COMPARATIVE ASSESSMENT OF PREVALENCE, RISK FACTORS AND ECONOMIC LOSSES OF LAMENESS IN SMALLHOLDER ZERO- AND PASTURE-GRAZED DAIRY COWS IN KENYA

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A Thesis Submitted to the Graduate School in Partial Fulfillment of the Requirement of Master of Science Degree in Livestock Production Systems of Egerton University

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DECLARATION AND RECOMMENDATON

Declaration

This thesis is my original work and has not been presented in this University or any other for the award of a degree.

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Recommendaton

This thesis has been prepared with our supervision and submitted for examination with our approval and recommendation as the University supervisors.

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DEDICATION

This work is dedicated to my late parents, wives, and children for their support, encouragement and understanding during the study period.

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ABSTRACT

Lameness is a cause of worry to dairy producers for being indicative of welfare problem with resultant economic losses from reduced milk yield, veterinary cost or premature culling. Risks for lameness are both animal and herd level factors, but the magnitude varies with housing conditions of the cows. This study compared farmer estimated and observed prevalence, types of lameness, risk factors and economic losses from lameness of cows in farms practicing zero- and pasture grazing. The study was conducted in Nakuru County, Kenya where zero- and pasture-grazed cows were obtained in an observational study design. In a random sample of 172 smallholder farms, 485 cows were examined for lameness, individual records and performance histories. Data were subjected to Chi square test, means comparisons and spearman rank correlation. Results showed that lameness prevalence was not different between zero-grazed (23.0%) and pasture grazed (20.2%) cows. The prevalence of lameness observed (22.1%) and that estimated by farmers (22.7%) closely matched with a strong positive and significant correlation ($r=0.959$; $p<0.05$). Four types of lameness were identified of which prevalence was in the order: laminitis (43.1%), digital dermatitis (32.1%), white line disease (14.7%) and sole ulcer (10.1%), but their prevalence did not vary with the grazing system. Lameness was more prevalent among the zero than pasture -grazed cows for cows kept on earth floor (46.4% vs 20.4%), small dairy breeds (46.0% vs 27.5%) or those kept on dry bedding (15.0% vs 4.9%). Estimated economic loss from lameness was 51% higher in zero- than in pasture grazing (KES 4,695.49 vs 3,109.41/farm/year) with a larger proportion attributable to production losses and veterinary costs. The loss is equivalent to loss of 104 to 157 litres of milk in a herd in a year for farmgate milk price of KES 30 a litre. Production losses were more in zero- than in pasture grazing (68.3 vs 55.7%) but veterinary costs were lower in zero- than in psture grazing (29.1 vs 34.4%). It is recommended that farmer training focuses on skills upgrading on routine care of claws and hooves to reduce incidences of lameness and the resulting economic losses from lameness.

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CHAPTER ONE
INTRODUCTION

1.1 Background information

Dairy farming is an attractive livestock enterprise in Kenya for generating income and improving food and nutrition security for smallholder farmers (Muthui *et al.*, 2014). This is attributable to a higher growth rate of 3-4% experienced in the dairy sub sector which now contributes 40% to the livestock gross domestic product (GDP) and 4% to the national GDP (Ministry of Livestock Development, 2010). It is projected that meeting the growing demand for milk for the increasing population, urbanization and expanding economic growth and changes in consumer preferences will be met from continued dairy intensification process . However, increased intensification practiced by smallholder dairy farmers for higher productivity may lead to welfare problems such as lameness to the dairy cows.

Lameness in cow can manifest as an abnormal gait, animal limping when walking or claw disorders. It is a cause of worry to dairy producers because it may be clinical condition accompanied with painful lesions which can result into severe animal welfare problem and production-limiting. Lameness in cows can be a cause of pain (Rushen, 2007), premature culling (Bielfeldt, 2005), drop in milk yield (Green *et al*., 2002), or suboptimal fertility (Garbarino *et al*., 2004). Because of these, lameness is associated with economic losses (Ettema and Ostergaard, 2006).

Prevealnce of lameness in cows show large variations, reflecting heterogeneity of risk factors. For example, Solano *et al*. (2015) reported lameness prevalence of: 16% in the Netherlands, 37% in Britain, 48% in Germany, and up to 63% in the USA. These Countries have in common intensive dairy production systems in which cows are kept in confined housing units. The confined housing corresponds to zero-grazing practiced by smalholder dairy farmers in Kenya, who account for about half (44%) of Kenya dairy farms in highlands (Bebe *et al*., 2003). Cows in smallholder dairy zero-grazing units could also be experiencing high prevalence of lameness and presenting problems of animal welfare and limiting their productivity.

Studies of lameness are few in Kenya, and the few suggest increased prevalence with the shift from pasture to zero grazing and over the years, which could mean that lameness present problem in smallholder farms. Gitau, (1999) reported lameness prevalence of 0.76% per month in cattle kept in pasture 24 hours a day and 2.14% in cows housed in zero grazing 24 hours a day in Kiambu farms. Mbuthia, (2007) performed a radiographic examination of 318 abattoir obtained claw samples of which 35% were subclinical and 21% chronic laminitis cases with 44% of the claws being of extreme deformities. These studies suggest that lameness are likely to be of economic concern in smallholder dairy farms practicing zero grazing. The loss can be from pain to the animal resulting in a reduction in feed intake and subsequent drop in milk yield, cause of premature culling and suboptimal fertility or increased costs in drug treatment and control. The two studies in Kenya (Gitau, 1999; Mbuthia, 2007) present empirical evidence limited only to prevalence and characterization of a few risk factors, and therefore are weak in informing the design of effective management interventions for preventing lameness.

Studies of lameness elsewhere have identified multiple risk factors including environmental, management, behavioral, nutrition, infection, and conformation or genetics (Bielfeldt, 2005; Solano *et al*., 2015). Environmental aspect of lameness includes housing types, floor type and cubicle design (Haskell *et al*., 2006). Management routine include claw trimming (Espejo *et al*., 2007) and overcrowding (Leonard *et al*., 1996). The average lactation length of lame cows could shorten due to premature culling or poor productive performance (Tranter *et al*., 1992).

The economic loss due to lameness arise from increased culling rate, decreased reproductive performance, increased days open or increased risk of mastitis (Mohamadnia, 2001). Though almost half of the national dairy herd in Kenya is kept in smallholder zero grazing units where risks for lameness is likely to be high, only limited empirical studies exists on this welfare and production limitation challenge in Kenyan smallholder dairy farms. This study proposes to fill this knowledge gap with an empirical study of the prevalence, risk factors and economic losses of lameness in smallholder farms. This should inform management interventions for improved animal welfare and herd productivity.

1.2 The statement of the problem

Majority of smallholder farmers in Kenya highlands have shifted from practicing pasture to zero grazing system. This sytem presents a risk for lameness for cow which can lead to production and economic loss. However, evidence is lacking on the effects at herd level (structures and management) and cow level risks for lameness and the influence on production and economic loss. The past empirical analysis of the extent of lameness problem have not associated the prevalence with defined risk factors and the resulting value of production losses. Therefore, testing the hypotheses that lameness problem differs between zero grazed and pasture grazed can reveal the extent of the problem and inform targeted interventions to support successful control of lameness in smallholder dairy farms.

1.3 Objectives

The overall objective of the study was to contribute to improved animal welfare and herd profitability through informed management interventions for controlling lameness in smallholder dairy farms.

The specific objectives were:

i. To compare farmer estimated and researcher observed prevalence of lameness between zero and pasture grazed dairy cows.
ii. To compare prevalence of types of lameness between zero and pasture grazed cows.
iii. To compare risk factors for lameness between zero and pastured grazed dairy cows.
iv. To compare economic loss estimates from lameness between zero and pasture grazed dairy cows.

1.4 Hypotheses

i. Farmer estimated and observed lameness prevalence is not significantly different between zero and pasture grazed dairy cows.
ii. Prevalence of types of lameness are not significantly different between zero and pasture grazed dairy cows.
iii. The risk factors for lameness are not significantly different between zero and pasture grazed dairy cows.
iv. Economic losses from lameness are not significantly different between zero and pasture grazed dairy cows.

1.5 Significance of the study

The study provided empirical evidence knowledge of the lameness status with the shift from pasture to zero grazing dairy herds managed by smallholder farmers. This study informed on farmers' perception of lameness prevalence and types, cow and herd level risk factors and economic losses towards lameness. The variation of lameness in pasture and zero grazed systems contributed to inform decision making in smallholder dairy systems where a shift from free to zero graing system is observed. Statistical testing provided comparison between the two systems. The comparison of extent of lameness in smallholder farms informed appropriate management interventions that when effectively implemented would improve animal welfare, production performance and herd profitability. Knowledge of individual cow and herd risk factors for lameness was essential in providing measures that help reduce economic losses from lameness in the herds.

CHAPTER TWO
LITERATURE REVIEW

2.1 Lameness Prevalence and Incidences

Prevalence of lameness appears to be on the rise in the UK indicating more than 35% (Barker *et al.,* 2010), in the United States 13% to 55% (Cook *et al*., 2016), in Canada 28.5% (Ito *et al*., 2010), Ethiopia 5.4% (Sulayeman and Fromsa, 2012) and Kenya smallholder dairy farmers, (Gitau, 1999). High lameness prevalence and variation highlight the need for a better understanding of the multifactorial origins and combination of risk factors related to the environment, management and individual cow (Vermunt, 2007). Approximately 80% of the dairy cows have one or more foot disorders (Somers *et al*., 2003) and about a third of these cows are visibly lame (Frankena *et al*., 2009). The incidence of lameness is reported to be over 50% (Hedges *et al*., 2001). Preventive strategies and therapeutic treatments are available, but dairy farmers may not put these measures into action (Bell *et al.,* 2009) as they tend to underestimate the problem (Whay *et al*., 2002). This is problematic, as the role of dairy farmers is crucial in improving dairy cow welfare through the prevention and treatment of foot disorders. Prevalence of lameness varies considerably among farms, regions and housing systems, although it is generally higher in free stall barn compared with tie-stalls (Cook *et al*., 2003; Sogstad *et al*., 2005) bedded packs (Haskell *et al*., 2006) and pasture systems (Hernandez *et al*., 2007). The mean prevalence of lameness on dairies in the United States range from 13% to 55% (Van Keyserlingk *et al*., 2012; Cooks *et al*., 2016). Housing of cows in concrete floor has also been associated with dairy lameness and was found that cows housed on concrete floor were 5 times more likely to be diagnose as lame compared with those housed on rubber mats (Vanegos *et al*., 2006). Lower lameness prevalence was reported in farms with sand bedding and deep bedding stalls compared with mattresses or little bedding (Ito *et al*., 2010; Chapinal *et al*., 2013). It is generally understood that deep bedding provides a comfortable lying surface that affects the lying behavior of the lame cows, influence their recovery and thus decreasing the risk of lameness (Cook *et al*., 2008).

