average in a minority of participating farmers. This may explain the use of different fodder crops with similar nutritive value (oats, sorghum and to some extent

Napier grass) despite limited land for fodder production. This result points to the need for long term farmers' training in feeding to improve on the practice. Knowledge level increased after training in both pilot and participating farmers.

Table 17: Knowledge level on feed management and rations formulation assessed before and after training in peri-urban.

Training items	Pilot farmers		Participating farmers	
	Before training	After training	Before training	After training
Planting and harvesting forages	100%	100%	23%	54%
Forage preservation and value addition	0%	100%	31%	77%
Cows' requirements	50%	100%	8%	54%
Feed formulation	0%	100%	8%	55%

Knwoledge level from very low (light blue) to very high (dark blue). White colour = knowledge inexistent. Shape size = proportion of farmers with knowledge of the practice.

Knowledge of milking and milk handling hygiene in rural was average to very high in both pilot and most of participating farmers in rural. Knowledge of cleanliness of milking shed was average in pilot farmers and high in 22% of participating farmers (Table 18). These results are in line with findings from Chapter 3 suggesting that smallholder farmers follow most hygienic practices during milking and handling processes.

Table 18: Knowledge level on hygiene milking and handling assessed before and after training in rural.

	Pilot farmers		Participating farmers	
Training items	Before training	After training	Before training	After training
Cleaning milking shed	100%	100%	22%	100%
Cleaning equipment	100%	100%	100%	100%
Hygiene of milker	100%	100%	100%	100%
Milking practice	100%	100%	100%	100%

Knwoledge level from very low (light blue) to very high (dark blue). White colour = knowledge inexistent. Shape size = proportion of farmers with knowledge of the practice.

In peri-urban, all farmers showed prior knowledge of milking and milk handling hygiene. This was improved after training in both pilot and participating farmers (Table 19).

Table 19: Knowledge on milking and milk handling hygiene in peri-urban.

	Pilot farmers		Participating farmers	
Training items	Before training	After training	Before training	After training
Cleaning milking shed	100%	100%	100%	100%
Cleaning equipment	100%	100%	100%	100%
Hygiene of milker	100%	100%	100%	100%
Milking practice	100%	100%	100%	100%

Knowledge level from very low (light blue) to very high (dark blue). White colour = knowledge inexistent. Shape size = proportion of farmers with knowledge of the practice.

Farm practices revealed that peri-urban farmers had good knowledge of forage planting and harvesting. But they knowledge of cows' feed requirement, feed formulation and value addition to crop residues was low. This was reflected by high refusals from feeding troughs probably because farmers fed forages without reducing to an acceptable size of less than 5 cm (Heinrich and Kononoff, 2002). Green fodder such as Napier grass was mostly fed when overgrown at about 2m high, indicative of reduced nutritive value (Wijitfan *et al.*, 2009). Additionally cows' body condition score was 2 and dry matter intake was low in both pilot and control group. The feeding intervention led to reduction of refusals from feeding troughs achieved by reduction of particle size by manually chopping forages. The major sources of dry matter, energy and crude protein were purchased feeds and collected fodder which constituted a challenge for peri-urban farmers who had to look for off-farm jobs to get money to purchase feeds for their dairy cows (Table 2). Moreover, farmers had plenty of maize stalks from previous planting season which they fed as supplement to green forages. Therefore, focusing on improving nutritive value of maize stalks, the training addressed feed cost challenges but also improved performance of cows. This is because urea treated crop residues provide higher nitrogen content and higher dry matter degradability (Kashongwe *et al.*, 2014). Hence treating maize stalks with urea may reduce cost of purchasing off-farm feeds for cows. The increased gradient in knowledge after training showed application of gained knowledge in feeding which was reflected in cows' performance. This is because body condition, dry matter intake, milk production and composition in both pilot and participating farmers increased as a result of trials (Table 21). Results from previous studies on the effect of treated crop residues on dairy cows' performance (Jabbar *et al.*, 2009; Kashongwe *et al.*, 2014) concur with our findings. The improvement in participating farmers suggests a spillover effect of feeding experiments to neighbouring farmers. This is because the three conditions favoring knowledge spillover within a cluster (smallholder herd) were verified (Fallah and Ibrahim, 2004). The labour pool due to geographical concentration of firms in the same industry was observed by the concentration of dairy farms within the same location. Availability of related materials and inputs was found in feeding materials and milking equipment which were similar within the area. The intensity of knowledge exchange between nearby farms facilitated exchange and application of the technology in participating farms. Farmers further suggested an improvement in utilizing the technique by using shredding machine to reduce time, work load, and obtain uniform particle size.

Rural farmers had good knowledge of planting and harvesting forages but availability of these feed resources were said to be affected by seasonality which might have motivated farmers to mention it as second priority challenge. A knowledge need in forage preservation arose that was addressed by feeding intervention through training and feeding trials. Prior knowledge of silage making was existent among few farmers but attempts to make it were unsuccessful. Dairy cows' feed requirement and feed formulation were also included in the training sessions. Knowledge gradient went from low to inexistent before training to high and very high after training, which was reflected in an improvement in milk yield and composition.

Table 20: Effects of intervention on feed intake, milk yield and composition in rural farms

	DMI (Kg)	Feed refusals	BCS	Milk Yield (Kg)
Control	8.5±0.5	-	2	3.1±0.6
Base	8.5±0.5	-	3	7.3±1.0
Intervention	14±0.7	<5%	3.5	8.7±1.0
% Change				
Intervention vs base	65%	-	-	19%
Intervention vs control	65%	-	-	181%

Table 21: Effects of intervention on feed intake, milk yield and composition in peri-urban farms

	DMI (Kg)	Feed refusals	BCS	Milk yield (Kg)
Control	6±0.1	>50%	2	9.1±2.0
Base	6±0.1	>50%	2	14.6±0.5
Intervention	12.5 ±0.1	<5%	3	17.5±1.4
% Change				
Intervention vs base	108%	-90%	--	20%
Intervention vs control	108%	-90%	--	92%

Table 22: Effects of intervention on milk quality

System	Feeding trial	$Log_{10}SCC$	TVC (cfu/ml)	$Log_{10}CC$ (cfu/ml)	*Staph. aureus*	*Strep.*spp
Peri-urban	Base	5.9±0.1	5.9±0.6	1.4±0.7[d]	Present	Present
	Intervention	6.1±0.1	7.2±0.6	7.5±0.7[d]	Present	Present
	Control	6.1±0.1	7.4±0.9	2.6±0.9[c]	Present	Present
Rural	Base	6.6±0.2	3.7±1.1	0.2±1.2[b]	Absent	Absent
	Intervention	5.8±0.2	6.5±1.5	0.0±1.7[b]	Absent	Absent
	Control	6.1±0.2	7.5±1.5	7.5±1.7[a]	Absent	Present

Means followed by different letters in superscript are significantly different at 5%.

Milk hygiene was included in the training sessions, although not mentioned as a challenge. Farmers expressed need for learning about new practices that can improve their milk quality. The initial knowledge assessment on hygiene revealed that farmers had good knowledge of hygienic practices (Table 19 and 20). However, this wasn't reflected in milk quality. In rural farms initial status of milk fat was higher at the start of experiment (6.8%) than in the control group (2.2%). Microbial quality was lower at end of trial (6.1 cells/ml $log_{10}SCC$, 7.2 cfu/ml $log_{10}TVC$, 7.5 cfu/ml $log_{10}CC$) and for control group (6.1 cells/ml $log_{10}SCC$, 7.4 cfu/ml $log_{10}TVC$, 2.6 cfu/ml $log_{10}CC$) than at the start of trial (5.9 cells/ml $log_{10}SCC$, 5.9 cfu/ml $log_{10}TVC$, 1.4 cfu/ml $log_{10}CC$) in peri-urban. In rural, $log_{10}TVC$ was higher after experiment (6 cfu/ml) and in the control group (7.5 cfu/ml) compared to initial status (3.7 cfu/ml). This shows that although farmers have knowledge of hygiene milking practices and mentioned willingness to learn practices to improve milk quality it is not yet a priority for them. Both internal factors such as milk yield, and feeding (Restrepo *et al.*, 2016), and external factors such as market access and milk price (Chapter6) contribute to the low attention paid by farmers on milk quality.

5.3.4 Farmers' perception about training sessions and experiments

Rural and peri-urban farmers mentioned that training sessions have provided them with in depth knowledge on utilizing feed resources and how to improve it for dairy cows feeding. '… *I have learnt how to make urea-treated maize stalks and I have seen it has improved milk production*…' (Pilot farmer). '*…I had never seen use of urea in dairy cows' feeds, but when we made it I took a quantity from Kamau and gave to my cow and it ate it very well and its body condition looks better. I cannot however talk about milk production because my cow is drying off…*' (Participating farmer).They mentioned that reducing particle size and mixing forages to be helpful in reducing cows' selection and refusals from feeding troughs. They also pointed out that the experiments has given them insight on how to manage better their feed resources despite limited land for fodder production. Formulation of balanced diets and mixing of all forages when feeding was also mentioned as positive input from training as it reduces time farmers spend cutting and carrying forages. '*…I never knew that you could mix forages together…'*. Farmers also noted they acquired knowledge on cleanliness of equipment, environment and the cow. They specifically noted that *'…each cow should have its' own towel and water when cleaning before milking…'*

To sustain knowledge gained, farmers mentioned that purchasing a shredding machine would help because *'… it's hard to cut maize stalks with a machete but with a shredding machine and with one person to help I can cut more and faster…*'. Purchasing a silage tube was also mentioned because '*…making silage with the tube is easier than with the pit, because when I see people making silage in a pit it often spoils because air gets in, but it is easier to keep silage tube airtight…*'(participating farmer). They also mentioned collecting as much maize stalks as possible during next harvest (in future) and planting enough green forages to meet cows requirements *'… in January 2017, I will have a lot of maize stalks and I will be able to prepare enough for my cows…'* (Pilot farmer). Farmers suggested that improving the cowshed would help them improve on cleanliness through *'… buying stones for the cowshed floor improve on cleanliness…'* (Pilot farmer).Intervention in milking practice was also found useful and farmers resolved to *'… use a different towel and water for each cow…*' and rural farmers milking in the grazing field acknowledge they need a change in their milking practice by *'… regularly changing the place where we milk because we have noticed cows getting mastitis when milked for a long time at the same place but we never knew it was due to the environment…*'.

5.4. Conclusion and recommendations

Improved practices suggested by farmers and introduced by researchers in a participatory knowledge sharing process had a direct impact to milk production and were perceived as useful by farmers. Milk quality did not improved after training and on-farm experiment suggesting that although knowledge of good practices is high in smallholder farms, it is not yet seen as a priority by farmers. Therefore more participatory research on farm-level intervention should be carried out in various locations to improve farmers' knowledge on good practices to increase production. Reinforcing regulations and strict control of milk quality at all points of value chain will restrict poor quality milk entering the market, hence compelling farmers to apply recommended milking and handling practices. This will help improve milk quality and reduce postharvest losses.

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CHAPTER SIX

INFLUENCE OF MARKET PARTICIPATION ON FARM HYGIENIC PRACTICES AND MILK QUALITY IN SMALLHOLDER DAIRY AND PASTORAL CAMEL HERDS IN KENYA

Abstract

This study assessed the influence of milk market-outlets on milk handling practices and quality from a sample of pastoral camel and smallholder dairy herds. Milk market outlets were defined as Regular Quality Testing (RQT) representing formal market outlets (cooperative and processors collection centers) or Irregular Quality Testing (IQT) represented by the informal market outlet (neighbours, small scale traders, hotels and milk bars). From both herds, milk was predominantly kept in non-food grade plastic containers (80 -100%) to sell to RQT market. Aluminum cans were dominant in peri-urban smallholder herds which had access to better roads and shorter distance to the intended market. Smallholder herds (rural and peri-urban) selling milk to both IQT and RQT produced more milk (21.9 Kg/herd/day) compared to herds selling milk only to RQT (14.1-14.7 Kg/herd/day) or only to IQT (7.9 -11.3 Kg/herd/day). This result suggests preference of high milk producing herds for consistent buying, access to credits, veterinary services and feeds supply provided by RQT. Milk from smallholder herds was of higher quality when destined to IQT ($Log_{10}SCC$ = 5.39 cells/ml) than when destined to RQT ($Log_{10}SCC$ = 5.63). Marketed milk from the pastoral herds was of poorer quality ($Log_{10}SCC$ =7.55 cells/ml) than milk from smallholder herds mainly as a consequence of insufficient water access. Milk was sold to RQT when price per litre was more than KES 28 ($p=0.032$).Milk delivered to RQT via collection centres and farm gates was negatively associated with RQT ($p<0.001$) probably because low milk price offered in RQT and additional transport costs reduce returns to farmers. The impact is more important in low producers (7.9-11.3 Kg/herd/day) who then turn to IQT. Traders in IQT offered higher milk price (35 Ksh /litre) as an incentive for farmers to produce better quality milk from good practices. Consistent milk uptake and support services of formal markets attracted high producing farmers despite lower price (28 Ksh /litre).This was a disincentive to implementing good practices, hence lower quality. Therefore, reinforcing quality testing at all points of the value chain will compel farmers to apply recommended practices. Additionally, supporting farmers to increase production and better regulation of milk prices in RQT will contribute to channel more milk into this market.

Key words: market participation, smallholder, pastoral systems, milk market outlets

6.1. Introduction

Access to markets is important for both smallholder and pastoral milk producers because milk sale is a source of regular stream of income to household and quality nutritious food for consumers. From both smallholder and pastoral herds, substantial amount of the milk produced end up in the market and largely in the informal market outlets, where quality requirements are reported not to be strict (Muriuki, 2001; Leksmono *et al.*, 2006). Market outlets can influence hygienic practices needed to produce high quality milk because there is economic loss to producers when milk is rejected at the market (FAO, 2003; Kuma, 2014). Additionally, market participation allows smallholders and pastoral milk producers to get integrated into the national economies (Obi *et al.*, 2011) and opportunities to contribute to poverty reduction through the cash income realized from sales of farm produce (Muriuki and Thorpe, 2001).

Markets impose specific requirements on quantity and quality which demands that milk producers adjust their management practices in particular food, vertical integration, product traceability and reliability of supply. Kenya has had a proliferation of informal milk trading since 1990s following implementation of market liberalization policy (Leksmono *et al.*, 2006).The informal small-scale traders sell mostly raw unchilled milk whilst the private dairy companies sell chilled, processed milk and dairy products. The demand for raw milk is high and attractive to small-scale milk traders and there are efforts to have them licensed as an incentive for them to market milk in the formal channels. The informal markets often offer higher prices to farmers and lower prices to consumers than the formal market (Leksmono *et al.*, 2006). This encourages farmers to sell all or part of their milk in the informal market channels, estimated to be in excess of 70% of marketed milk (NDMP, 2010).

However, there are hygienic concerns in milk handling along the informal milk value chains (Omore *et al.*, 2000; Leksmono *et al.*, 2006). The concerns about safety and quality of milk from informal channels include cleanliness of the personnel, the animal, and the equipment used for milking, bulking and transportation of milk (Lore *et al.*, 2006).Milk quality assessments have indicated that quality is poor in both smallholder and pastoral herds, but is poorer in smallholder rural than in peri-urban herds (Chapter five). This was explained to be a consequence of water scarcity; mud floor milk sheds constraining hygienic milking practices in the zero grazing units and no application of udder drying prior to milking. The objective of this study was therefore, to describe milking and handling practices by smallholder and pastoral milk producers and determine factors that influence their choice to participate in formal or informal markets.

6.2. Methodology

Sampling procedure

The study was in Nakuru and Isiolo Counties where respectively there are large population of typical rural and peri-urban smallholder dairy farms and prominent pastoral camel milk production oriented to urban market demands. The smallholder dairy herds were randomly stratified by rural and peri-urban while camel herds could only be sampled on basis of willingness of herders to participate in the study and accessibility of the site where the herd was being grazed. Faced with this situation, camel herds were sampled from rangelands and from peri-urban grazing areas to capture the diversity of camel milk production systems. List of farms/ herds representative of the sampled areas were obtained in Counties livestock/ veterinary offices.

Data collection

A total of 79 herds of which 32 were smallholder rural dairy (Olenguruone Division), 32 smallholder peri-urban dairy (Dundori Division) and 15 pastoral camel herds were visited. Data was collected using a semi-structured questionnaire, on-farm testing of milk sample and laboratory analyses of milk and feed samples. The questionnaire recorded information on production characteristics, milking practices, handling practices and market outlets. On-farm milk testing was with California Mastitis Test (CMT) (KENOTEST, Belgium) for udder quarters of all milking animals in the herds at the time of visit, alcohol and lactometer tests. The last two tests are routinely implemented at milk collection by formal milk market buyers as well as some informal milk traders prior to milk collection at the farm gate. The quality testing of these markets were used to define them as Regular Quality Testing (RQT) for formal market and Irregular Quality Testing (IQT). Individual quarter milk samples were collected when found positive for mastitis; otherwise a composite milk sample of the four quarters was collected in a sterile sampling bottle for laboratory analysis.

Laboratory analyses consisted of direct microscopic somatic cell count following the procedure outlined by Sarikaya *et al*. (2006). Briefly, milk samples were thawed to 25^{o}C then thoroughly mixed. An aliquot of 0.05 ml of milk was then collected and diluted in 9.95 ml of distilled water. From this solution 0.05 ml was pipetted and mixed with 0.95ml of Turk's solution. This was pipetted and put on an improved Neubaeuer Chamber where somatic cells were counted as average number of cells in the 4 corner cells and the center cell for both the upper and lower chamber.

Data analysis

Descriptive statistics were applied to provide an indication of the distribution of farm characteristics and hygienic handling practices for milk going to the different market outlets from each herd category. Regression models fitted with GLM procedures of SAS (2008) were run to assess influence of market outlets on SCC, milk yield and milk density when nested within the respective herds. The same approach was used for the effects on alcohol and mastitis test but with logistic regression using GENMOD procedure of SAS (2008) since the dependent variables (alcohol and CMT) were categorical. Finally, a logistic regression model (PROC GENMOD) was run to assess farmers' decision to participate in the formal or informal milk market.

6.3. Results

Characteristics of milk market outlets

Figure 13 illustrates the proportion (%) of morning and evening milk marketed and the milk consumed at home (by household and calves). Smallholders marketed more of the morning milk (54% in rural and 49% peri-urban) compared to evening milk (54 vs 22% in rural and 49 vs 24% in peri-urban) and consumed the remainder (24% in rural and 28% in peri-urban) of the total production. From pastoral herds, the first and second milking were in the morning and were marketed at the same time.

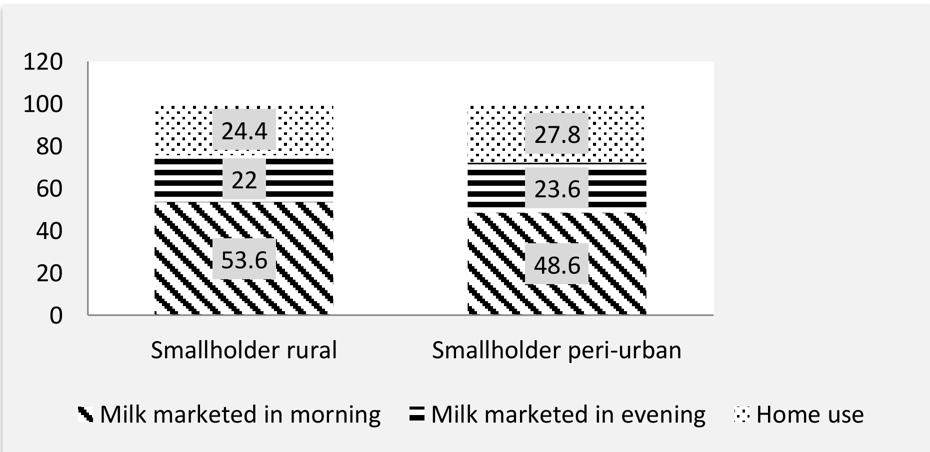

Figure 13: Production and home utilization of milk in smallholder dairy herds.

