LOCOMOTION SCORES AND THEIR ASSOCIATED FACTORS IN DAIRY COWS WITHIN THE SMALLHOLDER ZERO-GRAZING UNITS IN KIKUYU DISTRICT, KIAMBU COUNTY, KENYA

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DECLARATION

This thesis is my original work and has not been presented for award of a degree in any other university

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DEDICATION

TO

My father Samuel Keter, mother Margaret Keter, brothers Musa, Reuben, sisters Susan, Ruth, Irene, Nephews Clinton, Lawi, Reu and the love of my heart Lilian

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ABSTRACT

The designs and management practices in the smallholder zero-grazing dairy units in Kenya vary greatly between and within the dairy units. These variations serve as part of the risk factors for occurrence of claw disorders in the zero-grazed dairy cows. Early diagnosis of claw disorders is paramount for providing prompt corrective measures before irreversible claw damage occurs. Locomotion scoring systems have been employed as reliable method of making early diagnosis of cattle lameness. However, locomotion scores have not been evaluated in dairy cows reared under such varied smallholder zero-grazing factors. With this background, a study was designed for smallholder zero-grazing dairy units in Kikuyu district, Kiambu county, Kenya, to achieve the following objectives: 1. to evaluate farmers' knowledge, perspective and practice of claw trimming and how these are associated with locomotion scores of dairy cows, 2. to determine the dimensions, conformation and disorders of claws and how these are associated with locomotion scores of dairy cows, 3. to determine floor characteristics and slurry management in the smallholder zero-grazing units and how these factors influence locomotion scores of dairy cows. It was a cross-sectional study carried out in 100 purposively selected smallholder zero-grazing dairy units from which 161 dairy cows were selected and each examined. Each cow was evaluated and examined once for locomotion scores and claw disorders respectively, during the visits. The 5-score scale locomotion scoring system was used, which is based on back posture and limb placement was employed. Some of the data collected through visual observation and physical examination. They included: measurements of claw dimensions such as claw angle, toe length, heel height, claw height, claw diagonal, claw width and sole length. Presence or absence of claw disorders as well as floor characteristics were likewise evaluated by visual observation.

Other data were collected using structured questionnaire and these included lactation stage, parity, slurry removal, farmer awareness and perspective on claw trimming as well as whether or not claw trimming is done. Locomotion scores were determined by walking the cows within the unit and making observations. All data were recorded in data collection sheets. Data analysis included descriptive statistics and simple associations between variables and outcome using chi-square and simple one-way analysis of variance at $p< 0.05$ significance level.

The results indicated 94% of the farmers were aware of claw trimming, but cows were trimmed in only 43% of the units. The average locomotion score was 1.3 among the 161 zero-grazed dairy cows examined, which means they had either normal gait or mild lameness. Locomotion score was strongly associated with toe length [(F (2, 158) =11.77, $p < 0.0001$)] and the claw angle [(F (2, 158) =5.41, $p = 0.0054$)]. The claw disorders that had strong association with locomotion scores included corkscrew claws (O.R.=1.3, $\chi^2 = 35.43$, $p < 0.0001$), underrun (double) soles (O.R.=1.1, $\chi^2 = 33.67$, $p < 0.0001$), White line separation (O.R.=1.1, $\chi^2 = 24.23$, $p < 0.0001$), overgrown claws (O.R.=1.1, $\chi^2 = 10.90$, $p = 0.0043$), traumatic pododermititis (O.R.=1.7, $\chi^2 = 9.3758$, $p = 0.0092$) and horizontal hoof wall cracks (O.R.=1.2, $\chi^2 = 9.29$, $p = 0.0096$). The claw lesion weakly associated with locomotion scores was sole ulcer (O.R.=1.1, $\chi^2 = 5.9931$, $p = 0.0490$). The animal-level factors that had significant association with locomotion scores were breed of the cow (O.R.=1.2, $\chi^2 = 18.55$, $p = 0.0026$), parity (O.R.=1.2, $\chi^2 = 14.20$, $p = 0.0060$) and lactation stage (O.R.=1.1, $\chi^2 = 10.84$, $p = 0.0367$). Type of floor was found to significantly (O.R.=1.5, $\chi^2 = 40.47$, $p = 0.0016$) influence locomotion score, with higher locomotion score recorded in cows on extremely smooth concrete floors. Frequency of claw trimming was the only factor on claw trimming practice that was associated (O.R. = 1.30, $\chi^2 = 30.21$, $p = 0.0112$) with locomotion scores. By using locomotion scores the study concludes that dairy cows in the smallholder zero-grazing units are either not lame or mildly lame. However, observationally the claw disorders and lesions looked more severe than the corresponding locomotion scores. This leads to further conclusion that, observational locomotion scoring system may not be highly sensitive under the designs and floor types found in these smallholder zero-grazing dairy units. Further research on evaluation of sensitivity and validity of using locomotion-scoring systems for diagnosis of lameness under the varied smallholder zero-grazing dairy units in Kenya needs to be carried out. In addition, training of farmers on proper management of factors that predispose zero-grazed dairy cows to lameness is pertinent.