Lameness has a significant impact on health and welfare of the cow and leads to pain and discomfort and production losses (Rushen, 2007), reduces longevity (Booth *et al.,* 2004), and reduces milk production (Green *et al*., 2002) and reproductive performance (Garbiarino *et al*., 2004). Lameness has negative impacts on cattle and can reduce mobility and social interactions (Desrochers *et al.,* 2001). Lame cows often have reductions in feeding periods at the bunk, body condition score (BCS), and overall health (Vermunt and Greenough, 1994).

Negative effects on cattle can lead to substantial economic impacts through inability of cattle to recover, increased days on feed (DOF), cost of treatments, premature removal from feeding and death losses (Terrell *et al*., 2014). Correctly diagnosing and administering prompt treatment are essential to improve the health and recovery of a lame animal to return or to remain on feed and reach an optimal weight. Lameness has multi factorial aetiology resulting from interaction of factors related to housing, management, nutrition and animal factors (Clarkson *et al*., 1996). Lameness is painful, and affect productivity of dairy cows through its effects on milk production (Warnick *et al*., 2001; Whay *et al*., 1998), culling (Booth *et al*., 2004) and reproductive performance (Melendez *et al*., 2003). It reduces longevity (Booth *et al*., 2004), Milk production (Warnick *et al*., 2001; Green *et al*., 2002), and reproductive performance (Hernandez *et al*., 2001; Garbarino *et al*., 2004), and consequently has a great economic effect (Ettema and Ostergaard, 2006).

Incidence of lameness in dairy cows is high in the first 120 days and lower in the last three months of lactation period due to stress of heavy milk yield (Rowlands *et al*., 1985) and high energy intake in the early lactation. The incidence of lameness was reported to increase at a rate of 8% units per lactation (Espejo *et al*., 2006). Majority of lameness incidences come from hoof disorders, hoof lesions are a key cause for lameness (Tadich *et al*., 2010) and their development are associated with housing conditions, feeding strategy, and management factors Distinct factors such as interaction between floor surface and hoof (Haufe *et al*., 2009), floor physical properties (Frankena *et al*., 2009). Claw lesions account for between 60% and 90% of all lameness incidences in cattle in various countries of the world (Bergsten *et al.,* 1994; Manske *et al*., 2002). All these claw disorders and lesions have a direct or indirect effect on the dermis (corium) of the claw and are associated with laminitis (Belge and Bakir, 2005; Manske *et al*., 2002; Nocek, 1997). Adoption of confined housing in dairy cattle husbandry as is the practice in smallholder dairy production systems particularly in developing countries has led to higher incidences of claw disorders and about a half (44%) of smallholder dairy farms housing dairy cows in the Kenya highlands (Bebe *et al*., 2003) the prevalence of cow lameness could be high as well and resulting in substantial economic losses.

Lameness are measured by locomotion scoring has been a component of several welfare audits (Whay *et al*., 2003; Stull *et al*., 2004). Locomotion scoring has demonstrated features of repeatability and sensitivity (O'Callaghan *et al*., 2003). There have been several attempts for the precision of lameness early detection in dairy cattle using technological approaches, the prediction in the farm data on hoof track and visual locomotion scores (Song *et al*., 2008). Mat made of electrome chanical film, for detecting dynamic forces exerted by cow hooves during milking and image analysis (Song *et al*., 2008); system based on ground reaction force measurements as the animal walks freely through the system (Dyer *et al*., 2007), Its prevalence varies between 1% and 21% in different studies (Alban, 1995; Manske *et al*., 2002). Lame cows are in pain, show inappentence, decreased milk yield, and weight loss (Green *et al*., 2002; O'Callaghan *et al.,* 2003). Scientific studies have estimated that approximately 28.5% of Canada's dairy cattle population are lame (Ito *et al*., 2010).

Lameness is one of the most important welfare and productivity concerns in the dairy industry (Whay *et al*., 2003) and animal health concern of Canadian dairy farmers and veterinarians (Bauman *et al*., 2016). Lameness is often a result of pain in the limb or hoof of a dairy cow. Eighty-one percent of UK dairy producers reported feeling sorry for lame cows, which motivated their action to treat lameness (Leach *et al*., 2010), whereas UK cattle practitioners reported that treatment of both sole ulcers and digital dermatitis lesions was moderately painful. Although many in the dairy industry are concerned about lameness, the prevalence remains high. North American estimates suggest 21 to 55% of cows in freestall housing with a milking parlor are lame (Espejo *et al*., 2006; Ito *et al*., 2010; von Keyserlingk *et al*., 2012; Solano *et al*., 2015), with 46% of cows having hoof lesions (Cramer *et al*., 2008). Although tiestall barns account for 72% of Canadian dairy farms and 38% in the United States (Barkema *et al*., 2015), estimates of lameness prevalence in tiestall dairies are scarce. Early studies on tiestall herds conducted in Ontario, Canada, found lower estimates of lameness (3%) prevalence (Zurbrigg *et al*., 2005) and hoof lesions (26%; Cramer *et al*., 2009) than typically reported in freestall farms. However, the most recent lameness prevalence in Canadian tiestall herds reported was around 24% (Charlton *et al*., 2016). Automated milking systems (AMS) account for 5% of the dairies in Canada, but the numbers are increasing every year (Tse, 2016).. The continued high prevalence of lameness and the large variation in lameness prevalence among herds (Solano *et al*., 2015) indicate that producers have difficulty in successfully decreasing lameness in their herds. Dairy producers in the United Kingdom reported that time, labor, and financial constraints limit their ability to decrease lameness in their herds (Leach *et al*., 2010). Other possible barriers in lameness control may include a lack of awareness of the problem, ignoring the cause, or even underestimating the severity of the issue (Bell *et al*., 2009; Leach *et al*., 2010). Indeed, it has been reported that UK and US producers substantially underestimate the prevalence of lameness in their herds by 26 to 40% compared with trained assessors (Wells *et al*., 1993; Whay *et al*., 2003; Espejo *et al*., 2006). Those studies were conducted in freestall dairy farms with a milking parlor; no similar studies were conducted in tiestall or AMS farms.

Intensively housed dairy cattle spend most of their time indoors and the design of their housing can affect both health and behavior. Most research on cow comfort has focused on stall design, but for cows housed in freestalls, the flooring surfaces outside the stall may also be important. Dairy cows in North America are increasingly housed on concrete floors (USDA, 2002), and this flooring surface has been associated with an increased incidence of lameness and hoof problems (Vokey *et al*., 200; Somers *et al*., 2003).

In addition to influencing hoof health, concrete flooring can impair locomotion (Jungbluth *et al.,* 2003; Rushen, 2007), influence expression of estrus behavior (Phillips and Schofield, 1994), and grooming (Jungbluth *et al*., 2003). Cattle show distinct preferences for softer flooring for lying and standing (Lowe *et al*., 2001; Manninen *et al*., 2002; Tucker and Weary, 2004) and choose floors with more traction when walking (Phillips and Morris, 2001). For these reasons, there is increasing interest in alternative flooring materials for dairy barns, especially floors that have better friction and are softer than concrete. Given that cattle spend 4 to 6 hours per day eating in freestall barns, replacing the concrete flooring in front of feed bunks may be especially beneficial. Few studies, however, have examined the advantages of providing softer floors in front of feed bunks. Fregonesi *et al*. (2004) found that dairy cows spent more time standing near the feed bunk when on a rubber surface compared with concrete, but there were no effects on feeding time. In addition, the cows spent more time standing elsewhere in the pen even though this was concrete flooring. However, they examined cows in groups, and competition within groups may have masked the effects of rubber flooring.

2.2. Farmers perception of lameness

The farmer's perception of lameness problem was compared with the prevalence detected by observation of the milking herd, and 90% of farmers did not perceive lameness to be a major problem on their farm (Leach *et al*., 2010). Lameness perception is less of a problem for cows managed at pasture compared to zero-grazing herds (Olmos *et al*., 2009). The challenge of introducing animal welfare interventions is large when farmers are asked to change their actions on behalf of their animals (Whay, 2007). Improving animal welfare by reducing lameness requires that farmers adapt existing practices or resources. Research into human behavior shows that there is always an underlying resistance to change in itself (Rosenstock, 1974). To promote change, it is necessary to understand both the barriers that currently restrict farmers' efforts to control lameness, and the positive motivators for change (Whay, 2007). Once these are understood, progress could be made using techniques such as social marketing (Sorensen *et al*., 2008). One likely factor contributing to the sustained problem of lameness in dairy herds is that farmers underestimate the prevalence of lameness on their farms, and therefore do not perceive the need to take further action to control it. Farmers' perception of the prevalence of lameness in a herd was lower than that of a researcher who observed all cows individually, looking for lameness, (Wells *et al*., 1993; Whay *et al*., 2002; Bell, 2006) . It is possible that as a result of this type of underestimation, farmers do not consider lameness a large enough problem to warrant much attention, particularly in view of all the other demands on their time and effort.

The majority of lameness cases are due to lesions on the foot (Murray *et al.,* 1996). Therefore, regular monitoring of lesions at the hoof level allows for earlier interventions by producers and their advisors (Noordhuizen, 2003; Shearer *et al*., 2004). Through the use of earlier interventions, the number of severe lameness cases should decrease, and in turn, animal well-being should improve. Additionally, the observation of lameness has been classified as the most representative animal-based indicator of welfare in dairy cattle (Whay *et al*., 2003). There is an increasing societal concern about the moral and ethical treatment of food animals (Fulwider *et al*., 2008). Lameness is of welfare concern due to its debilitating effects and high prevalence in herds throughout the world (Cook, 2003). Furthermore, dairy cattle mortality is a major cause of economic losses and is an important animal welfare issue (Thomsen and Houe, 2006). A large retrospective cohort study with over 900 dairy farms reported that dairy operations with high prevalence of lameness (≥ 16 %) had 2.9 higher odds of on farm dairy cow mortality compared to dairy farms with low lameness incidence (McConnel *et al*., 2008), dairy cows that died on the farm because of lameness were usually euthanized by a farm employee or veterinarian. Lameness is perhaps the biggest challenge for dairy farmer to overcome as society becomes more concerned with the origin of their food and the welfare of farm animals.