There were diverse milk market outlets for morning and evening milk (Table 22), but the pastoral herds had milking restricted to morning hours only. Evening milk was mostly sold to neighbors from rural (61.8%) and peri-urban (77.0%) herds. The morning milk was delivered to collection centers owned by cooperative societies from rural (68.3%), peri-urban (58.8%) and pastoral (97%) herds.

Table 23: Milk market outlets in smallholder dairy cow and pastoral camel herds

Market outlets	**Smallholder rural (n=82)**		**Smallholder peri-urban (n=32)**		**Pastoral camel (n=15)**	
	Morning milk (%)	Evening milk (%)	Morning milk (%)	Evening milk (%)	First milk (%)	Second milk (%)
Cooperative societies	68.3	17.7	58.8	0.0	97.0	98.0
Traders	5.0	8.8	35.3	15.4	3.0	2.0
Processor collection centers	11.7	0.0	0.0	0.0	0.0	0.0
Neighbors	6.8	61.8	5.9	76.9	0.0	0.0
Hotels	0.0	5.9	0.0	0.0	0.0	0.0
Others	1.7	5.9	0.0	7.7	0.0	0.0

Regardless of the smallholder herd, most of evening milk was sold to (Figure 14) informal markets (63.4% in rural and 92.3% in peri-urban). However, a large proportion of milk produced in the morning was sold to formal markets (81.8% in rural and 65% in peri-urban) and milk sold to informal market outlets was more in peri-urban (35%) than in rural (10.2%) herds.

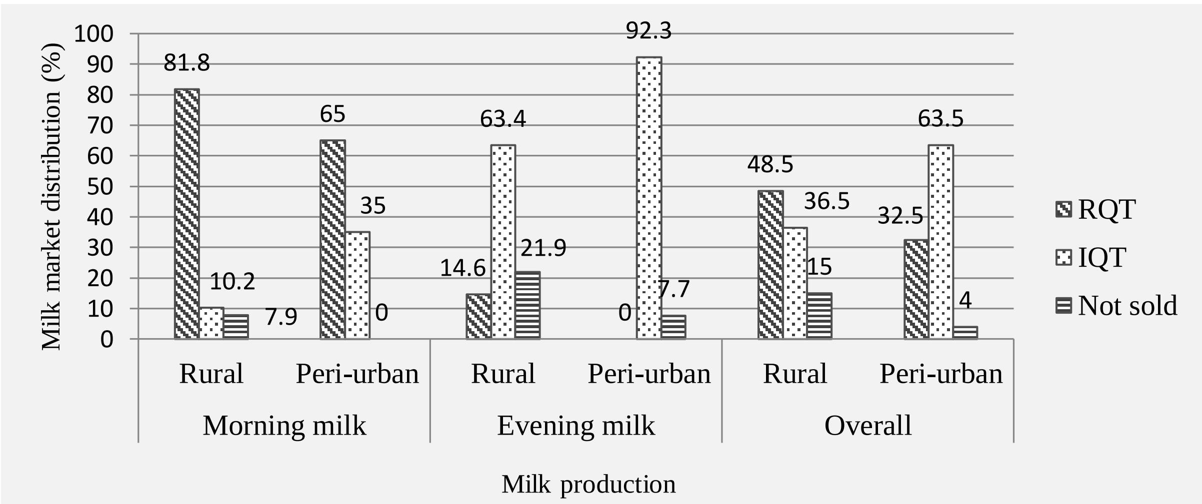

Figure 14: Market participation characteristics in smallholder dairy herds

Characteristics of hygienic practices by milk market outlets are presented in Table 24. Milking was done without washing of hands or udder and stimulation of milk letdown done by hand and by allowing calves to suckle prior to milking. Regardless of the market outlet, majority of smallholder farmers followed most of the milking hygienic practices including washing hands prior to milking, washing hands with detergents (soap), pre-milking udder preparation with udder washing and udder palpation to stimulate milk letdown.

Milk from pastoral herds was sold in market channels operated by women dominated cooperatives. Table 24 illustrates that use of plastic containers for milking was more frequent among smallholders regardless of the market outlet with rural farmers delivering milk to RQT to bulk milk for sell predominantly in plastic jerricans (80%) than their peri-urban counterparts (15.4%).

Table 24: Milking and handling containers used by smallholder dairy farmers selling milk to the different market outlets (%).

Production herds			Milking container		Milk pooling container	
			Plastic	Aluminum	Plastic	Aluminum
		RQT	100	0	50	50
	Rural	IQT	0	100	0	100
		RQT	100	0	40	60
Smallholder dairy	Peri-urban	IQT	100	0	33	67
		RQT	100	0	100	0
	Rangelands	IQT	-	-	-	
		RQT	0	0	100	0
Pastoral camel	Peri-urban	IQT	-	-	-	

Influence of market participation on farm hygienic practices and milk quality

Rural smallholders selling milk to both RQT and IQT market outlets produced more milk (21.95 kg/herd/day) compared to those selling only to RQT (14.06 kg/herd/day) or to IQT (7.95 kg/herd/day). This was true for the peri-urban smallholder farmers too, with those selling milk to RQT market outlets producing more milk (14.7 Kg/herd/day) than those selling milk to IQT market outlets (11.3 Kg/herd/day).

The somatic cell counts (Log_{10}SCC) was higher in pastoral milk compared to smallholder milk ((7.55 vs 5.35 cells/ml). Smallholder milk sold to RQT market outlets had higher log_{10}SCC (5.36 in peri-urban; 5.63 in rural) than those sold to IQT market outlets

(5.24 in peri-urban and 5.39 cells/ml in rural). Smallholder milk had insignificant differences in density regardless of the market outlet but was lower compared to pastoral milk (1.025 -- 1.028 vs1.030 g/ml).The rural smallholder milk had lower($p<0.05$) mastitis positive cases for milk sold to IQT markets outlets compared to milk sold to RQT market outlets (2 vs 5) but there was insignificant differences for peri-urban milk between milk sold to RQT and IQT market outlets. Mastitis positive milk samples was higher for pastoral and for smallholder milk which was sold to both RQT and IQT market outlets, unlike pastoral milk which was sold to RQT market outlets. However, milk from smallholders selling to both RQT and IQT showed no significant differences. Milk failing alcohol test followed similar trends with mastitis occurrence within and between the herd categories (Table 25).

Table 25: Quality parameters of milk from different marketing channels in smallholder and pastoral systems

Herd	Market outlet*	Daily yield (Kg/farm)	Log SCC (cells/ml)	Density (g/ml)	CMT**	Alcohol test **
Small rural	Both	21.95±11.54	5.86±0.19[a]	1.026±0.002[a]	0.0±0.1.4[ad]	0.0±1.4 [ad]
	RQT	14.06±4.92	5.63±0.05[a]	1.025±0.001[a]	0.3±0.6[a]	-0.7±0.6 [a]
	IQT	7.95±8.16	5.39±0.10[a]	1.025±0.002[a]	-25.7±0.6[bc]	-25.7±0.6[bc]
Smallholder peri-urban	Both	-	-	-		-
	RQT	14.73±5.44	5.36±0.14[a]	1.028±0.001[a]	-1.4±0.8[a]	-0.8±0.7 [a]
	IQT	11.25±11.54	5.24±0.35[a]	1.027±0.002[a]	0.0±1.0[a]	-1.1±1.2 [a]
Pastoral	Both	-	-	-	-	-
	RQT	40.72±4.71	7.55±0.13[b]	1.030±0.001[b]	2.6±1.0[d]	2.6±1.0 [d]
	IQT	-	-	-	-	

*Formal channel refers to milk delivered to cooperative owned or processors collection centers, informal channels include milk sold to traders, neighbours, hotels and milk bars.
**parameter estimates from regression models using PROC GENMOD modeled for probability of CMT positive and milk failing alcohol test.
Means for herds within a column with different letter superscript differ ($p<0.05$).

Determinants of participation in milk market outlets are presented in Tables 26. Milk price at milk delivery at collection centres and at the farm gates discouraged selling of milk to RQT market outlets compared to selling milk to IQT milk market outlets (P=0.032 for price and P<0.001 for milk delivery)

Table 26: Determinants of farmers' participation in formal or informal milk marketing in smallholder dairy herds

Variable	Level	Estimate (stderr)	Chi-sq	P-value
Hand washing	Yes vs no	-0.481 (1.096)	0.19	0.662
Use detergent for washing hand	Yes vs no	-0.087 (0.186)	0.22	0.639
Pre-milking preparation	Yes vs no	0.169 (0.311)	0.29	0.587
Dry teat prior to milking	Yes vs no	-0.266 (0.215)	1.53	0.216
Type of milking container	Aluminum vs plastic	0.197 (0.197)	1	0.318
Type of bulking container	Aluminum vs plastic	0.113 (0.185)	0.37	0.541
Access cooling facility	Yes vs No	-0.289 (0.184)	2.45	0.118
Daily milk yield	<5 ltr vs >8ltrs	-0.132 (0.174)	0.58	0.448
	5-8ltr vs > 8ltrs	-0.302 (0.281)	1.16	0.282
Price / litre	≤28 Ksh vs > 28 Ksh	-0.379 (0.176)	4.61	0.032*
Delivery point	Collection center vs none	-1.156 (0.339)	11.59	0.0007***
	Farm gate vs none	-0.906 (0.2447)	13.71	0.0002***
	Hotel/ milk bar vs none	-0.230 (0.452)	0.26	0.612
	Neighbouringbulking place vs none	-1.268 (1.031)	1.51	0.219
	Transport to buyer vs none	-0.942 (0.815)	1.33	0.248
Number of milking cows	≤ 2 vs >2	0.304 (0.179)	2.90	0.089

6.4 Discussion

Findings from this study show that about a half of the total milk production is sold in the morning, a quarter sold in the evening and the remaining quarter is kept for home use. These results are lower than the previous estimates for home consumption (40%) which raised concerns of forced consumption in smallholder households (Muriuki, 2001; Lore *et al*., 2006). The current study estimated that the proportion of milk retained at home is less than 25% of production and could not be labeled forced consumption because small volume of milk production (9 to 12kg/ herd/ day) and small proportion kept for home use shared between household use and calf rearing (2.5 kg/day).

More rural smallholder farmers delivered milk to collection centers (80%) using plastic jerricans compared to peri-urban farmers (15.38%)but jerricans are difficult to clean efficiently compared to aluminum or food grade plastic containers(Leksmono *et al*.,2006) though have the advantage when transporting milk along poor roads of rural areas and for milking camels in which the person milking stands to reach the udder. In contrast, peri-urban farmers access better roads and shorter distances to milk collection centers, and therefore pool milk in aluminum churns which are transported in motorbikes to collection centers (Leksmono *et al*., 2006).

Bulking of the milk from both rural and peri-urban farmers was in aluminum churns (60 to 67.6%). Milk from peri-urban areas goes to markets and collection centers through shorter distance on all-weather roads and therefore farmers used aluminum churns on motorbikes (58.3%) or on foot (41.2%). In contrast, milk from rural and pastoral go to the markets through long and not all weathered roads, which present risks of milk spillage on the way to the market for milk transported in aluminum churns..

Rural smallholders delivered more morning milk to collection centres than the peri-urban smallholders (80 vs 59%) who sold more milk to market outlets with IQT than those with RQT(35.3% vs 5%). Market outlets with RQT are classified formal channels while those with IQT or without RQT at all are classified informal, corresponding to market outlets described by Leksmono *et al*. (2006) in the peri-urban milk trade.

Evening milk is mostly sold to neighbors where quality testing is hardly implemented, because collection centers and traders only collect morning milk leaving farmers to search markets for the evening milk (Muriuki *et al*. (2001). The prominence of informal milk marketing, especially for afternoon milk and during rainy seasons, points to the need of increasing intake capacities of processors, and to empower informal milk traders in hygienic handling of raw milk for safety of consumers (Kurwijila, 2006).

In the pastoral herds, milking is twice in the morning then kept in fumigated bulking containers which are left under a shade at the entrance of the *Boma* where the transporter will collect the milk within 3 to 4 hours. Fumigation of bulking containers is a practice believed to increase shelf life of milk (Wayua *et al*., 2013). Milking twice in the morning is a strategic decision to allow the herd to be moved during the day in search of pastures and mineral licks and will hardly come back to same place. Also, before temperatures rise, milk has to be picked by transporters to deliver to urban market outlets (in Isiolo town).

Smallholder dairy farmers follow hygiene milk handling routines but pastoralists are constrained by persistent water scarcity to be able to practice pre-milking hygienic routines. Therefore hygiene practices that work for pastoral milk producers will be unique from those practiced by smallholder milk producers.

In the smallholder herd market participation was related to the quantity of milk produced, a practice which has been observed by Kuma *et al.* (2014). Farmers selling milk to both RQT and IQT (formal and informal) market outlets were producing more milk than those selling to single market outlet. Farmers' participation in RQT when milk production is high may be explained by long term advantages they obtain in terms of credits, veterinary services and feeds supply associated with cooperatives and processors offering embedded services. Access to these embedded services is graded on quantity of milk delivered to the collection centers, and therefore farmers producing small volumes of prefer selling milk to IQT (informal) market outlets (-0.38, p=0.03)which offer better prices and immediately but without embedded services.

Milk quality was lower for pastoral compared to smallholder herds and is likely related to water scarcity needed to implement hygienic procedures including hands washing, udder washing and cleaning of milking containers prior to milking. In smallholder herds, SCC was not different between milk delivered to RQT (formal)and IQT (informal) market outlets though there was tendency for higher SCC in milk sold to RQT (formal)market outlets. The same trend was observed for milk density, alcohol and mastitis occurrence, which implies that market outlets have not significantly influenced changes in milk quality at the production level. This is further reinforced by observations that hygienic practices in milking and handling, access to cooling facilities and number of milking animals had insignificant influence on participation in the RQT (formal) market outlets.

In contrast, milk price and delivery point had significant influence on a farmer participating in RQT (formal) over IQT (informal) market outlets, probably because farmers producing large volumes of milk preferring to sell milk to RQT (formal) market outlets though at lower prices (28 vs 32Ksh/ltr) while farmers with small milk volumes preferred selling milk to IQT (informal) market outlets which offer higher price/ litre (> 28Ksh).

Leksmono *et al*. (2006) reported that informal market outlets provide higher price per litre of milk to farmers, but this may not be sustainable in the long term because low access to credit and limited ability to produce surpluses milk for the market constraints market participation (Olwande and Mathenge (2012). These authors noted the importance of membership to farmers' organization towards enhancing market participation, which is true among present study sample. Although farmers' organization buy milk at lower prices, they facilitate to access credit and provide embedded supportive services including feeds, veterinary and credit through check off payment arrangements.

6.5 Conclusions and recommendations

Most of milk produced in the morning is sold through formal market, although food grade containers are not used for handling. Therefore, there is need to increase capacity of collection centers and reinforce existing regulation on milk handling containers. The preference for formal market by farmers producing large milk volumes and lack of consistent quality standards at collection do point to the need of improving extension services to increase milk production and train farmers' and traders in maintaining milk quality along the value chains.

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CHAPTER SEVEN

GENERAL DISCUSSION

7.1. Rationale of the study

The underlying rationale for this study is the loss of income, food and nutrition security for producers, entrepreneurs and consumers from milk postharvest losses (PHL) at milking, bulking, evening storage or at the farm gate in smallholder and pastoral herds. The motive was to quantify PHL and determine its associations with herd management and marketing practices to inform up scaling in extensions and development targeted interventions. The research questions that guided the study were:

i. There is no significant association between milking practices, mastitis infections and somatic cell counts with pre and postharvest milk losses
ii. Feeding practices have no significant influence on milk yields and quality
iii. Improvements of feeding and milk hygiene practices have no significant influence on production and quality of milk;
iv. Milk handling practices, production, quality and postharvest losses are not significantly different between milk market outlets.

7.2 Methodology

7.2.1. Sampling procedures

The study selected representative smallholder dairy and pastoral camel herds from rural and peri-urban areas because smallholder dairy farmers produce about 80% of total milk (Muriuki, 2003) while pastoral camel herds contribute about 12% of total milk production. Random sampling was possible for smallholders but not for pastoral herds because of their mobile nature. Although an effort was made to obtain a maximum variation in pastoral milk production by covering a wider area around Isiolo town, sampling within each of the locations visited was purposive and therefore a limitation for generalizations of the results. Data was obtained in cross sectional surveys at herd and animal levels and complemented with longitudinal action research to foster innovation capacity for finding solutions to low milk production and to low milk quality which impacts on postharvest losses. Action research could not be implemented with pastoral milk producers because of their frequent mobility in search for pastures and water.

7.2.2 Data collection and measurements

Both qualitative and quantitative data were collected for this study. Data on herd characteristics, milking, handling and feeding practices were collected through semi-structured questionnaire. Production records were collected through questionnaire in cross sectional survey and actual measurement in follow up data collections. Feed availability and utilization in farms were also collected through FEAST tool. Farm tests prior to milk samples collection included alcohol, density and mastitis. Data on mastitis was collected at three levels: quarter, cow/camel and herd to obtain a clear demarcation between these levels on prevalence of mastitis to inform intervention strategies. Animal level milk samples were subjected to laboratory analysis of somatic cell count and identification of mastitis pathogen to differentiate between herd levels and provide an overview of dilution effects since most of the milk is pooled when sold in the markets. Feed composition data was obtained through laboratory analysis and NRC, 2001. Knowledge level data was collected qualitatively on a scale (1 to 5) and treated quantitatively on the proportion of sample within each scale point.

7.2.3 Statistical procedures

Mixed analytical methods were applied for this study. Descriptive statistics (frequencies, means, standard deviation and percentages, correlation) were used in all objectives to characterize farmer practices and animal performance, mastitis occurrence and post-harvest losses. Inferential statistics with chi-square test were employed to determine associations between milking routing, handling practices and production herds while GLM was used to determine differential effects of feeding practices on milk quality, changes in milk yield and quality attainable with targeted training intervention on improved feeding and milk hygiene. Logistic regression in stepwise approach was fitted to quantify prevalence risk of mastitis pathogens at quarter, cow/camel and herd levels, to determine effects of market outlets nested within farm types on alcohol and mastitis testing; and to determine association between handling practices, farm characteristics and SCC. It was also used to determine associations of market outlets nested within farm types on SCC, milk yield and density. Poisson regression was used to determine factors' affecting farmers' decision to participate in formal (RQT) or informal (IQT) markets. Finally, knowledge level before and after interventions was qualitatively assessed on a gradient of 1 (very low) to 5 (very high). Employing several statistical procedures in this study was guided by the nature of the research conducted. Cross sectional survey data analyzed mainly with descriptive, inferential statistics and regression modeling provided and outlook of the data, the emerging associations between variable and the strength and direction of these associations. Follow-up data collection mostly recorded quantitative dependent variables within clusters and grouping variables identified during cross-sectional survey. Analysis of variance with GLM procedure of SAS was mostly used for this. Qualitative data analysis with knowledge level was added for the study on feeding and milk hygiene intervention because farmers' opinion was needed to validate findings and recommendations from cross-sectional and follow-up studies. Therefore, the use of different statistical approaches was to provide an in-depth extraction of information from data that allowed better understanding and reporting of PHL situation in smallholder and pastoral herds.