CHAPTER ONE

1.0 INTRODUCTION

1.1 General Background

Kenya has over 3.3 million dairy cattle (KNBS, 2012). Smallholder dairy units contribute over 70% of the total milk production in Kenya and provide subsistence for more than 600,000 low-income households (Republic of Kenya, 2008). These smallholder zero-grazing dairy units in Kenya vary in their designs and management practices. The management practices at times vary even within the same unit. These variations designs and management practices predispose dairy cows to likelihood of occurrence of lameness especially from claw disorders (Nguhiu-Mwangi *et al.*, 2008a; Nguhiu-Mwangi *et al.*, 2012). The large-scale dairy farms are fewer and are owned by few financially able individual families, private farms and public institutions.

Lameness in dairy cows continues to be a major cause of economic losses in dairy production industry all over the world (Kossaibati and Esslemont, 1997; DEFRA, 2003; Hernandez *et al.*, 2005). Lameness causes economic losses through lowered milk yield (Hernandez *et al.*, 2005), reduced reproductive performance (Sogstad *et al.*,2006), high culling rates, discarded milk due to withdrawal period for antibiotics used for lameness treatment and the additional time and labor required to care for lame cows (Shearer and Van Amstel, 2000). Lameness also contributes to financial losses due to payment for veterinary services and cost of drugs as well as loss of body condition due to its negative impact on nutrition and feeding behaviour (Huxley, 2013). Apart from economic effects, lameness compromises animal welfare because of the ensuing discomfort and pain, which make affected cattle unable to cope with their environment (Offer *et al.*, 2000;

Somers *et al*., 2003) and significantly change their social ranking, feed intake, sexual activity, productive traits and longevity (Hassall *et al*., 1993).

Claw disorders and lesions cause about 60% to 90% of all lameness in cattle (Sogstad *et al*., 2006; Nguhiu-Mwangi *et al*., 2008a). Some claw lesions are clinical, thus manifest through lameness while others are subclinical hence only recognized when exposed by hoof trimming. Cattle under zero-grazed units are more predisposed to claw conditions as a result of housing factors, nutritional, environmental and management stresses (Evgenij and Christer, 2005; Nguhiu-Mwangi *et al*., 2008a; Christoph, 2009). Moreover, zero-grazed cattle spend most of their time standing in small confined spaces in which their claws are exposed to excessive moisture from accumulated slurry and if the floor is concrete, pressure stress under the weight of the animal exacerbates development of claw lesions (Evgenij and Christer, 2005; Nguhiu-Mwangi *et al*., 2008a).

Structure and functional integrity of the horn of the claw is the foremost single requirement for maintaining claw health in dairy cows. Hence, any factor that weakens the horn or alters its conformation is likely to predispose the animal to conditions that lead to lameness (Christoph, 2009; Telezhenko *et al.*, 2009). The factors that affect claw health in the Kenyan smallholder dairy units are animal-and farm-based such as housing design, floor type, slurry accumulation, as well as nutrition and management factors (Nguhiu-Mwangi *et al*., 2008a).

The non-infective claw conditions especially those associated with laminitis are insidious, subtle and difficult to recognize early enough. These conditions manifest clinically at the phase when irreversible damage in the claw may already have initiated (Nocek, 1997; Belge and Bakir, 2005;

Nguhiu-Mwangi, *et al*., 2007). It is therefore necessary to make early diagnosis for prompt remedial treatment and management measures to be undertaken before extreme damage sets in.