2.3 Types of Cow Lameness

Lameness has a major effect on productivity (Lawrence *et al*., 2011) and compromises welfare in dairy cattle (Whay *et al*., 2003). It lowered conception rate and increased calving interval (Melendez *et al*., 2003; Sogstad *et al*., 2006), reduced ovarian activity during early postpartum period (Garbarino *et al*., 2004), as well as culling and occasional mortalities

(Enting *et al*., 1997). Claw lesions account for between 60% and 90% of all lameness incidences in cattle in various countries of the world (Bergsten, 1994; Manske *et al*., 2002). All these claw disorders and lesions have a direct or indirect effect on the dermis of the claw and are associated with laminitis (Manske *et al.,* 2002). Types of lameness include: laminitis, sole ulcer, white line disease, digital dermatitis, and foot rot. University of Florida Research herd in 1995 showed the incidence of clinical lameness in cows at 35 percent, Claw problems (sole ulcers and white line disease) accounted for 63 percent of the reported cases. Digital dermatitis and foot rot accounted for 20 percent, and 17 percent of the cases, respectively. The impacts of clinical cases of lameness, loss in production has been demonstrated for mixed causes of lameness (Green *et al.,* 2002; Bicalho *et al*., 2008; Mitev *et al*., 2011) as well as for specific lesions including sole ulcers (SU) (Amory *et al*., 2008; Green *et al.,* 2010), white line disease (WLD) (Amory *et al*., 2008), digital dermatitis (DD) (Faust *et al*., 2001; Pavlenko *et al*., 2011) and double sole (Green *et a*l., 2010).

Digital dermatitis is a bacterial disease that primarily affects the skin on the heels of cattle. The infection cause inflammation and skin damage, leading to pain and discomfort (Laven *et al*., 2000). It is a major cause of lameness in dairy cows (Laven *et al.,* 2000) and hence a significant problem for the dairy industry in many countries, causing reduced animal welfare and economic loss (Laven *et al.,* 2001). The majority of active digital dermatitis lesions are painful (Laven *et al*., 2000; Somer *et al.,* 2003)), so the primary consequence of digital dermatitis infection is likely to be pain. If the digital dermatitis is not treated, infected animals can remain lame for up to four months (Frankena *et al.,* 2009), implying ongoing pain and discomfort. Animals that are in sufficient pain to develop lameness also show other changes in behavior when compared to sound animals, such as an increase in lying time (Walker *et al*., 2008) and shorter total feeding time (Almeida *et al*., 2008; Palmer *et al*., 2012), which in turn might be expected to have some effect on productivity. Studies that have examined the effect of digital dermatitis on milk yield have given differing results and, although it is a major cause of lameness, digital dermatitis infection does not always appear to be associated with a significant reduction in milk yield. Amory *et al*. (2008) found that animals with digital dermatitis in England and Wales did not show a decreased milk yield during infection, but had a slightly increased milk yield after treatment. In two other studies, animals with digital dermatitis produced less milk, but the difference was not significant (Argaez-Rohriguez *et al*., 1997). Warnick *et al*. (2001) found that animals with digital dermatitis on two United State dairy farms showed a reduction in milk yield, but found that this reduction was not as large as for animals with some other causes of lameness. Using a large data set from Holstein cows on French farms, Relun *et al.* (2013) found that digital dermatitis caused a small but significant decrease in milk yield (<1 kg per day). Pavlenko *et al*. (2011) found that digital dermatitis affected Swedish Red and Swedish Holstein cows had a significantly lower milk yield (5.5 kg energy corrected milk per day) than healthy control cows. Gomez *et al.* (2015) found that the digital dermatitis infection history of heifers affected their milk yield during the first lactation; a reduction in milk yield of 199 kg or 335 kg milk over 305 days was found for cows that had experienced one or more than one digital dermatitis infection before their first calving respectively, when compared to cows that had not experienced a digital dermatitis infection before calving.

Despite the economic and welfare importance of this disease, many questions remain regarding its etiology, transmission, prevention and treatment. There are a number of reasons why the disease is proving difficult to deal with; firstly, the infection appears to be polymicrobial, with a variety of bacteria, particularly of the genus Treponema, isolated from lesions (Walker *et al*., 2008). In addition, the bacteria involved initially proved difficult to grow in culture, experimental infection models have been difficult to develop (Reader *et al*., 2011) and the mechanisms of disease transmission have thus remained rather mysterious. Recent advances in laboratory methods have meant that good progress has been made in the identification of the most important pathogenic bacteria, and in the detection of these bacteria in the animals and in the environment of farms with digital dermatitis infections (Reader *et al.*, 2011).

A wide range of infection levels has been found on infected farms, prompting investigations into both farm/herd level risk factors and animal level risk factors (for parity and stage of lactation) for digital dermatitis occurrence (Reader *et al*., 2011). Both the farm level and animal level risk factors can provide useful information when trying to minimise digital dermatitis infection levels and understand when risks of infection are highest. An interesting, but less investigated, aspect of digital dermatitis is that there appears to be individual variation between animals in susceptibility to the disease; (Laven *et al*., 200; Gomez *et al*., 2015) all found that some animals within a herd were infected repeatedly while others of the same breed and parity and kept under the same conditions were never infected. If the reasons for this individual variation in susceptibility could be identified, they could add to our understanding of the disease and contribute to the search for effective prevention and treatment methods.

Laminitis risks in the cow environment include assessment of factors that affect the time that cows stand on concrete and lie down in stalls, the quality of walking surfaces, and factors which impact the period of acclimation for heifers first introduced into confinement housing. Dietary risk factors include ration composition, as well as feeding management factors that may be related to ruminal acidosis. Ruminal acidosis is widely viewed as a major risk factor for laminitis (Nocek, 1997; NRC, 2001). Ruminal acidosis encompasses a wide range of physiological conditions and ranges from peracute acidosis that can result in death to the animal, through acute, sub-acute, and mild stages (Radostits *et al.*, 2000). The diagnosis of ruminal acidosis in a herd should be based upon a combination of supporting clinical signs, production records, diet characteristics, and ruminal fluid pH. Bergsten and Faull, (1996) identified abrupt changes when cattle are moved from relatively soft surfaces such as pasture or bedded packs onto hard surfaces of confinement barns as a risk factor for laminitis.

Sole hemorrhage, sole ulcer, and white line disease cause a large proportion of lameness in dairy cattle and have a high rate of recurrence (Hirst *et al*., 2002; Reader *et al*., 2011; Green *et al*., 2014). These diseases are prevalent in developed dairy systems worldwide (Barker *et al*., 2007), significantly affect cow welfare and farm profitability (Booth *et al.,* 2004; Sogstad *et al*., 2006), and have a plethora of associated risk factors (Cramer *et al*., 2009; Chapinal *et al*., 2013; Solano *et al*., 2015). Sole ulcers and sole hemorrhage appear to be different presentations of a similar disease process, which is likely through insult to the germinal epithelium of the sole and poor quality horn production, as a result of inappropriate transfer of forces through the foot (Bicalho and Oikonomou, 2013); white line disease may also precipitate from the same disease process where contusions occur in the soft tissues around the periphery of the base of the foot (Le Fevre *et al.,* 2001; Newsome *et al*., 2016). Epidemiological studies have demonstrated that body condition loss preceded lameness events, whether lameness was defined by visual detection of impaired mobility (Randall *et al*., 2015) or by Claw horn disruption lesions treatment incidence (Green *et al*., 2014). The distal phalanx is suspended from the hoof wall by strong ligamentous attachments, referred to as the suspensory apparatus of the distal phalanx, and is supported by the digital cushion, which is a modified layer of the subcutis that is situated beneath the caudal aspect of the distal phalanx. The cushion and associated structures are considered to be important in absorbing impact and dissipating forces during foot strike and limb loading, protecting the germinal epithelium that produces the sole horn (Lischer *et al.,* 2002). Thickness of the digital cushion has been assessed in several studies that used ultrasonography to measure the distance from the inner aspect of the claw horn to the distal surface of the distal phalanx, beneath the flexor tuberosity. The measurement incorporates 2 tissue layers: the subcutis (the digital cushion) and the dermis (corium). Previous works have termed combined measurements of the 2 tissue layers as "digital cushion thickness," where the measurement was taken beneath the axial aspect of the flexor tuberosity (Bicalho *et al*., 2009; Machado *et al.*, 2011), or "sole soft tissue thickness," where the measurement was taken in the midline of the sole (Toholj *et al*., 2014).

Bicalho *et al*. (2009) reported that body condition scores was positively associated with digital cushion thickness. This association could be biologically plausible because the digital cushion contains adipose tissue (Raber *et al*., 2006); therefore, lipid could be deposited to and mobilized from the digital cushion during periods of positive and negative energy balance. Further, having a thin digital cushion and corium thickness appears to predispose subsequent lameness from Claw horn disruption lesions (Machado *et al*., 2011; Toholj *et al*., 2014). A possible mechanism for the temporal association between body condition loss and lameness is that fat is mobilized from the digital cushion during negative energy balance, which leads to depletion of the digital cushion, poorer force dissipation of forces during foot strike, greater peak forces on the germinal epithelium, leading to hemorrhage and interrupted epidermal differentiation and cornification, the formation of poor quality sole horn, and subsequent lameness. However, previous works assessing the digital cushion and corium have assessed their combined thickness at a single time point (Bicalho *et al*., 2009; Machado *et al*., 2011; Toholj *et al*., 2014), and whether the digital cushion becomes thinner as body fat is mobilized is yet to be demonstrated. These are described in Table 1 below.

Table 1: Common types of lameness

Type of lameness	Pictorial description	Explanation of the condition
Sole ulcer		A painful type of noninfectious hoof lesion, Sign of sole bruises, inappropriate nutrition, Occur in a typical site (toe, heel), poor hoof trimming and result to bleeding
Laminitis		Sign of foot rot, acute swelling, bruises, edema of the skin, sole hemorrhage, blood stain in the sole of the hoof and puncturing of the sole. Associated with dietary problems e.g. overfeeding of concentrate in the parlor.
Digital dermatitis		A highly infectious condition often associated with a contaminated environment such as cows standing in slurry or potholes/puddles/dirty gateways along cow tracks. Sign of swelling and black crush which is covering the injury.
White line disease		Affect one or both lateral hind claws, characterized by hemorrhage, abscess, slight swelling, and discharge of pus/horn junction above abaxial wall. Sharp stones and tight turns are often associated with this condition in which the hoof wall separates at its weakest point.

Source: Greenough, 2007

2.4 Risk factors for Cow-Lameness

The risk factors associated with cow-lameness are significant animal welfare issue causing pain and compromising the ability of cows to express normal behavior (Webster, 1986). It includes; individual cow and herd level risk factors. Numerous risk factors for lameness in dairy cattle have been reported in the literature, including risk factors related to the external environment such as flooring surfaces and time spent standing (Bergsten *et al.,* 2015) as well as animal based factors that might affect structure and function of the claw such as milk yield, Body condition scores, and previous lameness events (Green *et al*., 2014). Low body condition scores and previous lameness are both risk factors for lameness that occur repeatedly over time and have been highlighted as important for lameness control (Green *et al*., 2014). Randall *et al*. (2015) showed that relatively low body condition precedes and is associated with an increased risk of a first lameness event in a cow's life. Consequently, management strategies to maintain appropriate body condition scores may provide an opportunity for the dairy industry to reduce lameness in herds. Hirst *et al*. (2002) demonstrated that dairy heifers with lameness-causing claw horn lesions were at greater risk of lameness in subsequent lactations.