7.3. Implications of the findings

7.3.1 Influence of milking practices, mastitis infections and somatic cell counts on postharvest milk losses

Milking practices may have influenced mastitis prevalence but not directly because there was no significant relationship. Lactation stage, mastitis occurrence and presence of *Staphylococcus aureus* increased milk SCC (Chap. 3). High SCC (>200,000cells/ml) was associated with milk production losses of 11% both in rural and peri-urban farms while PHL were 19% in smallholder and 57% in pastoral herds. The higher losses in pastoral herds compared to smallholder were due to the characteristics of the production system. Being a rangeland without developed amenities, there is limited access to water for washing hands, udder and equipment used in milk handling.

The difference within production herds were insignificant among the smallholder herds and among the pastoral herds whether in rural or in peri-urban. Milking practices were associated with high SCC and hence the PHL. Unhygienic milking units in smallholder peri-urban farms and non-use of individual towels during milking in smallholder rural were observed. Mastitis prevalence was very high in smallholder peri-urban (53%) and in rural (70%) herds which was associated with high SCC and losses. Milking and handling practices did not significantly affect SCC variation in milk, suggesting an indirect milk contamination from the milking person to the animal then from the animal to milk. The high presence of *Staphylococcus aureus* associated with increase in SCC (Carillo-casa and Morales, 2012) in smallholder peri-urban (56%), in smallholder rural (60%) and in pastoral herds (58%) confirms this finding. Unidentified infected animals constitute the reservoir for *Staphylococcus aureus* and animals' cross-contamination occurs during milking through milker's hands (Carillo-casa and Morales, 2012). Use of individual towel for milking, teat dipping using cleaning agents, clean cowsheds and cow/camel dry off period (35 to 60 days) were recommended. During the dry off period, herd level therapy, rather than quarter or cow/camel therapy should be applied in order to reduce prevalence of mastitis pathogens in herds. In the current situation, these recommendations are unlikely to be taken up by farmers, policy is therefore required. This is because farmers know hygienic practices but do not find incentives to produce higher quality milk since both bad and good quality milk are marketed predominantly in the informal channels (Chap. 3 and 5). Applying herd level mastitis therapy will require involvement of government agencies because it will require additional costs that farmers may not be willing to incur. Additionally, cross-farm contamination may occur during milk marketing with transporters handling milk, therefore mastitis control program may be developed rather at production system level than at the individual farm level.

The high level of milk PHL together with high prevalence of mastitis pathogens can raise public health concerns if milk is not properly handled along marketing chain. Most of milk being positive or negative for mastitis reached intended market outlet where inadequate heat treatment may not limit the action of spoilage and pathogenic microorganisms (Rebelein, 2010 and Hassan *et al*., 2009). Risks are higher with milk from pastoral camel herds because a reasonable amount is spontaneously fermented into *'suusa'* along the marketing channel without boiling (Mwangi, 2015).

7.3.2 Influence of feeding practices on milk yield and quality

Diversity of feeding practices were found in this study which included intensified systems (semi-zero and zero-grazing) encouraged by limited land for fodder production (Napier grass, oats) and characterized by use of crop residues and off-farm feed resources (forages and concentrates). The prominence of free grazing was found in rural smallholder herds where cows feed mainly on natural pastures supplemented with Napier grass and concentrates.

Pastoral herds were kept in the rangelands with camels feeding on available shrubs (53.3%) and grass (20%) and in peri-urban areas around Isiolo Town (26.7%) with camels feeding mainly on *Euphorbia tirucali*. The average low milk production in pastoral camel (1.5 kg/day), smallholder rural (6 kg) and peri-urban herds (5 kg) suggested inadequate feeding practices. Four major factors were found to contribute to the inefficiency of feeding practices to sustain milk production:

- Small farm sizes in peri-urban that limit fodder production and force farmers to use crop residues or purchase green fodder;
- Improper processing of green forage i.e. no wilting, no chopping of forages contributing to low dry matter intake;
- High forage to concentrate ratio (more than 8:2) leading to less digestible protein and readily available carbohydrates probably due to high cost of concentrates and their uncertain quality;
- Very low to no inclusion of forage legumes in the diets reducing the overall nutritive value of feeds in smallholder farms.

Feeding oats together with Napier and crop residues may reflect farmers' efforts to improve feeding need to support higher milk production, but farmers generally had limited knowledge on cow feed requirements and formulation of feed ration. Therefore, training in forage management, feed formulations, and value addition to crop residues through urea treatment was conducted in a participatory action research. The study was conducted in smallholder farms and findings presented in Chapter 5. Results showed increased knowledge of good feeding practices that was reflected in at least 19% increase in milk production, suggesting the potential for higher milk from current crossbred cows in smallholder farms. Dry matter intake that was identified as below requirements in Chapter 4, was increased by at least 60% and contributed to increase of nutritive value of feeds, hence, more milk. This could also contribute to channel more milk through formal market outlet since findings from Chapter 6 suggested that farmers producing higher volumes of milk prefer formal channel. This is because formal channels provide consistent buying, and support with extension services, feeding and other financial services.

Feeding practices in pastoral herds were constrained by feed resources locally available. Peri-urban herds were fed on *Euphorbia tirucalli* and attained higher milk yield (2.85 kg) compared to when grazing grass (2.02 kg) or browsing shrubs (1.37 kg). Higher milk yields attained on Euphorbia may suggest high nutritive value of this feed in addition to less energy spent unlike when trekking over long distance over rangelands in search of pastures and water.

7.3.3. Influence of milk market outlets on milk handling practices and postharvest losses

The underlying assumption was that due to regular quality control, milk from formal channels provides higher security to consumers than milk from the informal market. Peri-urban herds of smallholders and pastoral had more diversified market outlets, especially for morning milk than of rural herds. Smallholder rural and pastoral herds are far away from urban centres, which limits their marketing options for milk and mostly sell through cooperative collection centers. The rural farms therefore mostly transport milk in plastic containers because of ease of transportation on motorbike along poor roads (Chap. 6). The situation is different in peri-urban where states of roads and proximity to urban mark*et al*low small scale traders to pool milk from many farms in aluminum churns and transport it to market outlets. These traders offer better price per litre of milk to farmers and consumers (Leksmono, 2006). In aggregate, these small scale traders' market high volumes of milk, hence empowering them in hygienic handling of raw milk for safety of consumers will be public rewarding. Furthermore this study found high prevalence of mastitis and causing pathogens in milk and improper handling may pose public health issues to consumers. Indeed not keeping the cold chain throughout transportation may contribute to increase microbial loads in milk and pose a risk to consumers as reported by Omore *et al*., (2000). Improper heat treatment may fail to eliminate spoilage and pathogenic microorganisms pose health problems to consumers. Informal marketing of evening milk in smallholder rural and peri-urban points to the need of increasing intake capacities of collection centres.

In the current study proportion of milk retained home was less than 25% of production and could not be labeled forced consumption because volumes of milk produced were small (9Kg and 12kg/ herd/ day in peri-urban and rural respectively) and the proportion kept for home use was 2.4 and 2.5 kg/day in rural and peri-urban, respectively. This was shared between household use and calf rearing.

Smallholder farmers' participation to formal market was rather guided by quantity of milk produced than by quality. High producers preferred formal markets probably because it is more consistent and reliable than informal traders who can be intermittent and because of services provided by collection centres cooperative or processor owned. These organizations provide veterinary services, feeds, and sometimes loans to farmers which builds trust and consistent supply from farmers. Since these services are provided in accordance with volume of milk delivered, farmers with higher production obtain higher benefits. Farmers with lower milk yields who sell to informal market may not sustain their dairy farming enterprise because it does not provide a framework similar to that of a cooperative society which can buffer shortcomings in the production process. Smallholder farmers selling to formal market had lower milk quality than those selling to informal markets probably because market access conditions are not based on quality. They are rather based on trust and collection centres' clerks randomly perform quality tests at farm gate before collecting milk. These tests are systematically carried out at collection centers but due to pooling of milk, especially in peri-urban, milk failing tests is rarely returned to farmers. Informal traders on the other hand, because of the uncertain nature of their market, require milk of higher quality and therefore often perform quality tests before collecting milk. Milk quality is a major challenge that may explain together with feeding the low milk production of dairy cows in smallholder and pastoral herds. However, farmers are sensitive to information on feeding but not on quality. This may lead to a recoil of the dairy farming which is a major contributor to income and food securities of many families. Therefore, regulations need to be reinforced; incentives based on milk quality with a grading system may also be introduced. Milk prices in transport costs in formal channels should also be revisited to allow low producers to participate in formal markets. More effort should be put in place by regulatory body to control and channel milk from informal traders and to collect evening milk through formal channels.

7. 4 Conclusions

i. Milking practices were associated with production herds but not with mastitis infections which contributed to increase SCC and led to high postharvest losses.
ii. Feeding practices in smallholder dairy herds affected milk yield but not milk quality, while in pastoral camel herds both yield and quality were affected by feeding practices.
iii. Use of participatory action research increased farmers' understanding of improved practices for higher milk production
iv. Milk handling practices, production and quality were different between market outlets with informal market having higher farm gate quality but lower quantity.

7.5 Recommendations

The following recommendations are therefore made to farmers and extension workers:

- Herd level mastitis therapy, teat dipping, use of milking salve, keeping clean cowsheds and a dry off cow period should be observed.
- Feeding improvement strategies should include forage management, context specific ration formulations, use of concentrates and forage legume.
- Involving farmers in more participatory research to improve uptake of recommended practices

To policy makers:

- Regulations should be reinforced for milk quality control at collection.
- Certification of small scale traders should therefore be accelerated to ease product traceability and quality monitoring along the value chain.
- Strategies should be put in place to improve milk market price, transportation costs and milk uptake by formal markets

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APPENDICES

APPENDIX I: DATA COLLECTION TOOLS

I.a. Questionnaire for cross sectional survey:

ASSESSING EXTENTOF FARM-LEVEL POSTHARVEST MILK LOSSES IN SMALLHOLDER AND PASTORAL MILK SYSTEMS IN KENYA

Introduction

This survey is conducted by a postgraduate student of Egerton University in the partial fulfillment of a Doctor of Philosophy degree in Animal science. Thus its purpose is purely academic. You are kindly requested to provide information through interview with this questionnaire. Information provided will be confidential and shall only be used for the purpose of this study.

Household consent obtained [Yes] [No] Thank you.

1. **GENERAL INFORMATION**

Date	
Questionnaire code No:	
Name of respondent	
Name of enumerator	
Study Site	☐ Dundori Division ☐ Bahati Division ☐ Olenguruone Division ☐ Isiolo County
GPS point	

2. **HOUSEHOLD CHARACTERISTICS**

2.1 Name household head	
2.2 Gender	☐ Male ☐ Female
2.3 Education level	☐ None ☐ Primary ☐ Secondary

	☐ Tertiary
2.4 Household main occupation	☐ Crop farming ☐ Livestock farming ☐ Mixed crop-livestock farming ☐ Salaried employment ☐ Self employment

3. ESTIMATION OF FARM-LEVEL POST HARVEST MILK LOSSES

3.1. Animal characteristics

Number of animals					
	Breed	**Age**	**Parity**	**Lactation stage (days)**	**Milk yield**
Animal 1					
Animal 2					
Animal 3					
Animal 4					
Animal 5					

3.2. Milk characteristics

	Sampling point	**Milk quantity**	**CMT**	**SCC**	**TBC**	**CC**	**Density**	**Alcohol**
Animal 1	Milking							
	Bulking							
	Storage							
	Farm gate							
Animal 2	Milking							
	Bulking							
	Storage							
	Farm gate							
Animal 3	Milking							
	Bulking							
	Storage							
	Farm gate							
Animal 4	Milking							
	Bulking							

	Storage							
	Farm gate							
Animal 5	Milking							
	Bulking							
	Storage							
	Farm gate							

3.3. Estimation of milk losses

3.3.1 Quantity milk spillage	☐ Milking…….. Kg (or %) ☐ On farm bulking…… Kg (or %) ☐ Evening storage…… Kg (or %) ☐ Farm gate delivery…… Kg (or %) ☐ Total ………… (Kg)
3.3.2 Quantity spoilage	☐ Milking……………….Kg (or %) ☐ On farm bulking…… ...Kg (or %) ☐ Evening storage……… Kg (or %) ☐ Farm gate delivery…… Kg (or %) ☐ Total ……….Kg (%)
3.3.3 Possible cause of milk the spoilage?	……………………….. ………………………. ………………………..
3.3.4 Forced consumption (milk that was supposed to be sold but was not due to lack of market or market rejection)	…………… (litres / Kg)
3.3.5 Quantity of milk used at home/ day	
3.3.6 Quantity of milk used for calves	

4 CHARACTERISTICS OF ON FARM FEEDING PRACTICES

4.1. Information on basal diets offered to dairy cows

1. Pasture
2. Silage
3.Napier grass
4. Hay
5. Crop residues
6. Any other, specify……………

4.6.Type of concentrates offered

1. Commercial dairy meal
2. Homemade ration (specify ingredients used)
3. Mixed home and commercial dairy meal
4. Others, specify….

4.1. Farming system	☐ Zero grazing ☐ Semi zero grazing ☐ Free grazing				
Animal	**1**	**2**	**3**	**4**	**5**
4.2 Type of basal diet*					
4.3 Quantity offered					
4.4 Proximate analysis					
4.5 Minerals analysis					
4.6 Type of concentrates offered*					
4.7 Quantity concentrates offered					
4.8 Proximate analysis concentrates					
4.9 Mineral analysis					
4.10 Mineral supplements offered*					
4.11 Quantity offered					

*Sample required

5 CHARACTERISTICS OF ON FARM MILK HANDLING PRACTICES

5.27 Cow shed (floor)
1. Concrete
2. Timber
3. Earthen
4. Any other, specify……………

5.27 Cow shed (wall)
1. None
2. Concrete
3. Timber
4. Wire
5. Earthen
6. Any other, specify…………

5.27 Cow shed (roof)
1. None
2. Iron sheet
3. Grass thatch
4. Any other, specify………

4 5 5.1 How long have you been practicing dairy farming?	
5.2 Who milks the cow (s)?	
5.3 How long has he been milking cows	
5.4 Has the milking person been trained in milk handling?	☐ Yes ☐ No
5.5 Does the milking person wash hands before milking (observation)	☐ Yes ☐ No
5.6 Does the milking person use any sanitizer (detergent) for hands washing prior to milking?	☐ Yes (specify………………………..) ☐ No

5.7 Does the milking person use specific milking clothing	☐ Yes (specify………………………..) ☐ No
5.8 Use of gloves for milking	☐ Yes ☐ No
5.9 Do you wash udder prior to milking?	☐ Yes ☐ No (reason …………………….)
5.10 Water used for udder washing	☐ Cold water ☐ Warm water
5.10b Sources of water	☐ Borehole ☐ Roof catchment ☐ River ☐ Natural spring ☐ Tap water ☐ Any other, specify……………
5.11 Use of sanitizer for udder washing	☐ Yes (Specify…………………...) ☐ No (reason …………………….)
5.12 Do you practice pre-milking udder palpation?	☐ Yes ☐ No (reason …………………….)
5.13 What is the occurrence of teat lesions (observation)	☐ very high (over 75 % of the surface) ☐ high (50-75% of the surface) ☐ average (25- 50% of the surface) ☐ low (10- 25% of the surface) ☐ very low (less than 10% of surface)
5.14 Udder hygiene score	☐ free of dirt ☐ Slightly dirty (2-10% of the surface) ☐ Moderately covered with dirt (10-30% of the surface ☐ Covered with caked on dirt (over 30% surface)
5.15 Do you practice fore-stripping	☐ Yes ☐ No (reason …………………….)
5.16 Do you practice teat pre-dipping	☐ Yes ☐ No (reason …………………….)
5.17 What product do you use?	
5.18 Do you dry teats prior to milking	☐ Yes ☐ No (reason …………………….)
5.19 Do you administer any post milking treatment?	☐ Yes ☐ No (reason …………………….)
5.20 Do you practice a Mastitis test prior to milking?	☐ Yes ☐ No (reason …………………….)
5.21 What treatment do you use if mastitis positive	
5.22 What is the recurrence of mastitis in the same animal?	After…….days/ After…….months/ After…….years
5.23 How do you use the milk in case mastitis positive?	

5.24 How long does it take to milk one animal?	
5.25 What milking equipment do you use?	
5.26 How do you maintain it clean?	....
5.27Do you have a cowshed for the dairy cows?	☐ Yes ☐ No (reason …………………….)
Floor	☐
Wall	☐
Roof	☐
5.28 Cleanliness of milking place (mud and dung on the floor, humidity and bad smell)	☐ very dirty (over 75 % of the surface) ☐ dirty (50-75% of the surface) ☐ average (25- 50% of the surface) ☐ clean (10- 25% of the surface) ☐ very clean (less than 10% of surface)
5.29 Types of milking containers	☐ Plastic, ☐ Aluminum ☐ Others (specify)
5.30 Cleanliness of milk containers (presence of dirt, particles and milk residues in the container)	☐ very high (over 75 % of the surface) ☐ high (50-75% of the surface) ☐ average (25- 50% of the surface) ☐ low (10- 25% of the surface) ☐ very low (less than 10% of surface)
5.31 Types of bulking containers	☐ Plastic, ☐ Aluminum ☐ Others (specify)
5.32 Cleanliness of bulking containers (presence of dirt, particles and milk residues in the container)	☐ very high (over 75 % of the surface) ☐ high (50-75% of the surface) ☐ average (25- 50% of the surface) ☐ low (10- 25% of the surface) ☐ very low (less than 10% of surface)
5.33 Types of milk storage containers	☐ Plastic, ☐ Aluminum ☐ Others (specify)
5.34 Cleanliness of milk storage containers (presence of dirt, particles and milk residues in the container)	☐ very high (over 75 % of the surface) ☐ high (50-75% of the surface) ☐ average (25- 50% of the surface) ☐ low (10- 25% of the surface) ☐ very low (less than 10% of surface)
5.35 Detergent used for cleaning them?	....
5.36. Do you have access to any milk cooling system?	☐ Yes (Specify……………………) ☐ No
5.37. Do you know of any other means of	☐ Yes (Specify……………………)

preserving milk?	☐ No
5.40. Do you preserve milk?	☐ Yes (Specify……………………) ☐ No

6 MILK MARKET INFORMATION

1. How much milk did you produce in total today?	………… Kg
2. What is your average milk production of last week?	…………..Kg
3. How much milk did you use at home	
4. How much do you use for calves	
5. Did you donate milk last month (to family, members, church, neighbors)?	
6. If yes how often	After ……….. days
7. How much of the milk produced did you donate?	☐ …….. litres or ☐ Half of the production ☐ A quarter of the production ☐ Less than a quarter of the production
8. Do you sell milk?	☐ Yes ☐ No
9. If yes, how much do you sell 1 litres	………….. (Kshs)
10. How much milk did you sell today (morning)	………… litres
11. How much milk did you sell last evening?	………… litres
12. To whom did you sell last evening milk?	☐ Neighbours ☐ Milk bars ☐ Cooperative ☐ Processor ☐ Hawkers ☐ Others (specify)
13. To whom did you sell this morning milk?	☐ Neighbours ☐ Milk bars ☐ Cooperative ☐ Processor ☐ Hawkers

	☐ Others (specify)
14. Where was it bought from?	☐ Farm gate ☐ Neighbouring bulking place ☐ Cooling center ☐ Others (specify)
15. How was the milk transported to cooling center/ consumer	☐ By foot ☐ Motobike ☐ donkeys ☐ By car
16. How much are you charged for milk transportation?	
17. Is the milk subjected to quality test before selling?	☐ Yes (Specify…………………..) ☐ No
18. If yes who performs the test?	
19. Have you experienced rejection?	☐ Yes (Specify…………………..) ☐ No

I.b. FOLLOW-UP QUESTIONNAIRE: ASSESSING FARM-LEVEL POSTHARVEST MILK LOSSES AND ASSOCIATED CAUSES IN SMALLHOLDER AND PASTORAL DAIRY SYSTEMS IN KENYA

Introduction

This survey is conducted by a postgraduate student of Egerton University in the partial fulfillment of a Doctor of Philosophy degree in Animal science. Thus its purpose is purely academic. You are kindly requested to provide information through interview with this questionnaire. Information provided will be confidential and shall only be used for the purpose of this study.