One method that has been employed to make early diagnosis of lameness in cattle is locomotion or lameness scoring systems (Sprecher *et al*., 1997; Whay *et al.*, 1997). The first and most used locomotion scoring systems are observational, but have limitations of being subjective since they may vary with the observer (Sprecher *et al*., 1997). More recently, computer-based and automated locomotion scoring systems have been developed (Rajkondawar *et al*., 2002; Tasch and Rajkondawar, 2004; Pastell and Kujala, 2007, Pastell *et al*., 2008). However, the applicability of these latter locomotion scoring systems is a major challenge for the common farming systems owing to costs of the equipment and the skills required for its operation. The observational locomotion scoring systems require that cattle be evaluated as they walk on flat unyielding ground. Thus, ground floor type is an important factor in hoof health.

1.2 Justification for the study

Locomotion scoring is a means of not only making early detection of lameness but can also be used to track the effect of management, environmental factors and nutritional changes on incidence and severity of lameness (Socha *et al*., 2002). Application of locomotion scoring to make early diagnosis of lameness and the influence of associated factors has not been evaluated in smallholder zero-grazed dairy cattle in any part of the world. Therefore, this study evaluated floor types and animal-level factors that may be associated with locomotion scores of dairy cows in the smallholder zero-grazing dairy units in Kikuyu district, Kiambu county, Kenya. It was also necessary to evaluate the farmer knowledge on claw trimming, its practice in the smallholder zero-grazing dairy units and how these factors are associated with locomotion scores of the dairy cows raised in these units.

The results of this study will be disseminated to the smallholder dairy farmers with the aim of helping them improve the foot care of their dairy cows. This will guard against subsequent economic losses for the smallholder dairy enterprises and minimize animal suffering that would result into development of lameness, hence improve welfare of dairy cows.

1.3 Objectives of the Study

The study was carried out to achieve the following objectives:

1. To evaluate farmers' knowledge and perspective on claw trimming in dairy cows, claw trimming practice and how these factors are associated with the locomotion scores in the smallholder zero-grazing dairy units in Kikuyu district, Kiambu County, Kenya.

2. To determine dimensions, conformation and disorders of the claws and their possible association with locomotion scores in dairy cows in the smallholder zero-grazing dairy units in Kikuyu district, Kiambu County, Kenya.

3. To evaluate floor characteristics and slurry management and their association with locomotion scores in zero-grazed dairy cows in the smallholder units in Kikuyu district, Kiambu County, Kenya.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Economic importance of lameness in cattle

Lameness is a clinical manifestation of pain and discomfort involving the limb, caused by several conditions and ultimately impairs movement (Blowey *et al.*, 2004). The inability to walk could either be the effect of voluntary or involuntary response of the animal in an attempt to reduce the level of discomfort and pain resulting from injured or dysfunctional limb structures. Lameness is one of the greatest constraints to productivity, health and welfare of dairy cattle. Economic losses are incurred through several processes such as reduced milk yield resulting from scanty feeding due to pain and discomfort, discarded milk during treatment of lameness with antibiotics and increased risk of mastitis since the cow lies down most of the time. Other reasons for economic losses in lameness includes reduced reproductive performance through increased open days and inability to manifest signs of oestrus, high culling rate, loss of body condition, as well as extra time and labour required to manage the lame cows (Green *et al.*, 2002; Weaver *et al.*, 2005; Bicalho *et al.*, 2008; Alawneh *et al.*, 2011)

2.2 Functional Anatomy and dimensions of the claw

The foot begins from the fetlock to the distal end of the limb. It is divided into lateral (outer) and medial (inner) digits whose ends which are covered by the horn capsules are termed claws or hooves. Between the digits is the interdigital skin. Each digit is composed of the long pastern bone (proximal phalanx or P1), the short pastern bone (middle phalanx or P2) and the pedal bone (distal phalanx, coffin bone or P3). Caudal to the distal phalanx lies the navicular bone (distal sessamoid bone). The proximal and middle phalanges are outside the horn capsule but the distal phalanx and navicular bones are inside the horn capsule. The two joints in the foot are the proximal interphalangeal (pastern) joint and the distal interphalangeal (pedal) joint (Fig. 1). The deep flexor tendon is attached to the distal phalanx and the superficial flexor tendon is more proximal, but both are on the caudal aspect of the foot (Beteg *et al.*, 2007).