2.4.1 Individual Cow level risk factors for lameness

The individual cow risk factors associated with lameness include Breed, stage of lactation, digital conformation, age, heart girth, parity and reproductive status (Gitau, 1999). Risk increased with increasing parity, herd size and ratio of concentrate feed to total feed intake and it was increased with decreasing in body condition score. Housing cows on concrete floor has also been associated with dairy cow-lameness (Vanegos *et al*., 2006). The Jersey breed, which was a risk factor for lameness in Kenya, has uniquely shaped digits based hoof measurements (Gitau, 1999). This unique shape was associated with lameness and other digital lesions, and may therefore be the cause of the increased susceptibility of this breed (Gitau, 1999).

Table 2: Individual risk factors

Risk	Observation	References
Breed	Jersey, Frisian	Bicalho and Oikonomou, (2013)
		Gitau, (1999)
Age	Old age	Gitau, (1999)
Stage of lactation	Stages/level	Gitau, (1999)
Parity	High	Gitau, (1999)
Reproductive status	Dry or open	Gitau, (1999)

2.4.2 Herd level risk factors for cow-lameness

Herd level risk factors for lameness are important characteristics for dairy farmers in the control of lameness. Environmental and management risk factors include concrete surface (Somers *et al*., 2003), season (Wells *et al*., 1993), frequency of hoof trimming (Espejo and Endres, 2007), maintenance of cow tracks, and inappropriate animal handling (Chesterton *et al*., 1989). All affect production and eventually result to economic losses to the small holder farmers. Dietary risk factors associated with lameness include clinical and subclinical ruminal acidosis and high protein/low fiber lush rye grass pasture.

Herd level factors has a variety of lameness risk factors that have been identified and there are considerable differences in breeds, housing, nutrition, and management between these predominantly European studies and typical dairy farms in Ontario and the rest of North America (Refaai *et al*., 2013)**.** The restriction of movement is likely to predispose the cows to lameness (Greenough, 2007) and all these housing factors predispose cows to risk. Housing cattle on concrete has been linked to increased lesions and joint swelling (Rushen, 2007; Schulze *et al*., 2007), reduced claw health (Platz *et al*., 2007), and alterations in locomotion (Schutz and Cox, 2014). Concrete flooring can cause abnormal standing, lying, and transitional movements, as well as reduced traction, which can lead to injuries (Absmanner *et al*., 2009). Alterations in standing and lying behavior and postural changes, which are indicative of reduced comfort, have been observed in cattle housed on concrete compared to alternative flooring (Haley *et al*., 2001). When given the choice, cattle prefer other flooring substrates, such as straw, wood chips, or rubber mats, to concrete (Schutz and Cox, 2014). In the dairy industry, there is an emphasis on "cow comfort," with many researchers investigating flooring alternatives to improve animal health, hygiene, and welfare (Schutz and Cox, 2014). Alternative flooring includes straw, sand, wood chips, rubber mats, mattresses, and mastic asphalt. Flooring alternatives have the potential to improve animal soundness and longevity through improvements in leg and joint health and function (Onyiro and Brotherstone, 2008; Eicher *et al*., 2013), which may have an economic impact for producers.

Table 3: Herd level risk factors

Risk factor	Observations	Reference
Concrete floor	Medium to high risk	Somers *et al*. (2003)
Housing	Cubicles or open housing	Refaai *et al*. (2013)
Bedding	Moist	Mahendran and Bell, (2015)
Feed bunk space	Crowding	Vermunt and Greenbush, (1994)

2.5. Economic losses from cow-lameness

Lameness in cattle are serious welfare problems and is one of the major causes of economic losses in dairy production systems (Hernandez *et al*., 2005). These losses occur through various negative impact directly on cattle and indirectly on the dairy production system and these include reduced milk yield (Hernandez *et al*., 2005), discarding of milk due to withdrawal period of drugs used, cost of treatment, decreased reproduction performance and increased culling. Economic losses due to lameness can be divided to direct losses like increased culling rate, decreased reproductive performance, increased open days and increased risk of mastitis (Mohamadnia, 2005; Weaver *et al*., 2005; Hernandez *et al*., 2001). Similarly, Yaylak *et al*. (2010) reported that most economic loss due to lameness results from costs of early culling, reduction infertility and reduced reproductive efficiency. Lameness results in substantial economic losses. For example, Dutch dairy farmers lose 4–5% of their income due to lameness according to Enting *et al*. (1997). The dairy farmer might not consider lameness as important as other more-frequently occurring diseases such as mastitis or reproductive problems, due to the slow onset of some kinds of lameness (sole ulcer). The correct identification of claw problems requires careful examination of the claw, which may be difficult for the farmer to carry out. In long standing cases, the primary cause may no longer be present. This makes correct diagnosis and identification of the etiology difficult. Lameness in the herd may affect the farmer in several ways: increased labour requirement, increased treatment costs, reduced milk production, reduced fertility, and involuntary culling and decreased slaughter value.

2.5.1 Treatment costs

From an economic point of view, clinical lameness is considered to be one of the major health disorders in dairy cattle (Ettema *et al*., 2006). The costs of treating a lame cow differ across countries, across farms, across underliying diseases causing lameness, and across people responsible for treating the cow (Lucey *et al*., 1986; Esslemont *et al*., 1997). Lame cows are costly to the industry because they do not produce much milk and its condition can be escalate to the point that cows cannot walk and stop producing which could lead to cost of veterinary drugs and professional services in managing the conditions (Enting *et al.,* 1997). Claw trimming is an important component of both prevention and treatment, herds should be trimmed twice a year (Manske *et al*., 2002) and footbath are also use for treating lame cows , because monitoring these cows for healing and re-treating lesions are expensive and cost effective. Functional claw trimming is an important component of both prevention and treatment while smaller herds should be trimmed twice per year (Manske *et al*., 2002), Various compounds have been used for foot bathing (Holzhauer *et al*., 2012; Relun *et al*., 2013).

2.5.2 Control costs

Lameness control in dairy cattle is a critical issue, as it directly impacts the herd management, economics and welfare (Archer *et al*., 2011). Control of lameness include used for foot bathing (Holzhauer *et al*., 2012) and trimming. It is necessary to understand both the barriers that currently restrict farmer's effort to control lameness, Once these are understood, progress could be made using techniques such as social marketing (Sorensen *et al*., 2008). One likely factors contributing to the sustained problem of lameness in dairy herds is that farmers underestimate the prevalence of lameness on their farms, and therefore do not perceive the need to take further action to control it (Whay *et al*., 2002; Bell *et al*., 2006). Other health issues, such as mastitis, have a more immediately obvious cost, with a direct effect on milk price and amount of saleable milk (Blowey and Edmondson, 2000), and this may attracts farmer's attention or investment, at the expense of lameness. Herd measures like footbaths, hoof mats and foaming systems are also essential to control the extension of the disease and it has been reported that if claws are correctly trimmed at least once a year then the longevity of the herd may be extend for a year.

2.5.3 Loss in milk

Lameness is a major problem for dairy cows resulting in substantial reduction of milk yields and poor economic results. Ganchev and Mitev, (1997) outlined that the prevalence of foot diseases among cattle was 10–15% and that their economic impact was similar to that of serious problems as mastitis and infertility. Lameness causes significant economic losses at farms due to lower milk yield, difficult or impossible mating, additional costs for medications, labour costs and early culling of animals. Similar opinions have been reported also by other researchers (Penev, 2011; Penev *et al*., 2012). According to Simbirtsev and Terehov, (1982), losses of milk in cows with lameness could vary between 5 and 30% depending on the clinical manifestation of pain. Another investigation shows that depending on the severity of lameness, milk losses could be from 25 to 75% (Rousseau, 1987). Cows were shown to reduce their milk production even before lameness became overt (Warnick *et al*., 2001; Green *et al*., 2002). Several economic analyses demonstrated the negative impact of lameness on the farm budgets. In the Netherlands, cattle farm incomes have been reduced by 4–5% because of lameness (Enting *et al*., 1997). Weaver *et al*. (2005) outlined that lameness could incur higher financial losses from infertility— 34%, lower milk yields—25%, death or preliminary culling—13%, additional labour costs—13%, veterinary costs—8%, body weight loss—6%. Penev (2013) established that severe and prolonged lameness between the 61st and 200th lactation days exerted a considerable negative effect on milk yield and reproductive performance of dairy cows through increasing calving intervals and the number of inseminations per conception. The purpose of the present study was to evaluate the effect of lameness on economic parameters of Holstein-Friesian cows at three dairy farms with different average productivity and free-range production system variants.

A numerous studies was done by Green *et al*., (2002), the estimated reduction in mean daily milk yield after the onset of lameness was 1.63 liters (95% CI= 1.92) but slightly low and higher . A 350kg decrease in milk yield per lactation was observed for cows with heel lesions, but was attributed to a decrease in the length of lactation (Lucey and Rowlands, 1986). In Ethiopia on the impact of milk production due to lameness, reported that Lame cows produced 1.12kg (Green *et al*., 2002), compare to 3.1kg (Bicalho *et al.,* 2008) less milk per day than normal healthy ones and 12days longer to get pregnant compared with their none-lame counterparts (Alawneh *et al.,* 2011) and 1.7% involuntary culling of the herd (Whitaker *et al*., 2000). Evidence for loss of productivity due to lameness through premature culling, treatment costs and milk loss is important to persuade a reluctant farmers to consider changing the environment. In a study of lameness in three French research herds found that milk loss was about 25% of cases of lameness with median losses of 440 and 270 for early lactation and mid-to late lactation, respectively (Coulon *et al*., 1996). The impacts of lameness on milk yield in dairy cows; studies from Bulgaria (Mitev *et al*., 2011), Chile (Green *et al*., 2010), Finland (Rajala-Schultz *et al*., 1999), France (Coulon *et al*., 1996), Hungary (Gudaj *et al*., 2012), Israel (Yeruham *et al.,* 2000), Sweden (Pavlenko *et al*., 2011), the UK (Onyiro *et al*., 2008; Reader *et al.,* 2011) and the USA (Faust *et al.,* 2001; Juarez *et al*., 2003; Bicalho *et al.,* 2008) have all demonstrated that lameness has a negative impact on milk production. Apart from the decrease in milk yield the following cost should be considered: veterinary fee, cost of medication, valve of time, nursing the cow, decreased fees, reproductive efficiency, earlier culling and loss of body condition (Greenough, 2007). In a study of lameness prevalence in a sample of Virginia dairy herds, cows classified as clinically lame had lower 305 day mature equivalent production (−320 Kg; 95% CI −667, 27) than unaffected herd mates (Warnick *et al*., 1995). A prospective study in three French research herds found milk loss occurred following about 25% of cases of lameness with median losses of 440 and 270 Kg for early lactation and mid-to late lactation, respectively (Coulon *et al*., 1996**).** The behavior of lame cows is also affected: they are more restless at milking, spend more time lying down and eat more slowly (Hassall *et al.,* 1993; Juarez *et al*., 2003; O'Callaghan *et al*., 2003).