Household consent obtained [Yes] [No] Thank you.

4. GENERAL INFORMATION

Date	
Questionnaire code No:	
Name of respondent	
Name of enumerator	
Study Site	☐ Dundori Division ☐ Bahati Division ☐ Olenguruone Division ☐ Isiolo County
GPS point	

5. HOUSEHOLD CHARACTERISTICS

2.1 Name household head	
2.2 Gender	☐ Male ☐ Female
2.3 Education level	☐ None ☐ Primary ☐ Secondary ☐ Tertiary

2.4 Household main occupation	☐ Crop farming ☐ Livestock farming ☐ Mixed crop-livestock farming ☐ Salaried employment ☐ Self employment

6. ESTIMATION OF FARM-LEVEL POST HARVEST MILK LOSSES

3.1. Animal characteristics

Number of animals					
	Breed	**Age**	**Parity**	**Lactation stage (days)**	**Average daily milk yield**
Animal 1					
Animal 2					
Animal 3					
Animal 4					
Animal 5					

Follow up data collection form Date………/………/………/

District …………………….. Division………………… Location……………………..

Farmer Name... Sample ID................. Number of animals in milk.....…....

Animals' udder pict No…. milking area pict No …. Containers pict No …

CMT test

Animal	1	2	3	4	5	6
Quarter 1						
Quarter 2						
Quarter 3						
Quarter 4						
Remarks						

Other farm tests

Animal	1	2	3	4	5	6
Density						
Alcohol						
T °C						
pH						
Remarks						

Production

	C1	C2	C3	C4	C5					
Morning										
Evening										
Total										

Milk use

	Quantity sold	Market outlet	Quantity home	Quantity calves	Quantity stored
Today morning					
Last evening					
Total					

Feeding

Anima l\ diet	Basal diet type	Basal diet quantity	Quantity dairy meal	Quantity mineral salt
1				
2				
3				

4				
5				

Milking hygiene

Tick when appropriate	**Yes**	**No**
Milker washed hands prior to milking		
Use of water to clean udder and teats		
Warm water to clean udder and teats		
Cold water to clean udder and teats		
Milking ctnr plastic		
Milking ctnr alluminum		
Bulking ctnr plastic		
Bulking ctnr alluminum		
Udder hygiene score (1 to 4)		

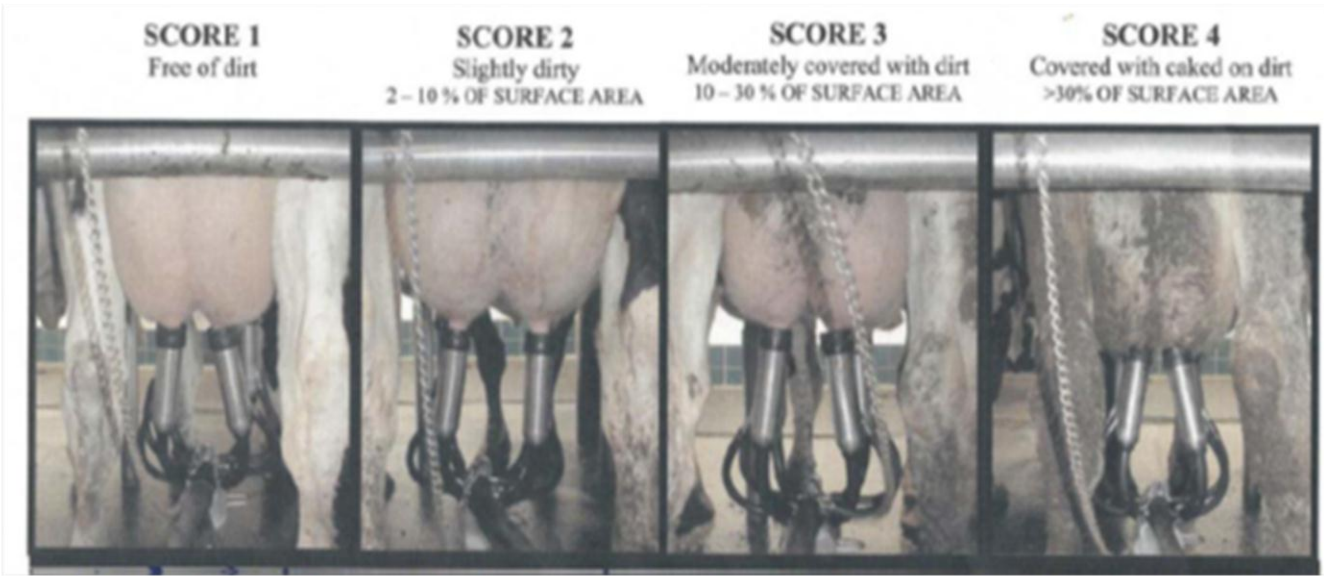


Figure 15: Udder hygiene scoring

I.c. FOCUS GROUP DISCUSSION GUIDEFOR THE RESEARCH ON ASSESSING FARM-LEVEL POSTHARVEST MILK LOSSES AND ASSOCIATED CAUSES IN SMALLHOLDER AND PASTORAL DAIRY SYSTEMS IN KENYA

Consent Process

Thank you for agreeing to participate. We are very interested to hear your valuable opinion on farm management practices that impact on milk production and quality.

- *The purpose of this study is to learn about milk post harvest losses. We hope to learn things that can be used to improve working conditions and other factors in Kenya.*

- *The information you give us is completely confidential, and we will not associate your name with anything you say in the focus group.*

- *We would like to tape the focus groups so that we can make sure to capture the thoughts, opinions, and ideas we hear from the group. No names will be attached to the focus groups and the tapes will be destroyed as soon as they are transcribed.*

- *You may refuse to answer any question or withdraw from the study at anytime.*

- *We understand how important it is that this information is kept private and confidential. We will ask participants to respect each other's confidentiality.*

- *If you have any questions now you can always contact a study team member like me, or you can call the project team leaders whose names and phone numbers will be given.*

Introduction:

1. Welcome
   Introduce yourself and the notetaker, and send the Sign-In Sheet with a few quick demographic questions (age, gender, cadre, yrs at this facility) around to the group while you are introducing the focus group.

   Review the following:

   - Who we are and what we're trying to do
   - What will be done with this information
   - Why we asked you to participate
   - If you are a supervisor, we would like to excuse you at this time

2. Explanation of the process
   Ask the group if anyone has participated in a focus group before. Explain that focus groups are being used more and more often in health and human services research.

About focus groups

- We learn from you (positive and negative)
- Not trying to achieve consensus, we're gathering information
- No virtue in long lists: we're looking for priorities
- In this project, we are doing both questionnaires and focus group discussions. The reason for using both of these tools is that we can get more in-depth information from a smaller group of people in focus groups. This allows us to understand the context behind the answers given in the written survey and helps us explore topics in more detail than we can do in a written survey.

Logistics

- Focus group will last about one hour
- Feel free to move around
- Where is the bathroom? Exit?
- Help yourself to refreshments

3. Ground Rules

   Ask the group to suggest some ground rules. After they brainstorm some, make sure the following are on the list.

- Everyone should participate.
- Information provided in the focus group must be kept confidential
- Stay with the group and please don't have side conversations
- Turn off cell phones if possible
- Have fun

4. **Turn on Tape Recorder**
5. Ask the group if there are any questions before we get started, and address those questions.

Questions

1. How do you milk the cows?
   - Hygiene
   - Equipment
   - Experience
   - How many times
   - Animal preparation for milking
   - Cleaning and type of containers used
2. What do you do with the milk?
   - Sale (channels the milk takes until final consumer; where, how and when, distance, contracts with buyers and price of milk)
   - Home consumption
   - Calves
   - Alternative uses of raw milk
   - Use of rejected milk
   - Forced consumption
   - Seasonal variation

- Who milks the cow
- How do you handle evening milk (storage /preservation)?

3. Milk yield per cow (average) dry and wet season?
4. Understanding of the post harvest losses?
   - Causes
   - (Spillage, Spoilage)
   - Handling of losses
   - Use of milk that lacks market or market rejected
5. Do you carry out any quality test on the milk?
   - Differentiate good nad bad milk (what test do you carry out)?
   - Proportion of milk that fails or pass
   - Who performs the test
   - Any training for milk quality testing?
6. Any relevant training?
7. Challenges

I.d. Feed Assessment Tool (FEAST): focus group and individual farmer questionnaires

Focus group discussion questionnaire

FEAST focus group discussion guide

1. General Farming System Description [60 Minutes]

Objective: Obtain a general picture of the farming and livestock system

1.1. **What is the typical farm size? What is the minimum, maximum and average cultivated land per household?**

- "Farm size" is considered to be cultivated land
- Also consider additional lands that may be leased or shared.
- Elicit responses from farmers and allow farmers to debate the responses and reach a final consensus.
- Where consensus is difficult to reach, taking individual land sizes of farmers present may give an indication of land sizes in the village

Minimum: [ ] Acres | Hectares | Local Units (circle one)

Average: [ ] Acres | Hectares | Local Units (circle one)

Maximum: [ ] Acres | Hectares | Local Units (circle one)

If local units, name of local unit: [ ]

1 hectare = [ ] *Local Units*

What are the common land tenure systems in the village?

[ ]

Is the land tenure system a constraint to livestock and fodder production? If so how?

[ ]

1.2. **What is the typical (or average) household size? On average, how many people have been living continuously in each household for the past 6 months?**

General Information

Fill this out in advance as much as possible.

Name of Site/Village: ____________

Name of Sub-District: ____________

Name of District: ____________

Country: ____________

Number of Households in the Area: ____________

To be considered a household, the dwelling must have a kitchen.

GPS Coordinates of Meeting Location[1]:

Latitude: ____________ **Longitude:** ____________

It is facilitator's responsibility, not participants', to determine GPS coordinates (if possible).

Number of Participants Present:

Males: ____________ **Females:** ____________

Date: ____________

Start Time: ____________ **Finishing Time:** ____________

[1] Record GPS co-ordinates in degrees, minutes and seconds i.e. +/- ddd, mm, ss

- Elicit responses from farmers and allow farmers to debate the responses and reach a final consensus.
- Where consensus is difficult to reach, taking individual household size of farmers present may help give an indication of HH size in the village

[ ] people per household

What percentage (%) of HH members are migrating out of the village for one reason or the other?

[ ] %

Record these reasons.

1.3. On a scale from 0 to 5, where 0 = no rainfall and 5 = heavy rainfall, how does the rainfall pattern vary over a year?

- Help farmers relate to the rainfall scores by explaining the range of scores and giving examples e.g. number of days receiving rainfall in a month as an indicator of amount of rainfall.
- Initiate a discussion about rainfall distribution throughout the year. Allow farmers time to debate and arrive at a consensus.
- Note that there could be differences in rainfall pattern even within a village depending on geographical factors such as altitude (high and lowlands), proximity to water bodies, mountains etc. where these are obvious construct more than one rainfall pattern e.g. for low and highlands.
- Guiding questions could include:
  - During which months do you receive the most rainfall here?
  - During which month do you receive the lowest amount of rainfall?
  - What score would you give for the amount of rainfall in those months?

Follow on to prompt farmers for scores to all the months throughout the year.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (0-5)												

1.4. **Name the cropping seasons that occur in this area. In which months do the various seasons occur (tick the appropriate boxes in the table below).**

- Farmer will often relate cropping seasons to rainfall and dry seasons. With this in mind:
  - Ask farmers to name the cropping seasons as they are locally known.
  - Ask farmers to indicate which months these cropping seasons occur. Also indicate the dry season months even though cropping may not be occurring
- Farmers may make reference to the type of crops grown or activities that occur during these cropping seasons during their discussions. Please record these crops /activities and months during which they are grown/occur.

Name of Season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.												
2.												
3.												

1.5. Availability of Water & Irrigation

1.5.1. **Is water for watering livestock available in the area?**

What percentage (%) of households have access to water? For watering livestock? ____ %

What types of water sources are available in the area?

Source	Seasonality

What are the distances covered to access water for drinking and watering livestock?

Distance	Seasonality

1.5.2. **Is irrigation available in the area?**

What percentage (%) of households have access to irrigation?

[ ] %

What types of irrigation are available in the area?

[ ]

What crops mainly benefit from irrigation?

[ ]

On a scale of 0 – 4; where 0 = low and 4 = high, how would you score the availability of water for livestock (including fodder production)?

[ ]

1.6. **When is labour most required?**

How much does it typically cost to hire daily paid labour by gender and activity (e.g., ploughing, seeding, weeding, harvesting, etc.)?

Activity	Males	Females

How much does the cost of labour vary throughout the year?

Maximum: **Minimum:**

Are labour costs affordable for most households?

Are many people leaving the farm to work in the city/town or seek education?

On a scale of 0 – 4; where 0 = difficult and 4 = easy, how easy is it to hire casual labour as and when required?

1.7. **What livestock are raised within the area? What are the animals mainly used for?** ***(Complete the table only for livestock species that are relevant to the survey area)***

Livestock species	Primary Use(s) (eg. production of milk for sale, production of milk for household consumption, meat production, draught, manure production etc.)	% of HH that own species.	Average number of animals per HH
Local Dairy cows			
Improved dairy cows			
Local dairy buffalo			
Improved dairy buffalo			
Draught cattle			
Draught buffalo			
Fattening cattle			
Sheep			
Goats			
Pigs			
Poultry – village			
Poultry – commercial			
Camels			
Horse			
Donkeys			

1.8. **What are the main sources and types of credit for livestock/cropping activities?**

Source	Seasonality

What are the shares (%) of formal / informal credit?

Formal: ____ % **Informal:** ____ %

What are the conditions for obtaining cash/credit for crop/livestock production?

What percentage (%) of local farmers have access to credit? ____ %

What percentage (%) of focus group participants aspired to access credit in the last 2 years?

____ %

On a scale of 0 – 4; where 0 = difficult and 4 = easy, how easy is it to access credit when required?

1.9. **Is land area available for cultivation increasing or decreasing, and why?**

Is land used for more than one crop per year?

If fallowing is practiced, how much land is cultivated vs. how much is put to fallow? ***(enter N/A if fallowing is not practiced)***

Cultivated: % **Fallow:** %
This is the amount of uncultivated land.

What is the reason for land being left fallow? Is the land being put to fallow increasing or decreasing, and why?

What is the cost to lease one ha or local unit of land?

If local units, name of unit:

1 hectare = *Local Units*

For the average household, what % of land is used for fodder vs. subsistence (staple cereals) vs. cash crops?

Fodder: % **Subsistence:** % **Cash Crops:** %

In case of extensive systems, is there enough land for supplying forage?

Is land for cultivation in short supply? On a scale of 0 – 4; where 0 = low and 4 = high, what is the availability of land for fodder cultivation?

1.10. **What is the distance / travel time to the local market?**

What is the cost of travel to the local market?

Are roads accessible throughout the year? Are there certain times of year or weather conditions when the roads are not accessible?

Who are the main suppliers of inputs in the area?

Supplier	Input Type

On a scale of 0 to 4, where 0 = never available and 4 = always available, how available are crop and farm inputs in the local markets when required?

- "Inputs" include items such as fertilizer, farm implements (hoe, sickle, plough etc.), seeds, feeds, animal health drugs, acaricides, water pumps/pipes, plastic sheeting, irrigation equipment etc.

2. Management of Livestock Species [60 Minutes]

Objective: Assess how livestock are managed within the area

2.1. Housing & Feeding of Livestock

How are livestock housed?

Types of structures used	
Feeding troughs provided?	
Bedding provided?	
Housed throughout the day or partially?	
Are animals housed together or separated (by age, species, sex or type)?	

What is the style of feeding (stall fed, tethered, open grazing or combination)?

If grazing, which areas are utilized?

Are there seasonal differences in style of feeding?

Are there differences in style of feeding by animal type?

What percentage (%) of farmers process feed for livestock in the area?

- Feed processing includes chopping, urea treatment, mixing etc

%

What types of feed are processed?

Do farmers mix homemade rations from processed feeds?

Of the farmers who process feed, what percentage are male vs. female?

Male: % **Female:** %

What percentage (%) of farmers offer concentrate feeds to their animals?

%

Is there any other seasonal variation in management methods?

2.2. **Veterinary / Animal Health Services**

What are some common types of health problems in the area that warrant veterinary attention?

What are the types of services available and who provides them?

Service	Provider(s)	Average Distance	Average Price

How common are traditional veterinary practices?

3. Problems, issues, opportunities within livestock system [30 Minutes]

Objective: Determine if farmers recognize feed as a major factor limiting animal production, and what farmers see as potential solutions.

3.1. **List the major problems faced by farmers in the area with reference to livestock production. What do farmers view as the solution to these identified problems?**

	Problem	Solution(s)
1		
2		
3		
4		
5		

3.2. **Complete pair-wise comparisons for the problems in the table below. For each comparison, record which problem is identified as the more important of the two.**

Pair	Problem Considered More Important
Problem 1 vs. Problem 2	
Problem 1 vs. Problem 3	
Problem 1 vs. Problem 4	
Problem 1 vs. Problem 5	
Problem 2 vs. Problem 3	
Problem 2 vs. Problem 4	
Problem 2 vs. Problem 5	
Problem 3 vs. Problem 4	
Problem 3 vs. Problem 5	
Problem 4 vs. Problem 5	

Rank problems based on number of times they were selected as more important in the pairwise comparisons (highest # = most important)

Problem	# of Times Chosen as More Important	Ranking (1 = most, 5 = least)
1		
2		
3		
4		
5		

Individual farmer questionnaire

FEAST individual farmer interview questionnaire

General Respondent Information

Date of Interview: ____________________

Interviewer Name: ____________________

Respondent Name: ____________________

Landholding Category: Landless | Small | Medium | Large (circle one)

Occupation: ____________________

Name of Settlement: ____________________

Name of Village: ____________________

GPS Coordinates of Interview Location[1]

Latitude: __________ **Longitude:** __________

It is interviewer's responsibility, not respondent's, to determine GPS coordinates (if possible).