2.5.4 Loss in premature culling

The average lactation length of lame cows was reported to be shorter mostly due to premature culling of some cows having poor productive performance (Tranker *et al*., 1992). It is costly and economic loss to a farmer in order to cull a cow, as it includes rearing cost of the replacement heifer and low milk yield (Bielfeldt, 2005). The decision to cull a cow is influenced by many factors such as parity, lactation stage, reproductive performance, health, calving season, milk yield and the welfare of cow (Rajala-Schultz and Grohn, 1999; Sogstad *et al.,* 2007), while risk of culling increased with increasing parity (Rajala-Schultz and Grohn, 1999). The culling of cows is a technique that may lead to herd improvement and increase profits or reduce costs by replacing sick or non-pregnant cows (Rajala-Schultz and Grohn, 1999). Culling is the departure of cows from the herd as a result of sale, slaughter, salvage, or death. Culling is referred to as either voluntary or involuntary. Voluntary culls are cows culled because they are poor producers, whereas invo- luntary culls are those culled out of necessity, due to mastitis, extreme lameness, poor reproduction or death. The association between lameness and culling suggests that animals which suffer from lameness are more likely to be culled. Studies on small numbers of herds in New York, USA demonstrated that cows with claw horn lesions were 1.7 times more likely to die or be culled (Machado *et al*.,

2010) and the hazard ratio for culling for lame cows diagnosed in the first half of lactation was two times that of non-lame cows (Booth *et al*., 2004). In a much larger US study, the odds of a herd being in a higher category of dairy cow mortality was higher on farms classified as having a high and moderate level of lameness (McConnel *et al.,* 2008). In a large Canadian study the median time to culling was for cows without hoof lesions and for cows with a lesion. After modelling, the culling hazard ratios were significantly higher for animals diagnosed with lameness. A study published by the National Animal Health Monitoring System in 1996 indicated that 15% of cows culled from dairy herds in the USA were culled because of 'direct effect' of lameness (Shearer and Van Amstel, 2007). Lameness is a frequent reason for culling (Booth *et al*., 2004); for instance, clinical lameness increased the risk of culling 6–12 times during the first two months of lactation in the study of Rajala-Schultz and Gröhn, (1999). Rajala and Grohn, (1999) culling proportions in dairy herds ranged from 20 to 35%. The risk of culling when lameness is diagnosed toward the end of lactation may represent more accurately the direct effect of lameness on culling, as its combined effect on other diseases, fertility, and production is less pronounced during this period, effects of lameness on culling increased only slightly, but decreased somewhat when pregnancy status and number of inseminations were included (Rajala-Schultz and Grohn, 1999). The decision to cull a cow is influenced by many factors such as parity, lactation stage, reproductive performance, health, calving season, milk yield and the welfare of cows (Rajala-Schultz and Grohn, 1999; Sogstad *et al*., 2007), while risk of culling increased with increasing parity (Rajala-Schultz and Grohn, 1999).

Lameness results in earlier culling of animals as well as lower carcass weight, conformation class, and fat cover class and hence a lower carcass economic value (Booth *et al.,* 2004). It has also been reported that prevention or early identification and treatment of the problem can improve the value of the carcass and reduce culling rates (Booth *et al*., 2004). Several studies have also shown that lameness has a negative effect on the fertility of dairy cows (Hernandez *et al*., 2001; Garbarino *et al*., 2004). The prevention of lameness is the most important step to reduce its welfare implications for cows and associated economic losses to the dairy farmers, Hence it is important to create a system that accurately predicts the occurrence of lameness, thus allowing farmers to target high risk animals with preventive strategies.

Lameness is a crucial welfare issue in modern dairy production (Espejo and Endres, 2007; Vermunt, 2007). Lame cows suffer discomfort and pain of long duration (Green *et al*., 2002). Additionally, the observation of lameness has been classified as the most representative animal-based indicator of welfare in dairy cattle (Whay *et al*., 2003). There is an increasing societal concern about the moral and ethical treatment of food animals (Fulwider *et al*., 2008). Lameness is of welfare concern due to its debilitating effects and high prevalence in herds throughout the world (Cook, 2003). Furthermore, dairy cattle mortality is a major cause of economic losses and is an important animal welfare issue (Thomsen and Houe, 2006). A large retrospective cohort study with over 900 dairy farms reported that dairy operations with high prevalence of lameness ($\geq$ 16 %) had 2.9 higher odds of on farm dairy cow mortality compared to dairy farms with low lameness incidence (McConnel *et al*., 2008), dairy cows that died on the farm because of lameness were usually euthanized by a farm employee or veterinarian. Lameness is perhaps the biggest challenge for dairy farmer to overcome as society becomes more concerned with the origin of their food and the welfare of farm animals.

A partial budgeting helps farm owners/managers to evaluate the financial effect of incremental changes and only includes resources that will be changed. It does not consider the resources in the business that are left unchanged. Only the change under consideration is evaluated for its ability to increase or decrease income in the farm business. Partial budgets are based on the principle that small business changes have effects in one or more of the following areas: 1. Increase in income, 2. Reduction or elimination of costs, 3. Increase in costs, 4. Reduction or elimination of income, the net impact of the above effects will be the positive financial changes minus the negative financial changes. A positive net indicates that farm income will increase due to the change, while a negative net indicates the change will reduce farm income. Partial budgeting compares the positive and negative effects of the propose change on the net income, you then separate positive and negative effects and list them in different section of partial budget.

Drop in milk yield and premature culling will be computed from partial budgeting techniques by comparing the sum of additional income and reduced costs with the sum of reduced income and additional cost in order to analysis total economic loss incur in the farms. The total economic loss due to conceptual failure will be computed as sum of mortality loss, loss in milk yield and cost of treatment of affected animals using (Singh *et al*., 2014) formula ($T1 = A + B + C$) while treatment cost and control cost will be computed using (Bennett, 2003) formula: $C = (L + R) + (T+P)$

Table 4: Economic losses

Source of loss	Computation approach	Reference
Drop in milk yield	Partial budgeting techniques	Bennett (2003); Sitawo *et al*. (2016)
Conception failure	Comparison of normal in a disease case/Total economic cost	Singh *et al*. (2014); Bennett, (2003); Sitawo *et al*. (2016)
Premature culling	Partial budgeting techniques Total economic cost	Singh *et al*. (2014); Bennett, (2003); Sitawo *et al*. (2016)
Control cost	Total economic cost (Bennett formula)	Bennett, (2003); Sitawo *et al.* (2016)
Treatment	Total economic cost (Bennett formula)	Bennett, (2003); Sitawo *et al*. (2016)

2.6 Methodological approaches in cow-lameness studies

In a study to manage under a pasture based system in Ireland dairy cattle with housing during the winter and grazing for the rest of the year. Chi-square tests was used to compare the proportions of the number of cows diagnosed with lack of lesions both infectious and non-infectious lesions and the number of specific lesions found during foot trimming. In a similar situation United States' representing 86% of the national dairy herd were surveyed regarding the occurrence of common dairy diseases or disorders (digestive, respiratory, gastrointestinal, lameness, mastitis, navel infection) and chi-square was used (Hill *et al.,* 2009). A study to estimate production losses in Canadian dairy herds' with *M. avium paratuberculosis* infection**,** a partial budget simulation model with four components of direct production losses (decreased milk production, premature culling, mortality and reproductive losses) was developed. While in other studies reviewed by the same author, estimation methods such as regression were utilized or directly multiplied the estimated prevalence with costs of effects associated with the disease studied such as decreased milk yield (Tiwari *et al*., 2008).

Thirunavukkarasu *et al*. (2010) concurs by calculating direct losses due to the disease by summing up the loss in milk yield during the affected period and multiplying it by the farm gate value of milk in their study quantifying economic losses due to milk fever in dairy farms. Economic losses due to culling and mortality were taken as the value of cow at slaughter**.** Total economic losses were then summed up as treatment cost, add milk reduction in (KES), and add cull value (KES). Milk loss (%) due to Bovine tropical Theileriosis in

Algeria has also been obtained by calculating mean milk loss weekly for two months. The affected herd was under treatment by subtracting milk yield during the first visit from milk yield from the second visit then divided by milk yield from the first visit multiplied by 100 (Ayachi *et al*., 2016). In assessing direct production losses and treatment costs due to four cattle diseases (Weersink *et al*., 2002), the estimated herd losses associated with John's disease on US dairy operations was calculated as value of production on a per cow basis for each of the farms**.** This net return was then regressed against a number of explanatory variables.

Regression models are relevant for obtaining a mathematical model to describe the relationship between observations of outcome variable with a set of explanatory or predictor variables (Hosmer *et al*., 1991). The outcome variable is quantified by applying multivariate analysis with logistic regression, multiple regression or generalized linear modeling. For instance, in a study by (Gitau, 1999), individual animal, and herd level factors were assessed for their association with lameness using logistic regression. The housing system and the type and condition of the floor were considered as herd level risk factors; while age, breed, heart girth, parity, reproductive status and stage of lactation were considered as the individual animal level risk factors.

The generalized linear model is an analysis of variance procedure that describes a statistical relationship between one or more predictors and a continuous response variable. The measure of effect of size in a generalized linear model is the adjusted squared multiple correlation (R^2) which is an estimate of the proportion of variance in the dependent variable explained by the model, the larger the R^2, the better the model predicts the data.

The Spearman's Rank Correlation Coefficient is non-parametric statistical measure used to study the strength and direction of association between the two ranked variables. Spearman's correlation determines the strength and direction of the relationship between your two variables rather than the strength and direction of the linear relationship between your two variables. This method will be applied to the ordinal set of numbers, which can be arranged in order, (i.e. one after the other so that ranks can be given to each). In the rank correlation coefficient method, the ranks are given to each individual on the basis of its quality or quantity and describes the degree of relationship between two variables. It uses ranks to test for association and does not depend on the assumption of an underlying bivariate.

2.6.1 Study designs for cow-lameness studies

Observational study is a process in which researcher observe ongoing behavior and measure or survey members of a sample without trying to affect them. The sampling designs are simple random sample, stratified random sampling and multistage random sampling. Simple random sampling select a group of subject (sample) for study from a larger group (a population). Each individual is chosen entirely by chance and each member of the population has an equal chance of being include in the sample. Stratified sampling is obtained by talking samples from each stratum or sub- group of a population and they use when population is heterogeneous or dissimilar. Multistage random sampling is constructed by taking a series of sample random samples in stages. It takes larger sample like a country and divide them in to regions and states. In an observational study the investigators do not intervene in any way but simply record the health, behavior, attitudes, or lifestyle choices of the study participants.

A cross sectional study is to obtain a representative sample by taking a cross section of the population and the study is suitable for estimating the prevalence of a behavior or disease in a population. In across sectional study, all the measurements for a sample member are obtained at a single point in time, although recruitment may take place across a longer period of time. In a study by Sulayeman and Fronma, (2012) in Hawasa Town Ethiopia, the researcher used cross sectional survey where each of the selected farms were visited every month to record a new cases and the length of recovery period for previously recorded lameness cases. The farms were selected by simple random sampling techniques and all the animal of each selected farm were included in the study. A cross sectional study is not longitudinal by design because in a longitudinal study, each participant is observed at multiple time points, thereby allowing trends in an outcome to be monitored over time. Longitudinal studies may be prospective or retrospective.

Experimental design is the process of planning a study to meet specified objectives. The purpose in designing an experiment for a system is to optimize certain characteristic of the experimental set up so that measured data provide useful information about the condition of the system. The control parameters of an experiment may include the excitation characteristics (sampling frequency, duration in structural dynamics), characteristics of output measurements (monitoring period). Planning an experiment properly is very important in order to ensure that the right type of data and a sufficient sample size and power are available to answer the research questions of interest as clearly and efficiently as possible. It assist in identifying the following Selecting a topic, identifying the research problem, conducting a literature review, to conduct a hypothesis, to determine the design of the research, to determine the research methods, to conduct the research and test the hypothesis and analyze the data.

2.6.2 Data collected in measuring cow-lameness

A study on prevalence of lameness stated that all environmental and management measures were collected from all pens where cows were housed on the day of the visit. Pens were assessed for type of flooring, width of feed alley, floor cleanliness, and floor slipperiness. Type of flooring was categorized as solid or slatted and concrete or rubber. Feed alley width was measured from the feed bunk to the curb of the stalls. Footbath were measured for every footbath used (Grandin, 2008). Prevalence of type of lameness were measured through observation of observed frequency, (e.g. sole ulcer, laminitis, digital dermatitis, white line disease).

2.6.3 Statistical approaches

The prevalence rate of claw disorder was calculated as percentage of the number of cows (CL) affected divided by the total number.

$$prevalence\ (\%) = \frac{CL * 100}{N} \tag{1}$$

Where CL represents the claw disorder, and (N) represents the total number of cows (Mwangi *et al.*, 2008).

Multiple logistic regressions were done through a step-down regression in which the risk factors that made the least variation to the occurrence of the claw lesions were eliminated one at a time through consideration of their odds ratios. Only the factors that were found to influence the occurrence of claw lesions significantly were retained in the model. The effects of confounding the risk factors were dealt with in the analysis but they were minimal because of the similarities of the management in the smallholder farms (Mwangi *et al.*, 2008).

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 ... \beta_n x_n + e \tag{2}$$

Chi-square (χ^2) is a non-parametric test which refers to the fact that the chi-square do not require assumption about population parameters nor do they test hypothesis about the population parameters. The most significant difference between the chi-square test and the other hypothesis test like the t test is the nature of the data. Type of lameness and prevalence of lameness will be used in chi-square test statistic because the data are frequencies rather than numerical scores.

$$\chi^2 = \sum \frac{(f_0 - f_\ell)^2}{f_0} \qquad (3)$$

Where f_0 is the observed frequency and f_e is the expected frequency

The generalized linear model is an analysis of variance procedure that describes a statistical relationship between one or more predictors and a continuous response variable. The first part deals with the overall model and asks how well the model describes the data regardless of the individual independent variables in the model. The second part examines the effects of individual independent variables especially to distinguish those independent variables that contribute significantly to prediction from those that add little to the model. The measure of effect of size in a generalized linear model is the adjusted squared multiple correlation (R^2) which is an estimate of the proportion of variance in the dependent variable explained by the model, the larger the R^2, the better the model predicts the data. It will be used in economic losses because generalized linear model is well suited when the response variable is continuous in nature or measured on a scale (Generalized linear model with logit link).

Regression models are relevant for obtaining a mathematical model to describe the relationship between observations of outcome variable with a set of explanatory or predictor variables (Hosmer *et al.*, 1991). The outcome variable is quantified by applying multivariate analysis with logistic regression, multiple regressions or generalized linear modeling. Logistic regression model has two components with the first being the random component where the distribution of Y is assumed to be binomial (n, π) where π is the probability of success. The second component is the systematic component where Xs are the explanatory or predictor variables and can be continuous, discrete or both and are linear in parameters ($\beta_0+\beta_1X_1+...+\beta_nX_n$). It estimates the probability of occurrence of an event in terms of odds ratio (Reed and Wu, 2013). Risk factors will be used in logistic regression model because response variable is binary in nature (yes/no).

CHAPTER THREE
MATERIAL AND METHODS

3.1 Study Site

The study was conducted in smallholder dairy farms in Bahati, Njoro and Lare Sub Counties of Nakuru County within the Kenya Highlands. Zero grazed dairy herds dominate in Bahati and in Njoro regions, while pasture grazed dairy herds dominate in Lare region.

3.2 Sample size determination and sampling procedure

The required minimum sample size was 254 cows determined from application of the formula of Thrusfield, (2007):

$$n = \frac{(1.96)^2 (P_{exp})(1 - P_{exp})}{d^2} \qquad (4)$$

Where, n = is the minimum sample size, P_{exp} = expected prevalence which was set at 21% from the estimates Mbuthia, (2007) reported in a sample of 318 cows, d = desired absolute precision, set to alpha 0.05 for detecting lameness at 5% level of probability represented by 1.96 value.

An observational study design was used to collect data on randomly selected farms. The staff of Animal Production Directorate in Bahati, Lare and Njoro Sub Counties provided the list of farms from which the individual sample farms were randomly selected for farm visits. A total 172 farms were randomly selected of which 70 farms were in Bahati and 45 farms were in Njoro where zero grazing dominates and 57 farms in Lare where pasture grazing dominates. The sampled farms were recruited in the study on the consent of the owner to participate in the study and allow for the examination of cows for lameness and the farm for risk factors.

3.3 Data Collection

3.3.1 Data on lameness prevalence

Farms were visited in the morning hours (7am to 12noon) during milking hours to enable observations of cows for lameness status, risk factors and to gather information for computing economic losses. The respondents were asked to estimate cases of lameness they have had in the herd within the last two years to obtain farmer estimated prevalence. Lameness was defined as cow limping or with abnormal gait. To ease identification, photographic illustrations of four lameness types: digital dermatitis, laminitis, sole ulcer and white line disease was used (Table 1).

A cow on the farm that had calved at least once or was pregnant qualified for examination for lameness. Each cow was allowed to walk then observed when in motion for any abnormality in locomotion. The cow was diagnosed as lame if they moved with clear abduction or adduction, showed clear impaired movement. A lame cow was then restrained in a standing posture in the farm crush and one hind limb lifted at a time using a rope tied to an overhead pole or cross-bar. The hooves were washed and cleaned to identify the site and type of lameness and to allow for physical clinical examinations. Lameness was recorded as yes or no for any of the four types of lameness: digital dermatitis, laminitis, sole ulcer and white line disease (Table 1). The farms visited had between 1 to 5 adult cows and in total, 485 cows were recruited in the study.

3.3.2 Data on risk factors for lameness

Data on risk factors were collected on individual cow and herd levels. Individual risk factors included: reproduction status, stage of lactation, parity and breed while the herd level risk factors were housing confinement, floor type, bedding condition, feeding space.

3.3.3 Data on economic losses from lameness

Farmers were asked to recall the history of each lame cow to enable estimation of economic loss from lameness. The recall data included treatment costs, consultation fee for veterinarian, footbath, trimming, drop in milk yield, abortion, milk withdrawal, and premature culling, hired labor, replacement in case of mortality and reporting of lameness cases to veterinarian. The estimated costs were recorded based on the difference between healthy and lame cow in the herd for milk yield (Warnick *et al*., 2001). Losses resulting from premature culling was obtained from the difference in market price of a culled cow and a healthy cow. Cost of lameness control were trimming, footbath and chemical, while costs of treatment included veterinary /consultation fee, drugs, bandages, application of antibiotic spray, and value of milk lost during the withdrawal period.

3.4 Data Analysis

3.4.1 Computing prevalence of lameness and risk factors

The farmer estimated lameness prevalence was computed from farmers' own estimates as percentage of lame cows in a farm over the last two years. The farmer estimated prevalence is the average of estimates from each farmer sampled. This was an indicator of how concerned and aware were farmers about the problem of cow-lamness in their herds. The observed lameness prevalence was calculated as a percentage of the number of cows lame divided by the total number of cows examined. Means comparisons and spearman rank correlation were applied to test for the difference between the farmer estimate and observed prevalence and possibility for partern correlation.

Four types of lameness were identified and their proportional differences tested with Chi-square ($\chi2$) statistics to detect whether some types of lameness were more prevalent than the others between zero- and pasture- grazed cows. Chi-square test statistic at the level of $p<0.05$ was used to determine associations between risk factors and the grazing system.

3.4.2 Estimatingeconomic losses from lameness

The economic losses from lameness case was computed in Microsoft Excel spreadsheet with the formula of Bennett, (2003):

$$C = (L + R) + (T+P) \quad (8)$$

Where: C = sum economic cost of lameness, L = production loss (drop in milk yield, abortion, milk withdrawal, premature culling), R = additional cost (labor hire, cow replacement cost and reporting), T = veterinary cost (drugs treatment and consultation fee), P = disease control cost (foot bath and trimming).

CHAPTER FOUR
RESULTS

4.1. Prevalence of lameness

Table 5 is a summary description for the 172 sample farms that were visited and 485 cows examined for lameness on those farms. More farms practiced zero-grazing (63.4%) than free grazing (36.6%) system, but the average herd size (2.8 cows) was not different between the two grazing systems.

Table 5: Description of sampled farms

Farmgrazing system	**Farms (n)**	**Cows (n)**	**Lame cows (n)**	**Mean±SD (min -max) herd size**
Zero-grazing	109	317	73	2.9±1.2 (1.00 - 5.00)
Pasture grazing	63	168	34	2.7±1.2 (1.00 - 5.00)
Sample total	172	485	107	2.8±1.8 (1.00 - 5.00)

Results in Table 6 show that the prevalence of lameness observed (22.1%) and that estimated by farmers (22.7%) were not different in the sample farms, whether for zero-grazed cows (23.7 vs 23.0%) or pasture-grazed cows (20.8 vs 20.2%). The observed and farmer estimated prevalence had a strong positive correlation (r=0.959, P = 0.0001) in the total sample as well as for the zero-grazed and pasture-grazed cows.

Table 6: Lamenes of cows estimated by farmers and observed objectively observed

Grazing system	Farmer estimated prevalence		Observed prevalence		Correlation coefficient	
	Farms (n)	(%)	Cows (n)	(%)	r value	P value
Zero-grazing	109	23.7	317	23.0	0.991	0.0001
Pasture	63	20.8	168	20.2	0.953	0.0001
Total sample	172	22.7	485	22.1	0.959	0.0001

4.2. Prevalence of types of cow- lameness

Four types of lameness were identified in the sample cows, of which the most prevalent were laminitis (43.1%) and digital dermatitis (32.1%) relative to white line disease (14.7%) or sole ulcers (10.1%). The prevalence of the four types of lameness did not significantly differ between zero- and pasture grazed cows (Table 7).