How much land do you own?: ______ Acres | Hectares | Local Units (circle one)

How much land do you cultivate?: ______ Acres | Hectares | Local Units (circle one)

If local units, name of local unit: ______ *1 hectare =* ______ *Local units*

Cooperative / Organization Affiliations (which household members?)

____

1. Use format +/- ddd, mm, ss

1. Livestock Holdings

Questions

- **What types of livestock do you currently own?**
- **What is the approximate weight of the animals?**
- **What is the dominant breed?**

Notes

- Explain to the farmer the livestock categories and age group terminologies used
- Only inquire about types of livestock that are relevant to the farm. Try to specify local breeds if possible.
- In the event that farmer does not know or cannot estimate the weight of his/her animals consult secondary sources such as literature or local extension staff. The Domestic Animal Diversity Information System has an inventory of livestock breeds at *dad.fao.org* which may be useful in determining livestock weights.

Type of Livestock	# Currently Owned	Approx. weight per animal (kg)	Dominant Breed
Local Dairy cows – lactating			
Local Dairy cows - non lactating (dry)			
Local Dairy heifers (>6mths old - < 1st calving)			
Local Dairy calves (<6mths old) – female			
Local Dairy calves (<6mths old) – male			
Improved dairy cows – lactating			
Improved dairy cows - non lactating (dry)			
Improved Dairy heifers (>6mths old - < 1st calving)			
Improved Dairy calves (<6mths old) – female			

Type of Livestock	# Currently Owned	Approx. weight per animal (kg)	Dominant Breed
Improved Dairy calves (<6mths old) – male			
Local buffalo – lactating			
Local buffalo cows - non lactating (dry)			
Local buffalo heifers (>6mths old - < 1st calving)			
Local buffalo calves (<6mths old) - female			
Local buffalo calves (<6mths old) - male			
Improved buffalo – lactating			
Improved buffalo - non lactating (dry)			
Improved buffalo heifers (>6mths old - < 1st calving)			
Improved buffalo calves (<6mths old) – female			
Improved buffalo calves (<6mths old) – male			
Bulls or castrated male cattle (> 2 year)			
Bulls or castrated male cattle (>6mths old - < 2 years)			
Bulls or castrated male buffalo (>2 years)			
Bulls or castrated male buffalo (>6mths old - < 2 years)			
Sheep			
Goats			
Pigs			
Poultry			

Type of Livestock	# Currently Owned	Approx. weight per animal (kg)	Dominant Breed
Camels			
Horse			
Donkeys			
Other (specify)			
Other (specify)			

2. Crops Grown on Farm

Questions

- **What crops are grown on your farm?**
- **How much would you normally expect these areas to yield (in local units)?**
- **What do you do with the residue material (as a percentage)?**

Notes

- ***EXCLUDE CROPS GROWN SOLELY FOR FODDER PRODUCTION*. WE WILL COLLECT DETAILS FOR THOSE CROPS LATER**
- If residue material is fed to livestock, obtain an estimate of grain yield from the farmer. If the farmer cannot provide estimate of grain yield the crop residue material will not count as contributing to the diet of the animal.

Cultivation Area & Yield (if using local units, specify below)			Residue Use (%) (if any allocated to 'other', specify below)				
Crop	Area[2]	Yield[3]	Feeding	Burnt	Mulching	Sold	Other*

Name of local unit (Area): ______ *1 hectare =* ______ *Local units*

Name of local unit (Yield): ______ *1 tonne =* ______ *Local units*

Specify "Other" Residue Use: ______

[2] Total area devoted to this crop
[3] Total yield harvested from the area specified e.g. tonnes NOT tonnes/ha

3. Cultivated Fodder

Questions

- **What plants (including deliberately planted forage trees) are deliberately grown on your farm for the primary purpose of feeding livestock?**
- **How much area is used to grow these crops?**

Notes

- Fodder crops are plants that are specifically grown for livestock feeding

Crop	Area[4]

Name of local unit (Area): ______ *1 hectare =* ______ *Local units*

[4] Total area devoted to this fodder crop

4. Collected Fodder

Questions

- **Do you collect any other naturally occurring green fodder material from surrounding areas?**
- **If so, how much does this material contribute to the total nutrition of your livestock (as a percentage)?**

Notes

- Naturally occurring green fodder can include:
  - Thinnings
  - Weeds from cropping areas,
  - Roadside weeds,
  - Naturally occurring grasses
  - Any other naturally occurring green material collected for livestock feed

Contribution of collected fodder to animals' diet (%): ______ %

5. Purchased Feed

Questions

- **What feeds do you purchase over a typical 12 month period?**
- **What is the price of these feeds?**
- **How much do you purchase (in kilograms) each time you purchase the feed?**
- **How many times throughout the year do you purchase each feed?**

Notes

- Feeds can include:
  - Crop residues
  - Green fodder
  - Commercially available mixed concentrate feeds
  - Industrial by-products
  - Any other material that is purchased for the purpose of livestock feed.

Feed Purchased	Typical Quantity per Purchase (amount and unit) [5]	Price / Local Unit[6]	Number of Times Purchased per Year

Name of local unit (Mass): ______ *1 local unit =* ______ *kilograms*

Local Currency: ______

[5] E.g. 4 quintals or 5 donkey loads or 3 maize sacks
[6] E.g. 4000 shillings per quintal or 250 birr per donkey load or 20 dollar per maize sack

6. Grazing

Questions

- **Considering everything eaten by livestock (eg. crop residues, roadside grasses cut and bought back to animal, grown fodder material, purchased feed), how much does grazing contribute to the overall nutrition of livestock over the course of a year (as a percentage)?**

Contribution of grazing to animals' nutrition (%): ______ %

7. Sources of Household Income

Questions

- **From the list given, what are the four main sources of household income? What percentage (%) of household income do each of these sources contribute?**

Notes

- Percentages for all sources must add up to 100%

Income Source (Select 4)	Contribution to Income (%)
Cash crops	
Dairying	
Fattening animals - cattle	
Fattening animals - sheep and goats	
Food crops	
Laboring/service	
Off- farm business	
Poultry (eggs)	
Poultry (meat)	
Remittances	
Other (Specify)	
Other (Specify)	
Must add up to 100%	*100*

8. Cattle Sales by Category (per Household)

Questions

- **How many ruminants (cattle, sheep, buffalo, goats) have been sold (or slaughtered for home consumption) over the past 3 years?**
- **What was the approximate weight of the animals sold?**

Type of Livestock	# of Males Sold	Approx. weight per male (kg)	# of Females Sold	Approx. weight per female (kg)
Number of **cattle** sold over past 3 years[7]				
Number of **goats** sold over past 3 years				
Number of **sheep** sold over past 3 years				
Number of **buffalo** sold over past 3 years				

[7] Note – make sure the numbers are over the whole 3 years and NOT an annual average

10. Milk Yield, Home Consumption and Sales

Questions

- **What is the average milk yield in litres per day per household over the course of a year?**
- **What is the average price received per litre of milk over the course of a year?**
- **How much milk is retained for household consumption per day?**

Notes

- If household consumption is fairly consistent over the course of a year, it is not necessary to estimate monthly variances.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total average milk yield (litres/day)[8]												
Average price received for milk (per litre)												
Amount of milk retained for household use (litres/days)[9]												

[8] Note – this is for the whole farm and NOT the yield per cow

11. Seasonality

Questions

- **On a scale of 0-10, where 10 = excess feed available, 5= adequate feed available and 0=no feed available, how does the availability of feed vary over an average year?**
- **How much does each source of feed contribute to the diet of the animals throughout a year? (Proportion of nutrition derived from different sources)**

Notes

- To make this section quicker and easier for respondents, show them their responses on the chart as they are answering, to allow them to visualize trends.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Feed availability (score 0-10)												

(Continued on Following Page)

Sources of Feed by Month (rate on a scale of 1-10, total for all sources for each month must add up to 10)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Crop residues (eg. rice straw, maize stover)												
Legume crop residues from legume crops (eg. chickpeas, lentils)												
Green forage (eg. roadside weeds, cut fodder crops, tree leaves etc)												
Grazing												
Concentrates (eg. Wheat bran, grains, oilseed cakes)												
Other – Specify												
Other – Specify												
Must add up to 10!	10	10	10	10	10	10	10	10	10	10	10	10

This is the end of the Individual Farmer Interview.
Thank the respondent for their time.
Explain that the data will be analyzed to identify major issues and potential solutions related to livestock feed, and the findings and recommendations will be shared with the community once the study is complete.

Full questionnaires available at: https://www.ilri.org/feast

I.e. PRODUCTION RECORD SHEET: On_farm feeding and hygiene interventions in smallholder dairy herds

Farmer				**Milk Yield (Kg)**				
Cow	**Feed 1**	**Feed 2**	**Grazing Hrs/ Feed 3**	**Before**	**Day1**	**Day 8**	**Day 15**	**Day 22**
Farmer				**Milk Yield (Kg)**				
Cow	**Feed 1**	**Feed 2**	**Grazing Hrs**	**Before**	**Day1**	**Day 8**	**Day 15**	**Day 22**
Farmer				**Milk Yield (Kg)**				
Cow	**Feed 1**	**Feed 2**	**Grazing Hrs**	**Before**	**Day1**	**Day 8**	**Day 15**	**Day 22**
Farmer				**Milk Yield (Kg)**				
Cow	**Feed 1**	**Feed 2**	**Grazing Hrs**	**Before**	**Day1**	**Day 8**	**Day 15**	**Day 22**
Farmer				**Milk Yield (Kg)**				
Cow	**Feed 1**	**Feed 2**	**Grazing Hrs**	**Before**	**Day1**	**Day 8**	**Day 15**	**Day 22**

APPENDIX II: Additional information

Chapter 3:

II. a. Socio-demographic information

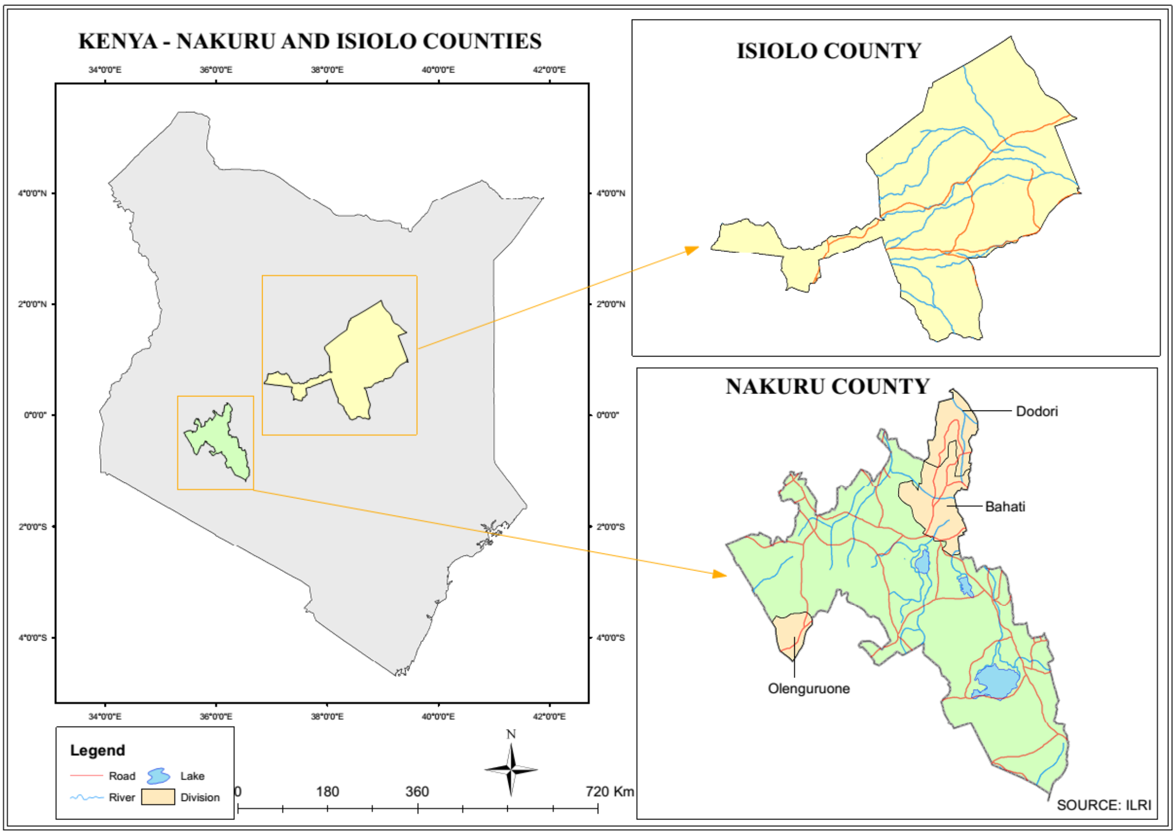


Figure 15: Map of the study sites

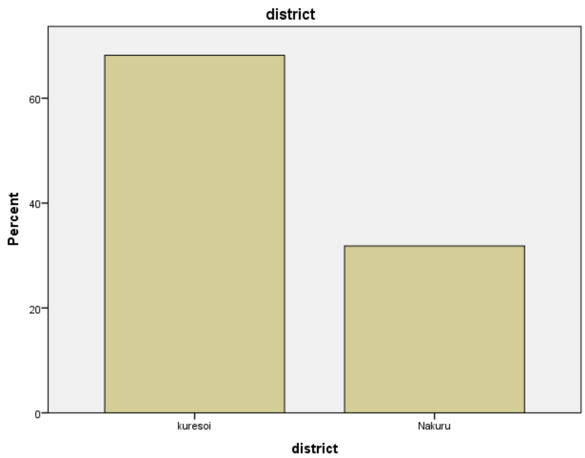
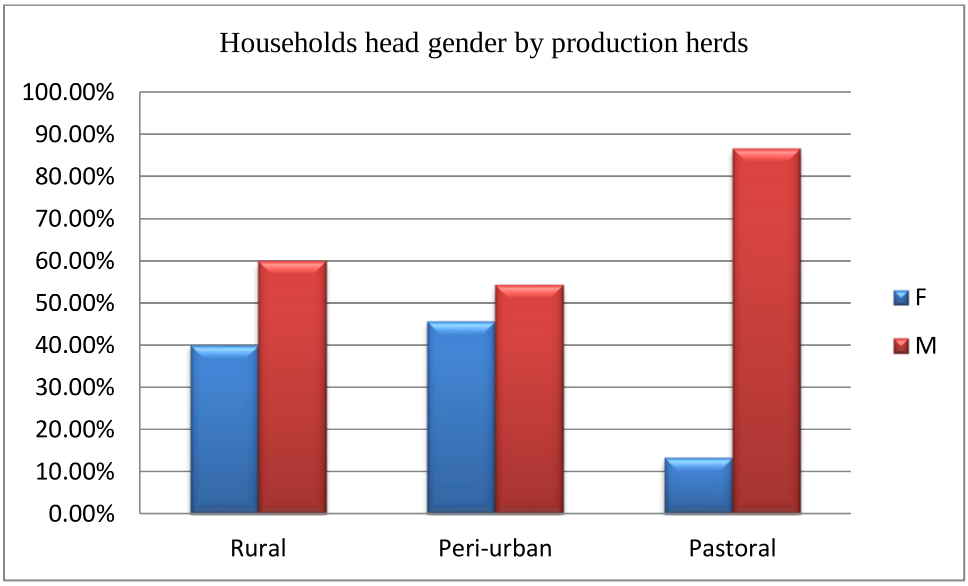
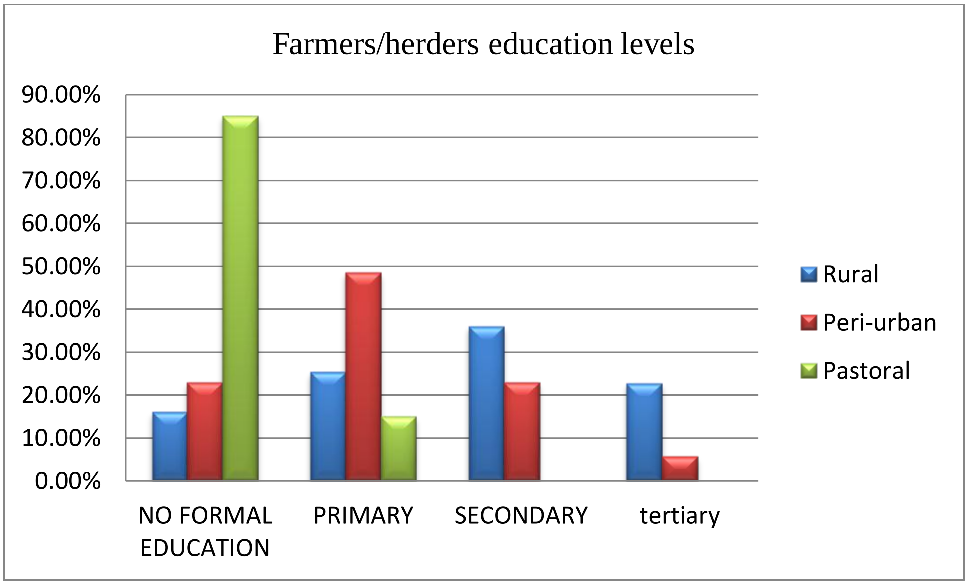
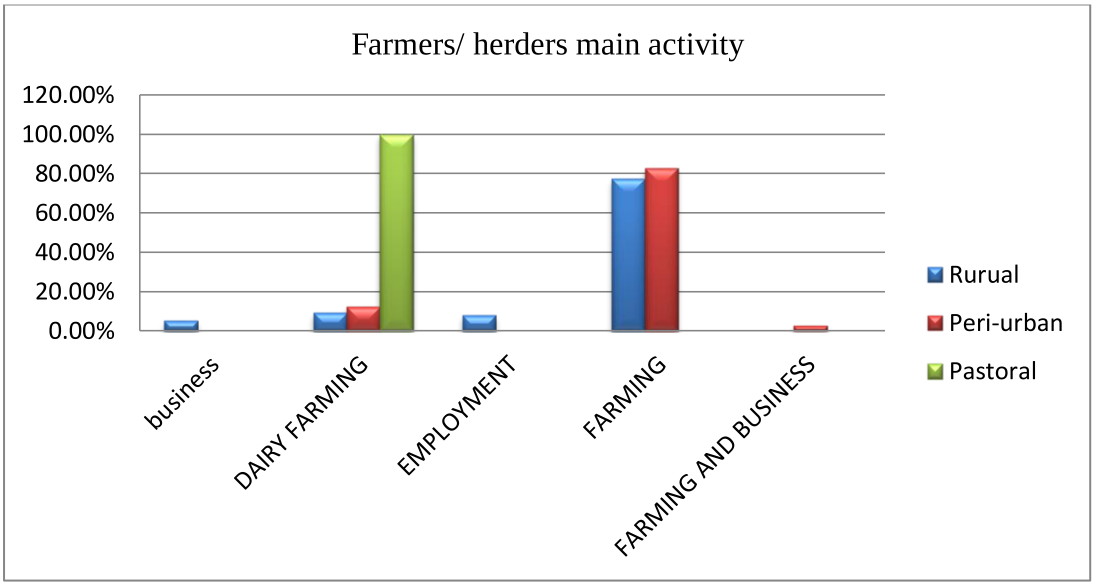
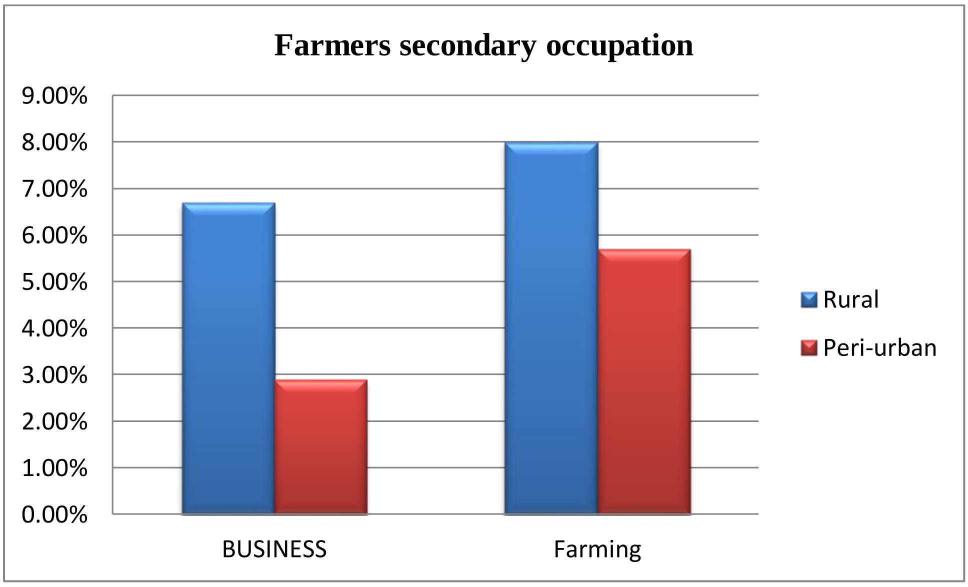


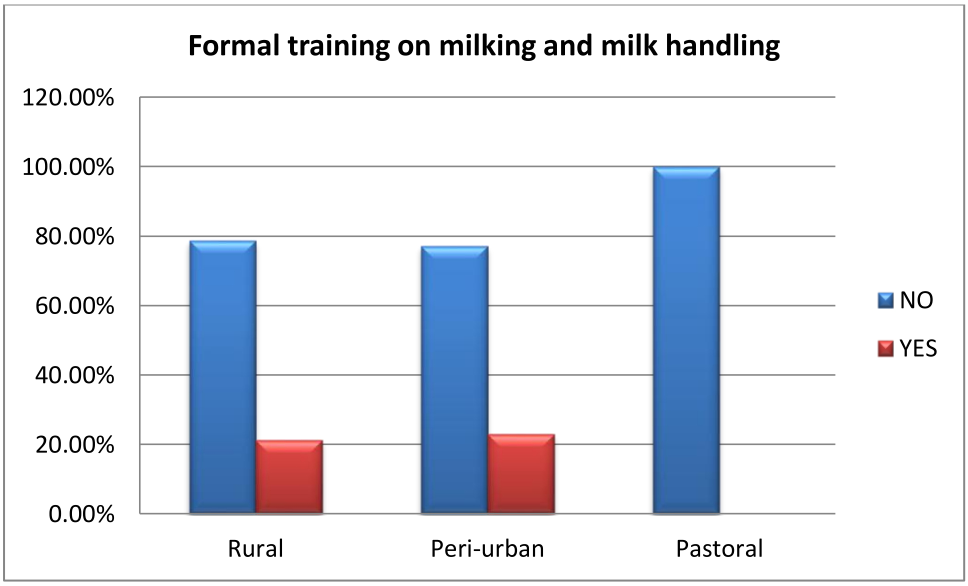
Figure 16: Proportion of interviewed farmers in Kuresoi (Rural) and Nakuru (peri-urban)

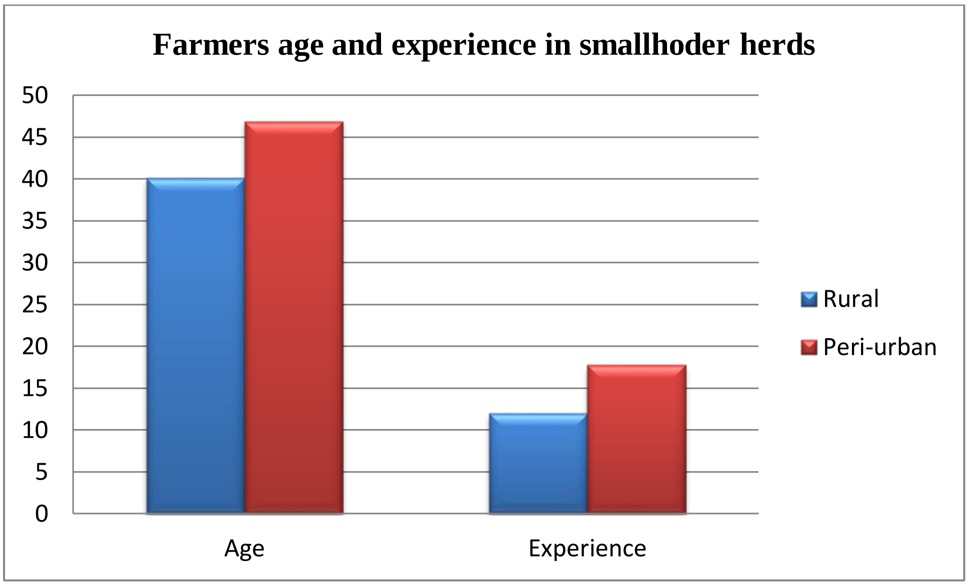

Households head gender by production herds
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Rural
Peri-urban
Pastoral
F
M


Farmers/herders education levels
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
NO FORMAL EDUCATION
PRIMARY
SECONDARY
tertiary
Rural
Peri-urban
Pastoral


Farmers/ herders main activity
120.00%
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
business
DAIRY FARMING
EMPLOYMENT
FARMING
FARMING AND BUSINESS
Rurual
Peri-urban
Pastoral


Farmers secondary occupation
9.00%
8.00%
7.00%
6.00%
5.00%
4.00%
3.00%
2.00%
1.00%
0.00%
BUSINESS
Farming
Rural
Peri-urban


Formal training on milking and milk handling
120.00%
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
Rural
Peri-urban
Pastoral
NO
YES



II. b. Morphology and characteristics of Staphylococci and Streptococci identified in milk samples

Herd	Characteristics	Gram stain	Catalase	Coagulase	Hemolysis	Suspect organism	Frequency
	Black colony with clear halo						
	Black colony without halo						
	Black mucoid colony without halo						
	Grey to black colony						

II. c. ANOVA tables

Table 27: Effects of practices on SCC

Source	DF	SS	MSq	F	P
Model	6	39.33	6.55	49.38	<0.0001
Error	41	5.44	0.13		
Corrected total	47	44.78			

Rsq = 0.88; Coeff. Var = 6.07; Root MSE = 0.36; SCC mean = 6.0

Table 28: Effects of practices within systems on SCC (Table 6)

Source	DF	SS	MSq	F	P
Model	7	2.63E16	3.76E15	5.26	0.0002
Error	42	3.00E16	7.14E14		
Corrected total	49	5.63E16			

Statistics for Table of hand washing in different production herds

Statistic	DF	Value	Prob
Chi-Square	2	67.8977	<.0001
Likelihood Ratio Chi-Square	2	67.3162	<.0001
Mantel-Haenszel Chi-Square	1	37.4311	<.0001
Phi Coefficient		0.9271	
Contingency Coefficient		0.6799	
Cramer's V		0.9271	

Statistics for Table of Udder washing in production herds

Statistic	DF	Value	Prob
Chi-Square	4	73.5217	<.0001
Likelihood Ratio Chi-Square	4	73.4186	<.0001
Mantel-Haenszel Chi-Square	1	30.5069	<.0001
Phi Coefficient		0.9647	
Contingency Coefficient		0.6943	
Cramer's V		0.6821	

Statistics for Table of HAND Washing

Statistic	DF	Value	Prob
Chi-Square	2	67.8977	<.0001
Likelihood Ratio Chi-Square	2	67.3162	<.0001
Mantel-Haenszel Chi-Square	1	37.4311	<.0001
Phi Coefficient		0.9271	
Contingency Coefficient		0.6799	
Cramer's V		0.9271	

Statistics for Table of Udder washing

Statistic	DF	Value	Prob
Chi-Square	4	73.5217	<.0001
Likelihood Ratio Chi-Square	4	73.4186	<.0001
Mantel-Haenszel Chi-Square	1	30.5069	<.0001
Phi Coefficient		0.9647	
Contingency Coefficient		0.6943	
Cramer's V		0.6821	

Statistics for Table of SYSTEM by DRY_TEAT

Statistic	DF	Value	Prob
Chi-Square	2	79.0000	<.0001
Likelihood Ratio Chi-Square	2	106.6518	<.0001
Mantel-Haenszel Chi-Square	1	4.4824	0.0342
Phi Coefficient		1.0000	
Contingency Coefficient		0.7071	
Cramer's V		1.0000	

Statistics for Table of SYSTEM by MILK_CTNR

Statistic	DF	Value	Prob
Chi-Square	2	16.8161	0.0002
Likelihood Ratio Chi-Square	2	20.2648	<.0001
Mantel-Haenszel Chi-Square	1	12.6910	0.0004
Phi Coefficient		0.4614	
Contingency Coefficient		0.4189	
Cramer's V		0.4614	

Statistics for Table of SYSTEM by BULK_CTNR

Statistic	DF	Value	Prob
Chi-Square	4	21.2620	0.0003
Likelihood Ratio Chi-Square	4	27.5590	<.0001
Mantel-Haenszel Chi-Square	1	17.9554	<.0001
Phi Coefficient		0.5188	
Contingency Coefficient		0.4605	
Cramer's V		0.3668	

Statistics for Table of SYSTEM by CALVES

Statistic	DF	Value	Prob
Chi-Square	4	113.7003	<.0001
Likelihood Ratio Chi-Square	4	109.9126	<.0001
Mantel-Haenszel Chi-Square	1	10.9048	0.0010
Phi Coefficient		1.1997	
Contingency Coefficient		0.7681	
Cramer's V		0.8483	

Statistics for Table of SYSTEM by COWSHED

Statistic	DF	Value	Prob
Chi-Square	2	34.3446	<.0001
Likelihood Ratio Chi-Square	2	40.0045	<.0001
Mantel-Haenszel Chi-Square	1	12.3885	0.0004
Phi Coefficient		0.6593	
Contingency Coefficient		0.5505	
Cramer's V		0.6593	

Logistic regression for mastitis occurrence in pastoral herds

Type 3 Analysis of Effects

Effect	DF	Wald Chi-Square	Pr > ChiSq
system	1	142.4750	<.0001

Analysis of Maximum Likelihood Estimates

Parameter		DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept		1	-0.3978	0.0187	453.5282	<.0001
system	ext	1	0.2230	0.0187	142.4750	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
system ext vs per	1.562	1.452	

Logistic regression for mastitis occurrence in smallholder herds

Type 3 Analysis of Effects

Effect	DF	Wald Chi-Square	Pr > ChiSq
system	1	31.7095	<.0001

Analysis of Maximum Likelihood Estimates

Parameter		DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept		1	-2.3470	0.0463	2564.3806	<.0001
system	peri	1	0.2610	0.0463	31.7095	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
System peri vs rural	1.685	1.405	2.021

Table 29: Milk fat

Source	DF	SS	MSq	F	P
Model	1	3.8	3.8	2.8	0.1
Error	108	150.2	1.4		
Corrected total	109	154.1			

Table 30: milk SNF

Source	DF	SS	MSq	F	P
Model	1	0.04	0.04	0.11	0.7
Error	108	42.8	0.40		
Corrected total	109	42.87			

Table 31: Density

Source	DF	SS	MSq	F	P
Model	1	0.3	0.3	0.05	0.8
Error	108	683.9	6.3		
Corrected total	109	684.2			

Table 32: Lactose

Source	DF	SS	MSq	F	P
Model	1	0.1	0.1	0.9	0.3
Error	108	13.6	0.1		
Corrected total	109	13.7			

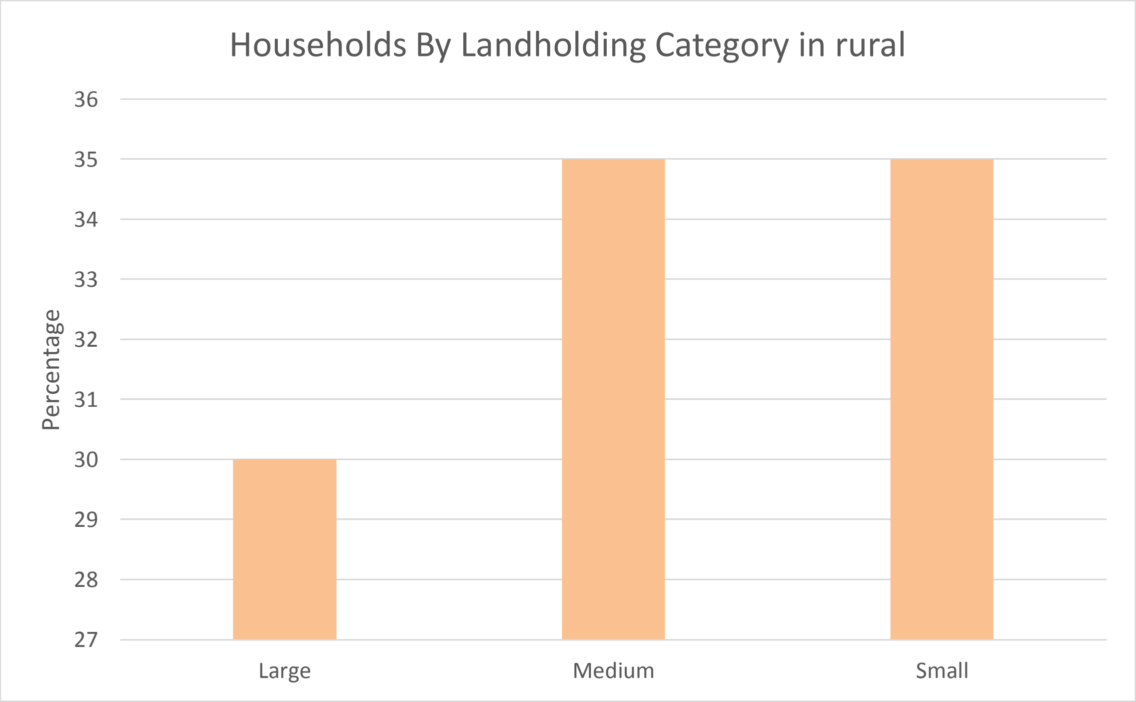
Table 33: Solids

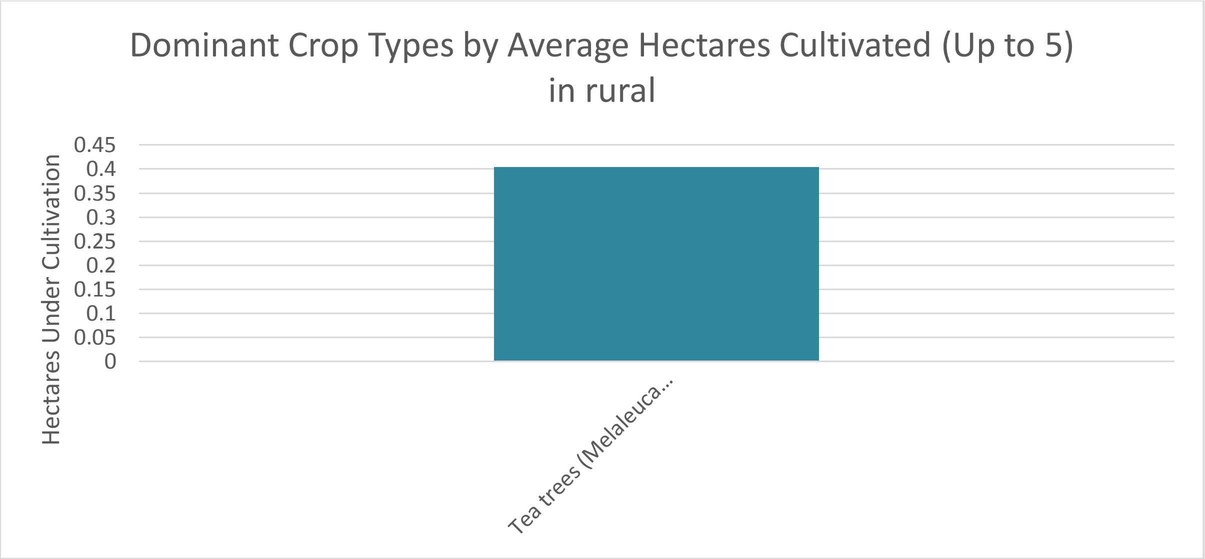
Source	DF	SS	MSq	F	P
Model	1	7.4	7.4	0.03	0.9
Error	107	0.3	0.003		
Corrected total	108	0.3			