Table 7: Prevalence of types of lameness

Cow grazing	Types of lameness (%)				Overall prevalence	Chi square statistics
	Digital dermatitis	Laminitis	White line disease	Sole ulcer		
Zero	30.1	43.8	15.1	11.0	23.0	Value 0.4818
Pasture	36.1	41.7	13.9	8.3	20.2	df= 3
Total sample	32.1	43.1	14.7	10.1	22.1	p= 0.9229

4.4. Risk factors of lameness

Results in Table 8 show that the risk factors for lameness significantly different between zero and pasture grazed dairy cows were floor type (p=0.0001), breed (p=0.0108) and bedding condition at 10% of significance (p=0.0586). Lameness was more prevalent among zero grazed than pasture -grazed cows for those kept on earth floor (46.4% vs 20.4%), small dairy breeds (46.0% vs 27.5%) or those kept on dry bedding (15.0% vs 4.9%). In this sample cows, animal level risk factors not significantly associated with lameness under grazing management were reproductive status, stage of lactation and parity. Of the herd level risks for lameness, feeding space was not a significant risk for lameness.

Table 8: Animal and herd level risk factors of lameness

Risks	Level	Grazing System		Effects Signifance	
		Pasture grazing N (% lame)	Zero grazing N (% lame)	Risk	Grazing
Bedding condition				0.0011	0.0586
	Dry	8 (4.8)	140 (15.0)		
	Wet	160 (21.3)	177 (29.4)		
Floor type				0.0001	0.0001
	Concrete	1 (0.6)	233 (14.6)		
	Earth	167 (20.4)	84 (46.4)		
Feeding space				0.0001	0.9131
	Adequate	168 (20.2)	229 (16.2)		
	Not adequate	0 (0)	88 (40.9)		
Breed				0.0001	0.0108
	F/A(Large)	66 (11.7)	251 (16.7)		
	Others (small	91 (27.5)	77 (46.0)		
Reproductive status				0.0702	0.4439
	Lactating	127 (19.7)	230 (26.5)		
	Not lactating	41(22.0)	87 (13.8)		
Satge of lactation				0.0061	0.1960
	Early/mid	98 (22.4)	187 (30.1)		
	Late	28 (10.7)	44 (11.1)		
Parity				0.0001	0.6166
	0-2	97 (17.5)	178 (10.6)		
	>3	71 (23.9)	139 (29.1)		

4.5 Economic loss from lameness

Results showed that economic losses per farm per year from lameness were 51% more in zero-grazing than in pasture grazing (KES 4,695.49 vs 3,109.41). A larger proportion of the economic loss was due to production loss and veterinary costs, but economic loss attributed to production loss was 12.6% higher in zero-grazing than in pasture grazing (68.3 vs 55.7%) and the loss attributed to veterinary costs was 5.3% lower in zero-grazing than in psture grazing (29.1 vs 34.4%). The disease control and additional costs accounted for less than ten percent of the economic loss, whether in zero or pasture grazing farms.

Table 9: Estimated economic loss (KES/farm/year*) of lameness in smallholder zero and pasture grazed dairy cows

Loss	Variables	Zero grazing		Pasture grazing	
		KES/farm/yr	%	KES/farm/yr	%
Overall		4,695.49		3,109.41	
Production loss	Milk loss	1, 235.75	26.3	850.88	27.3
	Milk withdrawal	764.55	16.3	587.94	18.9
	Premature culling	1205.50	25.7	294.12	9.5
	Sub total	*3, 205.80*	*68.3*	*1732.94*	*55.7*
Veterinary cost	Treatment	928.10	19.8	805.90	25.9
	Consultation	438.00	9.3	264.70	8.5
	Sub total	*1366.44*	*29.1*	*1070.6*	*34.4*
Disease control	Trimming	20.5	0.4	229.41	7.4
	Sub total	*20.5*	*0.4*	*229.41*	*7.4*
Additional cost	Labor hire	78.78	1.7	61.76	2.0
	Reporting	23.97	0.5	14.71	0.5
	Sub total	*102.75*	*2.2*	*76.47*	*2.5*

*Data obtained did not support attaching loss to footbath, abortion and replacement

CHAPTER FIVE
DISCUSSION

5.1. Prevalence of lameness

This was an observational study of lameness in a sample of zero grazed and pasture grazed cows in a randomly selected 172 farms. In this study, lameness was a two-point score (yes/no) for limping or with abnormal gait as described by Manske *et al*. (2002). The specific lameness types (digital dermatitis, laminitis, sole ulcer or white line disease) were identified with the help of photographic illustrations by Greenough, (2007). The sample farms had small herd sizes (1 to 5) and in aggregate, 485 cows were examined for lameness. This was to estimate prevalence and test whether there is a significant difference between observed and farmer estimated prevalence in zero and pasture grazed dairy cows. It was found that prevalence of lameness observed and estimated by farmers are not significantly different between zero and pasture grazed dairy cows. It had been expected that prevalence would be higher in zero grazed than in pasture grazed dairy cows (Gitau, 1999; Mbuthia, 2007) because housing confinement in pasture grazing is only restricted to nighttimes after daytime grazing in the pastures. This implies that in smallholder farms, lameness is a problem in both zero grazed and pasture grazed dairy cows.

The observed lameness prevalence (22.1%) compares with the estimates obtained in intensive smallholder dairy systems of Kiambu in the Kenya highlands (Gitau, 1999; Mbuthia, 2007) and in industrial dairy herds (Espejo *et al*., 2006; Sarjokari *et al.,* 2013; Salono *et al.,* 2015; Charlton *et al*., 2016). But prevalence was much higher than 3.5% estimated in Ethiopian smallholder dairy farms (Sulayeman and Fromsa, 2012). Smallholder dairy management in Kenya differs from those of industrialised countries and from those of Ethiopia, which reflect different risks exposures. Compared to smallholder dairy herds in Kenya, those of the industrialised countries have larger herds with much higher milk production from greater silage and concentrates feeding and periods of housing confinement are longer in a year, while floor designs are more sensitive to reducing lameness and veterinary care is better (Cramer *et al*., 2008). On the other hand, compared to herds in Ethiopia, those in Kenya predominatly practice dairy zero grazing, farmholdings and herds are smaller but proportion of exotics dairy cattle are larger with higher milk production (Mayberry *et al.,* 2017).

Lameness is a cause of worry to farmers because it can be sub-clinical or clinical condition resulting in economic loss from drop in milk yield, sub optimal fertility, replacement costs or veterinary costs (Alawneh *et al*., 2011; Bruijnis *et al*., 2012). Lameness therefore should attract attention of the farmer, but the action they can take towards lameness cases in the herd is whether they perceive lameness as a problem (Leach *et al*., 2010). In this study, prevalence estimated by farmers was very closely comparable to the observed prevalence of lameness, indicating that farmers are aware of and do not underestimate lameness problem in their herds. The estimates by farmers refered to locomotion problem during the last two years. They could easily recall cows with locomotion problem in the last two years because it is easy to detect locomotion problem in small herds (1 to 5 cows) that they keep. This finding contrast those of Leach *et al*. (2010) in the UK that farmers do underestimate lameness prevalence in their herds. High prevelance of lameness despite high level of awareness found in smallholder farms reflects a general low health care by smallhoders (Leach *et al.,* 2010)

In this study, interests on lameness prevalence extended to identifying types of lameness that are more prevalent than the others between zero and pasture grazed dairy cows. Results showed that laminitis (43.1%) and digital dermatitis (32.1%) were more prevalent relative to white line disease (14.7%) or sole ulcers (10.1%), but their prevalence was not different between the zero and pasture grazed dairy cows. This study did not determine risks specific of the types lameness. Future studies can be designed to determine specific risk factors for each types of lameness. At present, farmers need to pay more attention to controlling laminitis and digital dermatitis lameness. High prevalence of laminitis and digital dermatitis lameness can be linked to hygiene conditions (manure and moisture) in the housing or night holding ground in day pasture grazed cows, in reference to finding of Holzhauer *et al.* (2006) and Relun *et al.* (2013). Evidence of this is muddy earth floor and wet beddings found significant risks for lameness in this study. The earth floor is often muddy in smallholder farms, which can expose cows to the risks of lameness. Some authors have associated laminitis with feeding high-quality pastures (Vermunt, 1992; Macky, 1994; Westwood and Lean, 2001), but in the sample farms pasture quality was generally poor. The prevalence of sole ulcer in this study (8.3 to 11.0%) was less than 26% estimated in the finding of Hedges, (2001); Manske *et al.* (2002) but the prevalence of white line disease (14.7%) compared to those reported by Relun *et al*. (2013); Newsome *et al*. (2017) for industrialised countries.

5.2. Risk factors for lameness

Both animal and herd level risk factors for lameness were examined in this study to test whether the risks were significantly different between the production systems. Earth floor was a risk for lameness for zero grazed than for pastured grazed cows. Earth floor is a common feature in zero-grazing housing units found in smallholder farms. The earth soils and manure accumulation where cleaning is not regular exposes cows to foot rots. Dry bedding instead of wet bedding, was a risk for lameness for zero grazed than for pastured grazed cows. This may be related to the dry earth floor already found significant risk for lameness as well as limited exercising that occurs in zero grazing units. The results contradicts those of Greenough, (2007); Sanders *et al.* (2009) who reported that wet conditions could increase spread of infectious bacteria, potentially invading the hoof to cause infection. Cook *et al.* (2008) as well have reported that dry bedding provides a comfortable bedding surface that affects the lying behaviors of lame cows, influencing their recovery and thus decreasing the risk of lameness. Furthermore, Relun *et al.* (2013); Holzhauer *et al*. (2006) found that access to pasture and wetness was associated with an increased risk of digital dermatitis which was the second highest lameness type in pasture grazing system in this study (36.1%).

Lameness was more prevalent among the small dairy breeds (27.5 - 46% for the Guernsey and Jersey) than the large dairy breeds (11.7 -16.7% for the Fiesian and Ayshire) and the prevalence among the small breeds was higher for zero grazed than for pastured grazed cows (46.0% vs 27.5%). This could be associated with the condition of housing provided by the farmers through bedding condition and concrete floor where cows stay for a period of time in that moist, muddy and hard floor, with less movement. This is in agreement with USDA, (2002) reported that dairy cows in North America are increasingly housed on concrete floors and this flooring surface has been associated with an increased incidence of lameness and hoof problems (Vokey *et al*., 2001; Somers *et al*., 2003). This was unexpected because heavier cows have greater pressure on the foot and they are heavier milkers (Sarjokari *et al*., 2013).