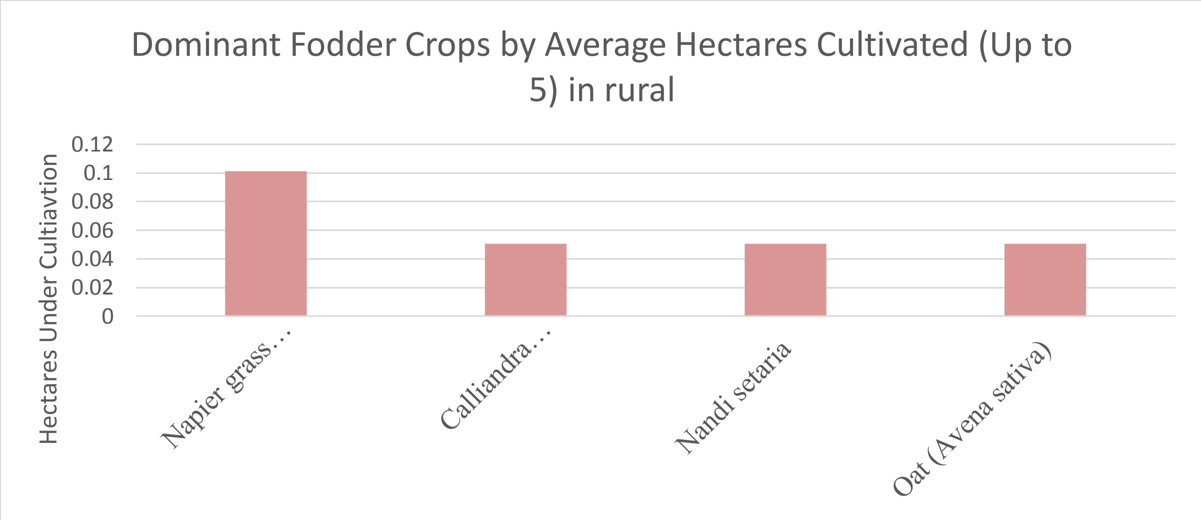
Table 34: Protein

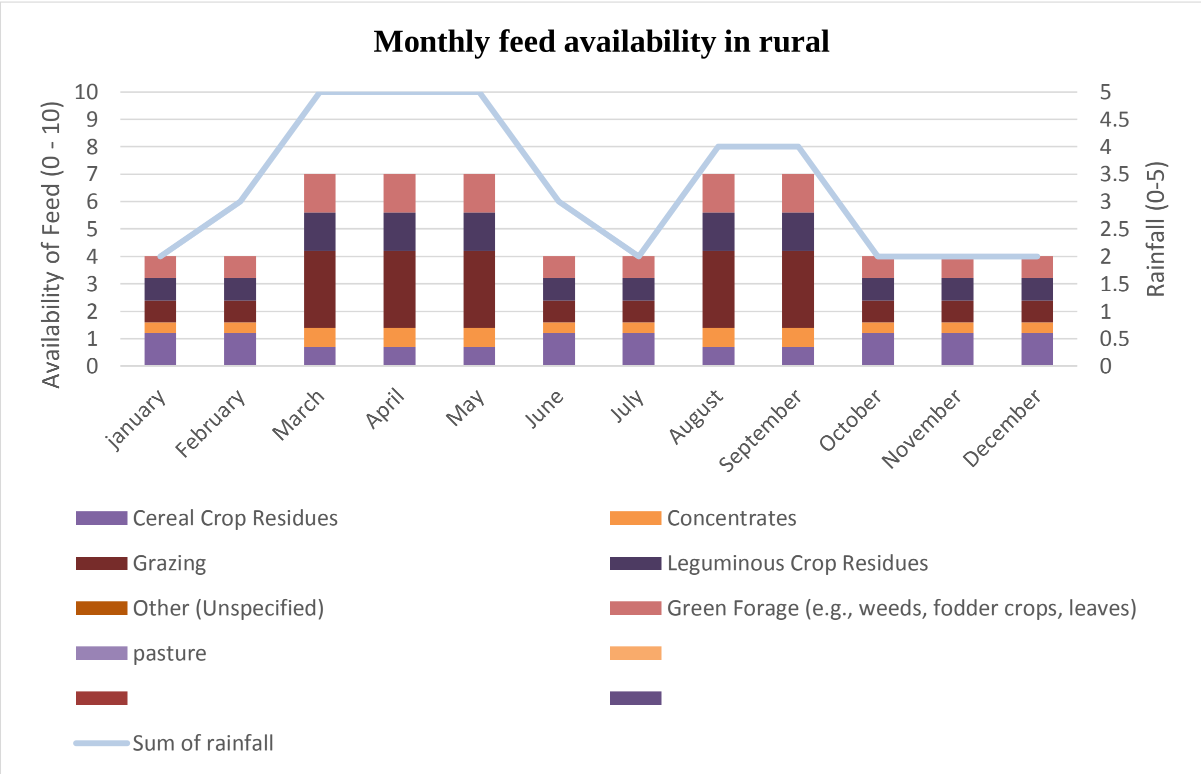
Source	DF	SS	MSq	F	P
Model	1	0.003	0.003	0.05	0.8
Error	108	5.6	0.05		
Corrected total	109	5.6			

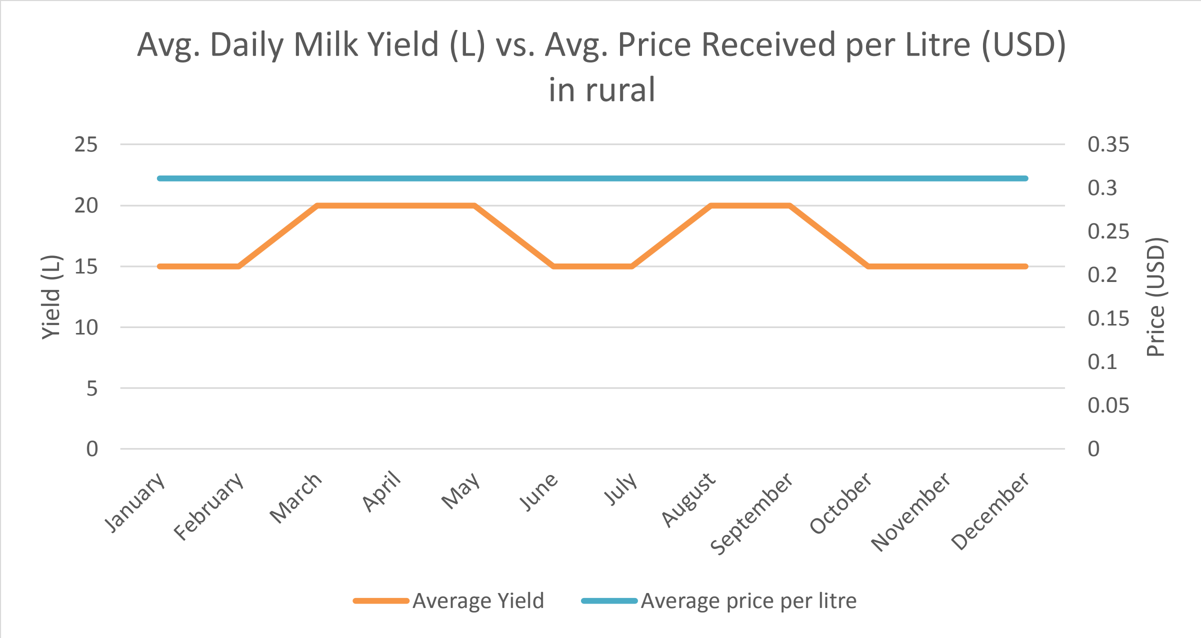
Chap 4 and 5

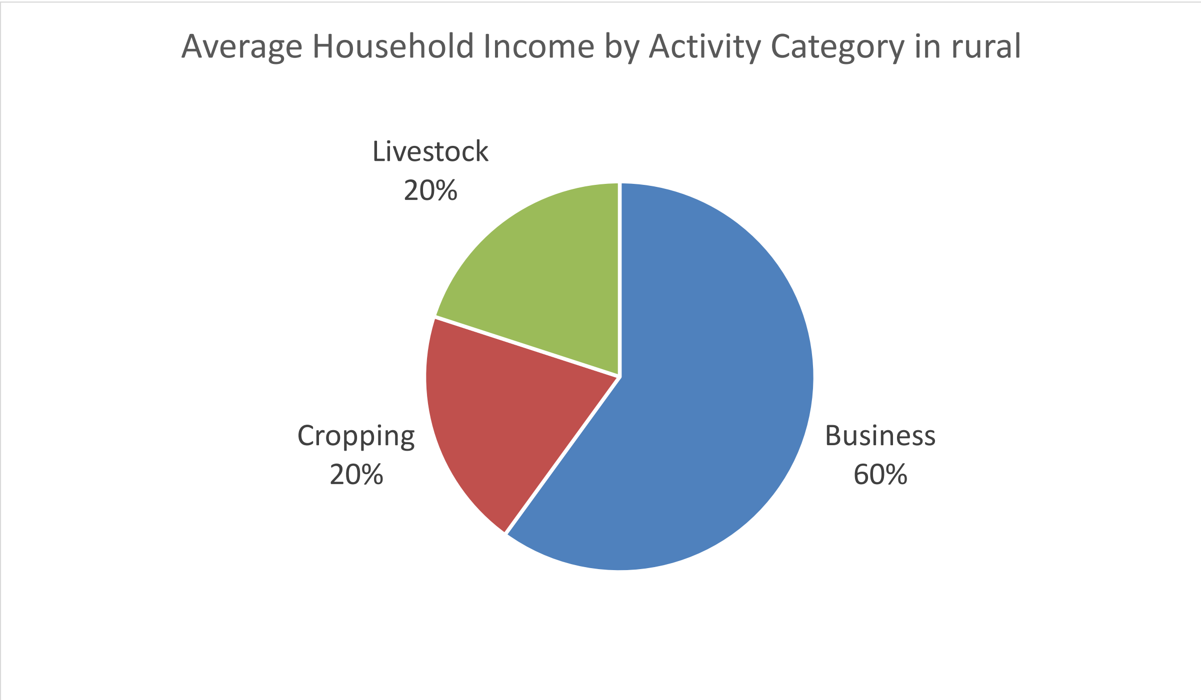





Dominant Fodder Crops by Average Hectares Cultivated (Up to 5) in rural
Hectares Under Cultiavtion
0.12
0.1
0.08
0.06
0.04
0.02
0
Napier grass…
Calliandra…
Nandi setaria
Oat (Avena sativa)


Monthly feed availability in rural
Availability of Feed (0 - 10)
Rainfall (0-5)
10
9
8
7
6
5
4
3
2
1
0
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
january
February
March
April
May
June
July
August
September
October
November
December
Cereal Crop Residues
Concentrates
Grazing
Leguminous Crop Residues
Other (Unspecified)
Green Forage (e.g., weeds, fodder crops, leaves)
pasture
Sum of rainfall


Avg. Daily Milk Yield (L) vs. Avg. Price Received per Litre (USD) in rural
Yield (L)
Price (USD)
25
20
15
10
5
0
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
January
February
March
April
May
June
July
August
September
October
November
December
Average Yield
Average price per litre


Average Household Income by Activity Category in rural
Livestock 20%
Cropping 20%
Business 60%

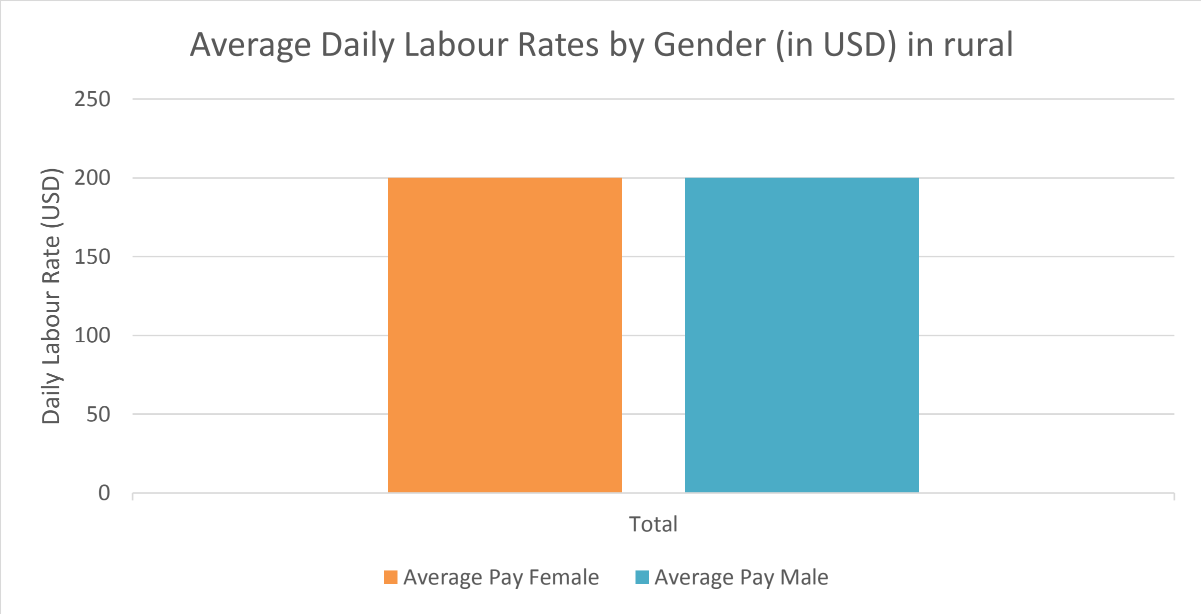
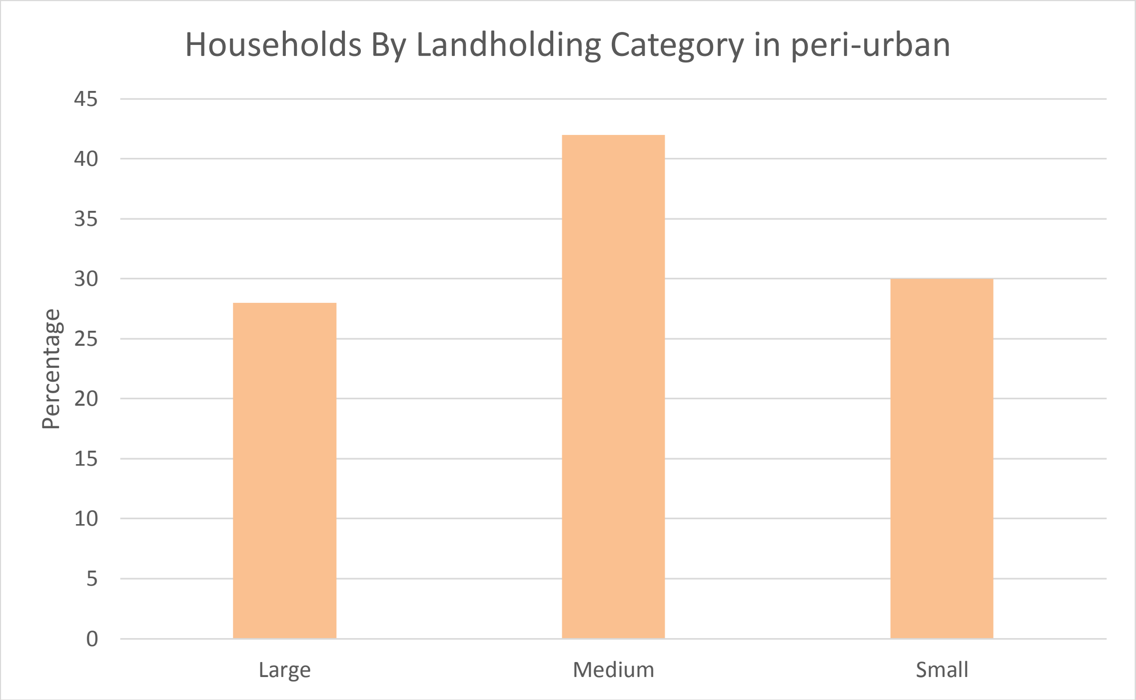


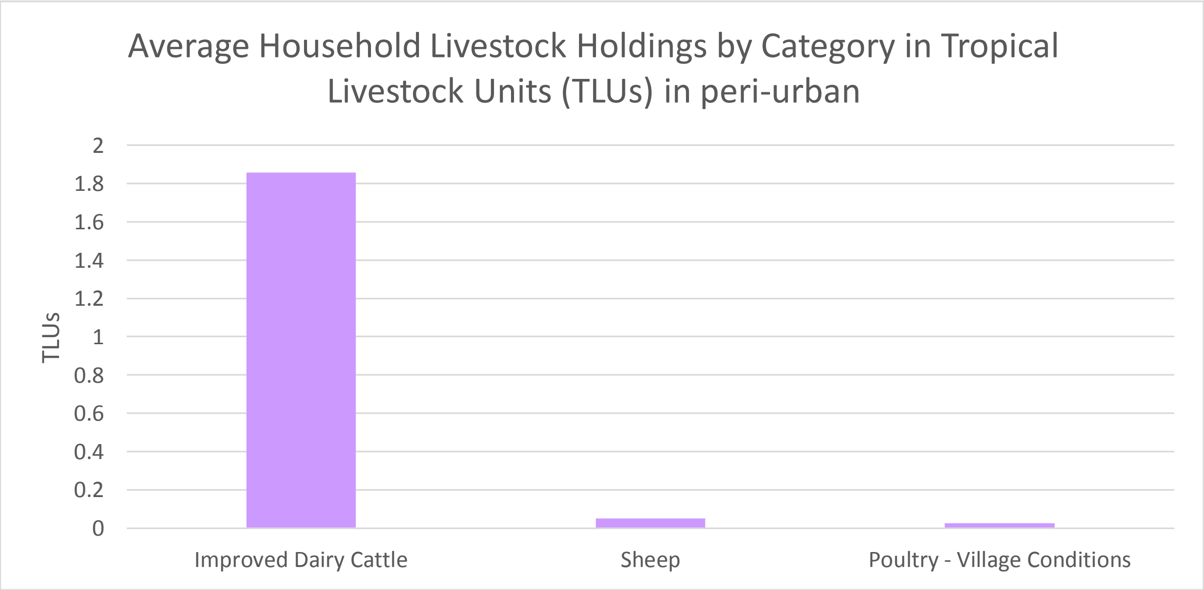
Table 35: Summary farm data in rural

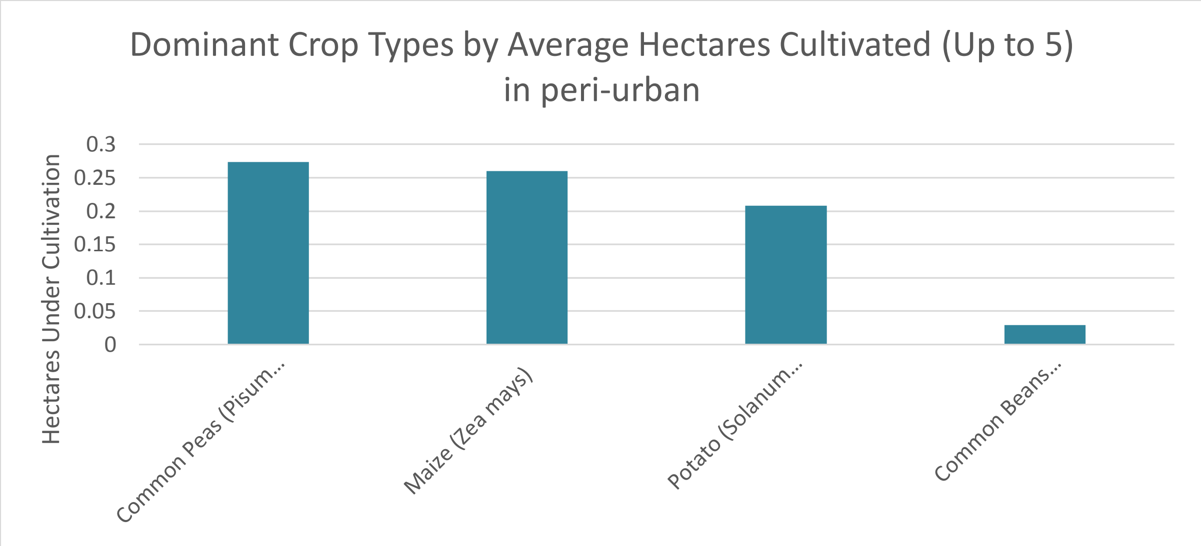
Percentage off take cattle (%)	0	%	TLU cattle sold or slaughtered past 3 years/(3 * total cattle TLU)
Percentage off take sheep and goats (%)	N/A	%	TLU shoat sold or slaughtered past 3 years/(3 * total shoat TLU)
Total income earned from milk sales	164,500.00	In Kenyan Shilling	Average daily milk sales (USD) by month x Days in month / current USD exchange rate
Amount spent on purchased feeds	30,500.00	In Kenyan Shilling	Sum for all purchased feeds of (Price in local currency x Quantity purchased in local units each time purchased x Number times this amount is purchased in a typical year)
Percentage of income from milk sales spent on purchased feeds	19	%	Amount spent on purchased feeds / Total income earned from milk sales
Total amount of milk produced per year	6240	Litres/hh	(average monthly yield for Jan) + (average monthly yield for Feb) etc
Average price received for milk throughout the year	28.00	In Kenyan Shilling	Monthly average price milk/liter in local currency
Average price received for milk throughout the year	0.31	In US Dollar	Monthly average price milk/liter in US dollars

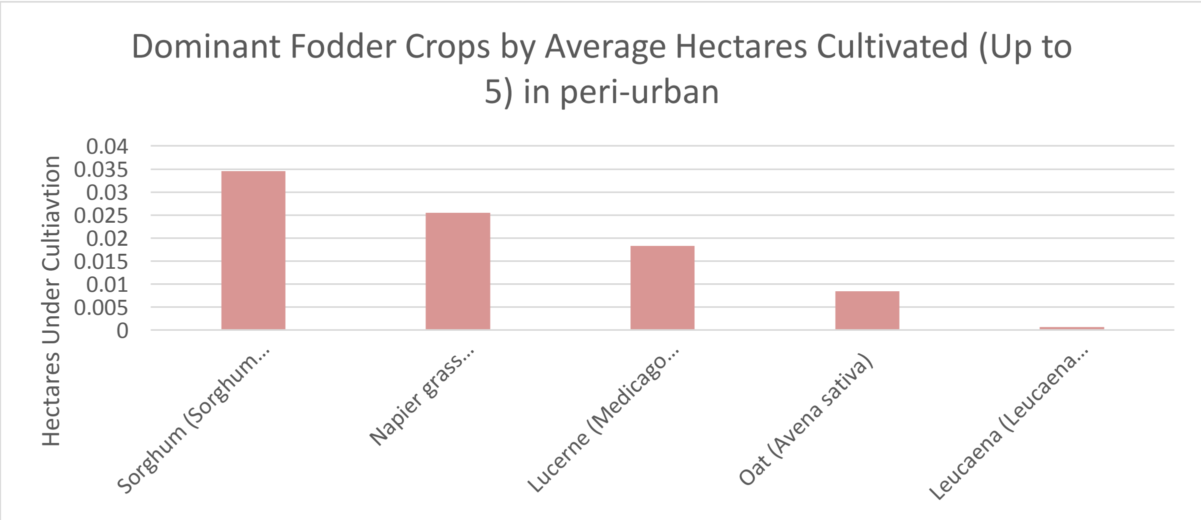
Total amount of milk retained throughout the year	365	Litres per hh	(Average milk retained for household use for Jan x 31) + (Average milk retained for household use for Feb x 28) etc
Percentage of milk sold	94	%	((Total amount of milk produced per year -Total amount of milk retained throughout the year)/ Total amount of milk retained throughout the year)*100
Average production per female dairy animal per day	3.12	Litres/cow/d	Total amount of milk produced per year/(sum of TLU of female dairy cattle)/365
Average production per lactating dairy animal per day	4.07	litres/cow	C8/(sum of TLU of female lactating cattle)/365
DM amount (kg) of total diet per household	36043.073	kg	Sum of DM from different diet components (from Contributions Table)
ME amount (MJ) of total diet per household	339266.631	MJ	Sum of ME from different diet components (from Contributions Table)/1000
CP amount of total diet (kg) per household	3533.835	kg	Sum of CP from different diet components (from Contributions Table)/1000
CP:ME ratio	10.416	g CP/MJ	Total CP / Total ME
Milk yield per J ME	18.393	litres/J	Total amount of milk produced per year / Total ME
Total crop area (ha)	0.404686	ha	Grand total from "crop cultivation" graph
Total forage area (ha)	0.25292875	ha	Grand total from "fodder cultivation" graph
CR yield per ha (=total CR DM/total crop area)	0.00	kg DM/ha	DM from crop residue/Total crop area
Forage yield per ha (=total forage DM/total forage area)	11136.00	kg DM/ha	DM from Forage crops/Total Forage Area
Forage crop area as percentage of cropped area	38	%	Total Forage Area / (Total Forage Area + Total Crop Area)

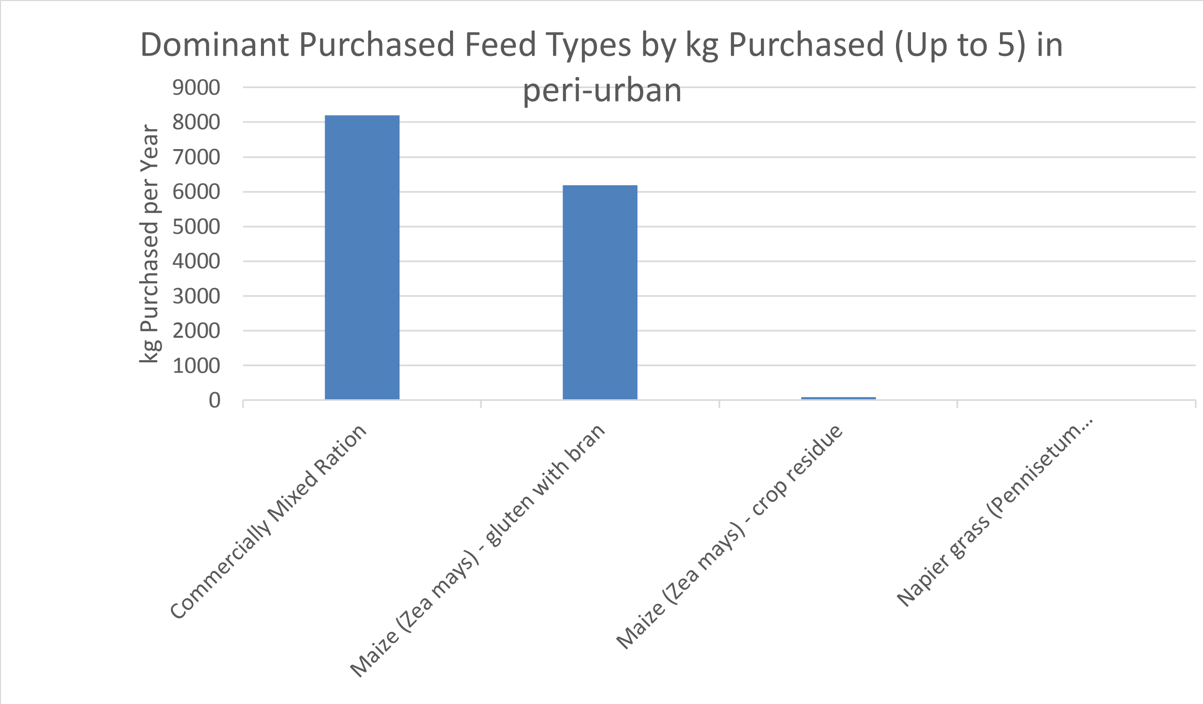
Peri-urban


Households By Landholding Category in peri-urban
Percentage
45
40
35
30
25
20
15
10
5
0
Large
Medium
Small


Average Household Livestock Holdings by Category in Tropical Livestock Units (TLUs) in peri-urban
TLUs
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Improved Dairy Cattle
Sheep
Poultry - Village Conditions

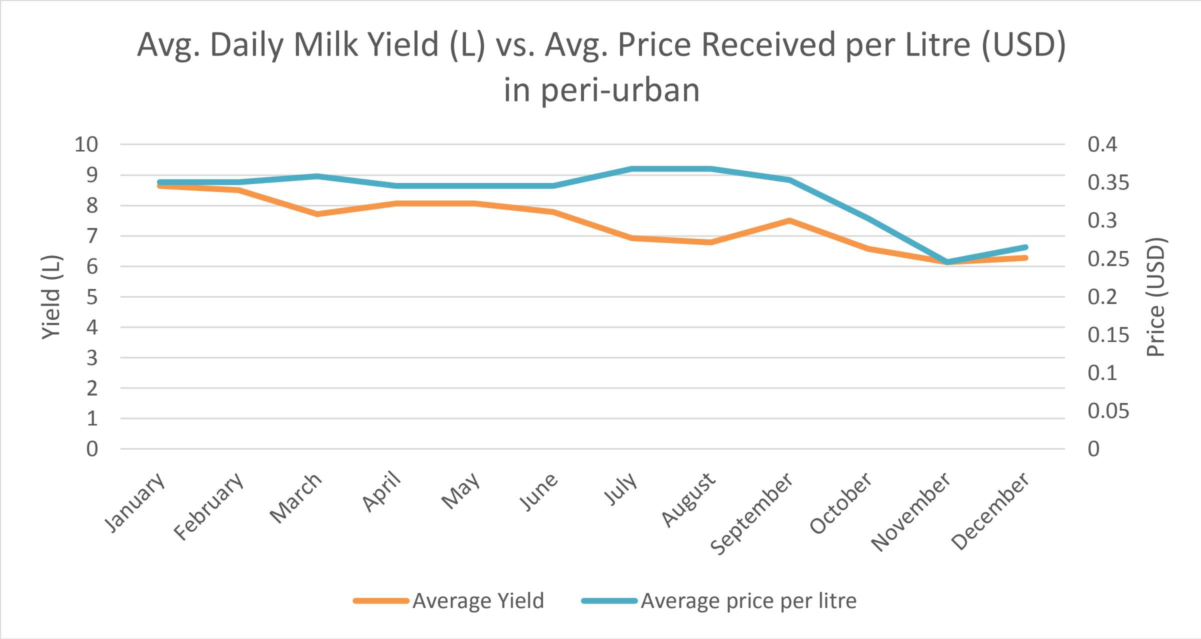

Dominant Crop Types by Average Hectares Cultivated (Up to 5) in peri-urban
Hectares Under Cultivation
0.3
0.25
0.2
0.15
0.1
0.05
0
Common Peas (Pisum...
Maize (Zea mays)
Potato (Solanum...
Common Beans...


Dominant Fodder Crops by Average Hectares Cultivated (Up to 5) in peri-urban
Hectares Under Cultiavtion
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Sorghum (Sorghum...
Napier grass...
Lucerne (Medicago...
Oat (Avena sativa)
Leucaena (Leucaena...

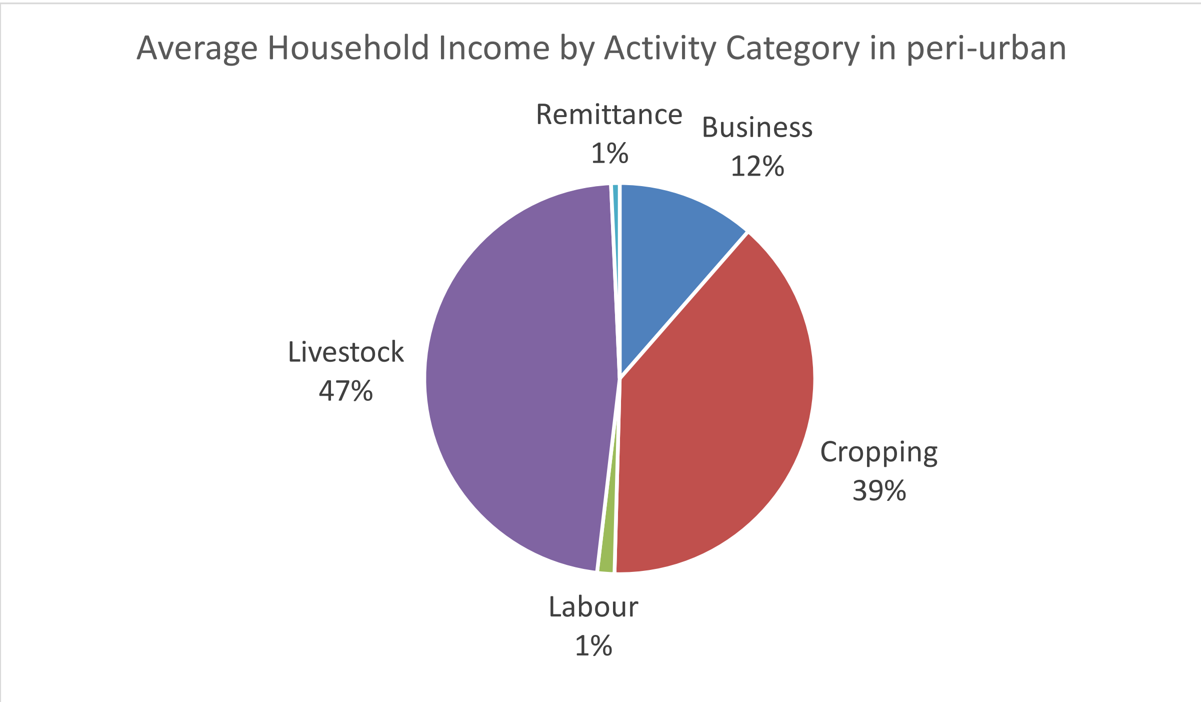


Dominant Purchased Feed Types by kg Purchased (Up to 5) in peri-urban
kg Purchased per Year
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Commercially Mixed Ration
Maize (Zea mays) - gluten with bran
Maize (Zea mays) - crop residue
Napier grass (Pennisetum...

Availability of Feed (0 - 10)
Rainfall (0-5)
january
February
March
April
May
June
July
August
September
October
November
December
Cereal Crop Residues
Concentrates
Grazing
Leguminous Crop Residues
Other (Unspecified)
Green Forage (e.g., weeds, fodder crops, leaves)
Sum of rainfall



Avg. Daily Milk Yield (L) vs. Avg. Price Received per Litre (USD) in peri-urban
Yield (L)
Price (USD)
10
9
8
7
6
5
4
3
2
1
0
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
January
February
March
April
May
June
July
August
September
October
November
December
Average Yield
Average price per litre



Average Household Income by Activity Category in peri-urban
Remittance 1%
Business 12%
Livestock 47%
Cropping 39%
Labour 1%

Table 36: Summary farm data peri-urban

Percentage offtake cattle (%)	2	%	TLU cattle sold or slaughtered past 3 years/(3 * total cattle TLU)
Percentage offtake sheep and goats (%)	0	%	TLU shoat sold or slaughtered past 3 years/(3 * total shoat TLU)
Total income earned from milk sales	454,094.50	In Kenyan Shilling	Average daily milk sales (USD) by month x Days in month / current USD exchange rate
Amount spent on purchased feeds	3,027,510.00	In Kenyan Shilling	Sum for all purchased feeds of (Price in local currency x Quantity purchased in local units each time purchased x Number times this amount is purchased in a typical year)
Percentage of income from milk sales spent on purchased feeds	667	%	Amount spent on purchased feeds / Total income earned from milk sales
Total amount of milk produced per year	2704	Litres/hh	(average monthly yield for Jan) + (average monthly yield for Feb) etc
Average price received for milk throughout the year	30.03	In Kenyan Shilling	Monthly average price milk/liter in local currency
Average price received for milk throughout the year	0.33	In US Dollar	Monthly average price milk/liter in US dollars
Total amount of milk retained throughout the year	601.2142857	Litres per hh	(Average milk retained for household use for Jan x 31) + (Average milk retained for household use for Feb x 28) etc
Percentage of milk sold	78	%	((Total amount of milk produced per year -Total amount of milk retained throughout the year)/ Total amount of milk retained throughout the year)*100
Average production per female dairy animal per day	0.57	Litres/cow/d	Total amount of milk produced per year/(sum of TLU of female dairy cattle)/365
Average production per lactating dairy animal per day	0.67	litres/cow	C8/(sum of TLU of female lactating cattle)/365
DM amount (kg) of total diet per household	287026.999	kg	Sum of DM from different diet components (from Contributions Table)
ME amount (MJ) of total diet per household	3205197.741	MJ	Sum of ME from different diet components (from Contributions Table)/1000
CP amount of total diet (kg) per household	43447.601	kg	Sum of CP from different diet components (from Contributions Table)/1000

CP:ME ratio	13.555	g CP/MJ	Total CP / Total ME
Milk yield per J ME	0.844	litres/J	Total amount of milk produced per year / Total ME
Total crop area (ha)	5.3980315	ha	Grand total from "crop cultivation" graph
Total forage area (ha)	0.612289918	ha	Grand total from "fodder cultivation" graph
CR yield per ha (=total CR DM/total crop area)	5151.91	kg DM/ha	DM from crop residue/Total crop area
Forage yield per ha (=total forage DM/total forage area)	44385.04	kg DM/ha	DM from Forage crops/Total Forage Area
Forage crop area as percentage of cropped area	10	%	Total Forage Area / (Total Forage Area + Total Crop Area)

Chap 6:

Hand washing by market outlet

Statistic	DF	Value	Prob
Chi-Square	5	0.3579	0.9964
Likelihood Ratio Chi-Square	5	0.6100	0.9875
Mantel-Haenszel Chi-Square	1	0.2501	0.6170
Phi Coefficient		0.0638	
Contingency Coefficient		0.0636	
Cramer's V		0.0638	

Sanitizer for hands washing

Statistic	DF	Value	Prob
Chi-Square	5	7.9057	0.1615
Likelihood Ratio Chi-Square	5	11.0484	0.0504
Mantel-Haenszel Chi-Square	1	2.8618	0.0907
Phi Coefficient		0.2997	
Contingency Coefficient		0.2871	
Cramer's V		0.2997	

Pre-milking udder preparation

Statistic	DF	Value	Prob
Chi-Square	5	13.6173	0.0182
Likelihood Ratio Chi-Square	5	8.8480	0.1153
Mantel-Haenszel Chi-Square	1	0.1170	0.7323
Phi Coefficient		0.3934	
Contingency Coefficient		0.3661	
Cramer's V		0.3934	

Drying udder prior to milking

Statistic	DF	Value	Prob
Chi-Square	5	4.0809	0.5378
Likelihood Ratio Chi-Square	5	6.4561	0.2643
Mantel-Haenszel Chi-Square	1	2.4870	0.1148
Phi Coefficient		0.2153	
Contingency Coefficient		0.2105	
Cramer's V		0.2153	

Type of milking container

Statistic	DF	Value	Prob
Chi-Square	5	5.1514	0.3977
Likelihood Ratio Chi-Square	5	4.8920	0.4292
Mantel-Haenszel Chi-Square	1	1.0570	0.3039
Phi Coefficient		0.2419	
Contingency Coefficient		0.2352	
Cramer's V		0.2419	

Type of bulking container

Statistic	DF	Value	Prob
Chi-Square	5	8.1797	0.1466
Likelihood Ratio Chi-Square	5	7.5702	0.1816
Mantel-Haenszel Chi-Square	1	1.0570	0.3039
Phi Coefficient		0.3049	
Contingency Coefficient		0.2916	
Cramer's V		0.3049	

Milk price

Statistic	DF	Value	Prob
Chi-Square	5	18.8532	0.0020
Likelihood Ratio Chi-Square	5	20.5621	0.0010
Mantel-Haenszel Chi-Square	1	0.0186	0.8916
Phi Coefficient		0.4629	
Contingency Coefficient		0.4200	
Cramer's V		0.4629	

APPENDIX III: List of publications and conference presentations

1. Characteristics of farm-level practices attributed to postharvest losses in smallholder and peri-urban herds. Poster presented at the Tropentag conference 2016, BOKU University, Vienna, Austria.
2. Implications of informal milk marketing for food security and safety in smallholder dairy farms in Kenya. Paper accepted for presentation at National Food and Nutrition Symposium, Safari Park hotel, 23-25 November 2016, Nairobi, Kenya.
3. Influence of on-farm feeding and hygiene interventions on milk yield and quality in smallholder dairy herds. *Paper submitted to Journal of agricultural extension and Education*
4. Associations between milking practices, udder inflammations and milk postharvest losses in smallholder dairy and pastoral camel herds in Kenya. *Paper submitted to Preventive Veterinary Medicine Journal*
5. Evaluation of smallholder dairy and pastoral camel herds' feeding practices in Kenya. *Paper submitted to Tropical Animal Health and Production.*
6. Influence of milk market outlets on milking hygienic practices and milk quality in smallholder and pastoral herds in Kenya. *Paper submitted to Journal ofFood policy.*