Though lactation stage and parity were not significant risk factors for lameness in this study, Bicalho *et al*. (2008); Barker *et al*. (2010) have reported that early lactation is a risk factor for lameness. Rowlands *et al*. (1985) reported that incidence of lameness in dairy cows is highest in the first 120 days in zero grazed and lowest in the last 3 months of lactation due to the stress of heavy milk yield. Lameness was more prevalent among older parity cows, but not significantly different between zero grazed and pasture grazd cows. In other studies, risk for lameness increases with advancing parity as reported by Sogstad *et al.* (2005) that most lameness are associated with third or higher parities. Other studies have reported constrasting results, for instance Smits *et al*. (1992) found that first parity cows were twice as seldom clinically lame than older cows.

5.3.Economic losses from lameness

Lameness causes pain, which distracts animals from feed intake subsequently resulting in drop in milk yield, sub optimal fertility, pre mature culling and expenditures on veterinary treatment. In this study, aggregate economic losses were substantially higher (51% more) in zero-grazing than in pasture grazing (KES 4,695.49 vs 3,109.41/farm/year). This can be attributed to more production losses, which were about twice (1.85) more in zero than in pasture grazing, where lameness cases were 3.2% fewer. Production loss was computed as a difference between production of healthy and lame cows, adapting the approach of Warnick *et al*. (2001) of comparing milk loss before and after lameness. Included in production loss were milk loss through drop and withdrawal during antibiotic treatment and cost of pre mature culling . A larger proportion of the aggregate economic loss was due to production losses (56-68%). Some authors have observed a drop in milk yield and pre mature culling associated with lameness (Warnick *et al*. 2001; Green *et al*. 2002). Warnick *et al*. (2001); Green *et al*. (2002) reported a reduction in milk yield attributable to clinical lameness, but the losses were not significantly different between pasture and zero grazing, which departs from the present findings. Higher economic losses in zero grazing than in pasture grazing in the present study may have resulted from differences in severity of claw and hoof lesions (Penev, 2011; Penev *et al*., 2012). Weaver *et al*. (2005) aportioned financial loss from lameness to drop in milk yields (25%), death or preliminary culling (13%), additional labor costs (13%) and veterinary costs (8%).

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The results of this study show that:

i. Lameness prevalence is not different between zero- and pasture grazed cows. The observed prevalence closely marched the estimates by farmers with a strong positive and significant correlation.
ii. Four types of lameness were prevalent in the order: laminitis, digital dermatitis, white line disease and sole ulcer, but their prevalence did not differ between the grazing systems.
iii. Risk factors for lameness was high for cows on earth floor, small breeds and dry floor among the zero than the pasture grazed cows.
iv. Economic loss was 51% higher in zero-grazing than in pasture grazing, with a larger proportion attributable to production losses and veterinary costs. Production losses more in zero-grazing but veterinary costs lower in zero-grazing.

6.2. Recommedations

i. Results indicated that farmers are aware of the lameness problem in their dairy herds, but routine claw and hoof care is evidenced by high prevalence of over 20%. Training should therefore focus on skills upgrading on routine care of claw and hoof lessons.
ii. Laminitis and digital dermatitis were more prevalent lameness, but their specific risks were not identified. Further studies can investigate the risks for different types of lameness in smallholder farms.
iii. Most of the risk for lameness were herd level risks rather than animal levl risks. Improved routine herd management aspects can thus reduce incidences of lameness.
iv. A larger proportion of the economic loss from lameness could be attributed to production loss and veterinary costs. Because improved routine herd management aspects can reduce incidences of lameness, their adoption will be relevant for reducing economic losses associated with lameness.

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APPENDIX A
EGERTON UNIVERSITY

DEPARTMENT OF ANIMAL SCIENCE

Research on comparing Prevalence, Risk Factors and Economic Losses of Lameness Respondent Consent

This survey is conducted by a post graduate student of Egerton University in the Department of Animal Sciences in partial fulfillment for a Master of Science Degree in Livestock Production Systems. The information provided will be used for academic purposes only and will be treated with ultimate confidentiality.

Please declare your consent {Yes/ No }

Date--------------------------------------- **Questionnaires no-------------------------**

Enumerators name---------------------------------- **Tel no---------------------------**

SECTION A: Farm information

Farm owner(full name)	Production system	Location	Sub county/division	Telephone number

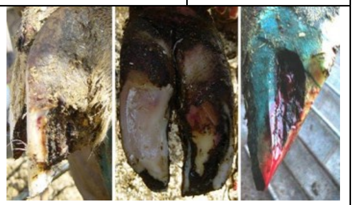
B1/ Farmer perception of lamenessin the herd

Is lamenessbeena problem in your herd in the last three years? Yes=1; 2=No [ ]

Estimate the proportion (%) of lame cows in your herd in the last two years [ ]

B/Lameness prevalence

Please observe and record lameness condition and types for each cow in the farm

Animal no	1	2	3	4	5	6	7	8
Lameness condition 1=Yes; 0=No								
Type of lameness								
1=Digital Dermatitis 2= Laminitis 3=Sole ulcer 4=White line disease	 1.Digital dermatitis		 2.Laminitis		 3.Sole ulcer		 4.White line disease	

C1 /Cow level risk factors

From observation of the individual cows, please indicate their risk status for each in the farm

Animal level risk factors	1	2	3	4	5	6	7	8	9	10
Breed(1=Friesian- 2 =Others –specify)										
Reproductive status(1=lactating, 2= not lactating										
Stage of lactation (level) 1= Early/middle (5month), 2= Late (6-9months)										
Parity (number)										

C2/ Herd level risk factors

From observation of the farm and herd, please indicate for each cow as is relevant their risk status for lameness

Herd level risk factors	1	2	3	4	5	6	7	8	9	10
Housing confinement										
Floor type										
Bedding condition										
Feeding space										
Maize Silage										

Key:

Housing[confinement	**Floor type**	**Beeding condition**	**Feeding space**	**Silage feed**
1=Confinement 2=Occ/notconfinement	1=Concrete 2=Earth	1=Dry 2=Wet	1=Adequate 2=Not adequate	1=Yes 2=No

D2/Economic losses

L = the cost of lameness in terms of the value of the loss in expected output due to lameness, R = increase in expenditure on non-veterinary resources due to lameness, T = the cost of inputs used to treat lameness, P = the cost of disease prevention measures.

Cost	**Source of loss**	**Units**	**Lame cow**	**Not lame**	**Compute**
Veterinary costs	Drugs treatment costs per cow	KES per cow			
	Consultation fee cost per cow	KES per cow			
Disease control	Foothbath (chemical)	KES per cow			
	Trimming	KES per cow			
Production loss	Drop in milk yield	days *milk price			
	Abortion	(days*milk*price			
	Milk withdrawal	Days * milk price			
	Premature culling	Cost of cow			
	Mortality	Cases probability			
Additional cost	Labour hire	KES/cow/day			
	Replacement of any	KES /cow			
	Reporting	Air time cost			

APPENDIX B

Association between risk factors and grazing systems

Parameter	DF	Estimate	Error	Chi-Square	Pr > ChiSq
Intercept	1	-1.5580	0.1499	107.9671	<.0001
grazing pasture	1	-0.2409	0.1248	3.7262	0.0536
bedding dry	1	-0.4605	0.1416	10.5758	0.0011

Parameter	DF	Estimate	Error	Chi-Square	Pr > ChiSq
Intercept	1	-1.2221	0.1220	100.3507	<.0001
grazing pasture	1	-0.3354	0.1315	6.5019	0.0108
breed Friesian	1	-0.6731	0.1217	30.5827	<.0001

Parameter	DF	Estimate	Error	Chi-Square	Pr > ChiSq
Intercept	1	-1.5672	0.1334	137.9487	<.0001
grazing pasture	1	-0.6125	0.1453	17.7571	<.0001
floor concrete	1	-0.8139	0.1432	32.3023	<.0001

Parameter	DF	Estimate	Error	Chi-Square	Pr > ChiSq
Intercept	1	7.4176	77.1962	0.0092	0.9235
grazing pasture	1	8.4248	77.1962	0.0119	0.9131
feeding adequate	1	-0.6394	0.1408	20.6384	<.0001

Parameter	DF	Estimate	Error	Chi-Square	Pr > ChiSq
Intercept	1	-1.4193	0.1414	100.7738	<.0001
grazing pasture	1	-0.0898	0.1174	0.5861	0.4439
reproductive lactatio	1	0.2437	0.1346	3.2782	0.07

Parameter		DF	Estimate	Error	Chi-Square	Pr > ChiSq
Intercept		1	-1.5834	0.2054	59.4520	<.0001
grazing	pasture	1	-0.1756	0.1358	1.6720	0.1960
stageoflact	early	1	0.5462	0.1992	7.5154	0.0061

Parameter		DF	Estimate	Error	Chi-Square	Pr > ChiSq
Intercept		1	-1.4223	0.1231	133.4906	<.0001
grazing	pasture	1	0.0611	0.1221	0.2506	0.6166
parity	0-2	1	-0.4539	0.1184	14.6910	0.000

Pearson Correlation Coefficients

	prodsyst	lameprob	lamcond
lameprob	0.01738 0.7026	1.00000	0.95860 <.0001
lamcond	0.01956 0.6674	0.95860 <.0001	1.00000

Correlation Coefficients

	zero	pasture	lameprob	lamcond
zero	1.00000	-0.02608 0.6865	-0.03157 0.6251	0.99131 <.0001
pasture	-0.02608 0.6865	1.00000	0.95260 <.0001	-0.03163 0.6244
lameprob	-0.03157 0.6251	0.95260 <.0001	1.00000	-0.03692 0.5676
lamcond	0.99131 <.0001	-0.03163 0.6244	-0.03692 0.5676	1.00000

Type of lameness

		type of lameness					Total
		no case	dd	laminitis	soleulcer	whitelinedise ase	
production system	zero	244	22	32	8	11	317
	pasture	113	11	7	1	2	134
	semizero	21	2	8	2	1	34
Total		378	35	47	11	14	485

APPENDIX C
RESEARCH AUTHORIZATION

NACOSTI

NATIONAL COMMISSION FORSCIENCE, TECHNOLOGY ANDINNOVATION

Telephone +254-20-221[illegible]471, [illegible]349,310571,[illegible]
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Ref No **NACOSTI/P/17/52335/20079**

Date **24th November, 2017**

Darboe Momodou
Egerton University
P.O. Box 536-20115
EGERTON.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Quantifying cow-lameness prevalence, risk factors and economic losses in smallholder dairy herds in Nakuru County, Kenya,"*** I am pleased to inform you that you have been authorized to undertake research in **Nakuru County** for the period ending **24th November, 2018.**

You are advised to report to **the County Commissioner and the County Director of Education, Nakuru County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

G P Kalerwa

GODFREY P. KALERWA MSc., MBA, MKIM
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Nakuru County.

The County Director of Education
Nakuru County.