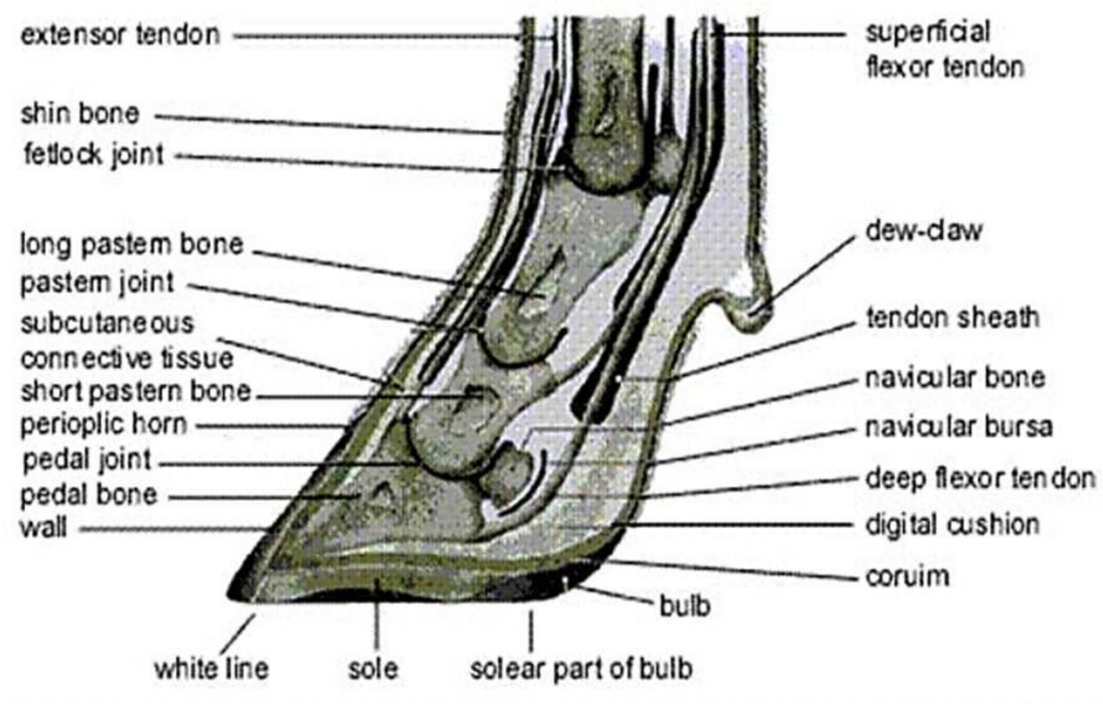

Figure 1: Schematic diagrams of the bovine digit viewed from the lateral mid-line section aspect, showing bones and joints and the horn capsule, (Adapted from Lameness in dairy cows by Three Rivers Vets, 2014).

The claw comprises of the sole, heel bulb and walls, which consist of axial, abaxial and dorsal wall surfaces. The junction between the sole and the walls of the claw is the white line, which is the weakest and fibrous connection of the horn capsule. Coronary band (coronet) is the junction between the proximal rim of the horn capsule and the skin. The proximal interface between the hard part of the horn capsule and the coronary band is a soft, shiny portion of the horn capsule known as the periople, which holds the moisture of the hoof. The horn capsule is the epidermis of the claw. The corium, which is the dermis of the claw lies between the horn capsule and the distal phalanx. It has the horn-secreting cells and contains blood vessels and nerves. New horn is produced continuously and gradually grows towards the surface of the claw. Eventually the new horn is keratinized to become hard capsule. Underlying the heel bulb is the digital cushion, which is the subcutaneous tissue of the claw (Jo Speed, 2010). The digital cushion has two functions: 1) to cushion the corium from pressure exerted by the pedal bone when the cow walks, and 2) to pump blood back up the leg when the cow walks (Beteg *et al.*, 2007).

The normal hoof wall has superficially visible lines (rugae) or growth rings running horizontally on it. These growth rings slope slightly toward the heel indicating that the heel wears faster than the toe. The hardest part of the claw is the abaxial wall, followed by the sole while the heel bulb is softer than the sole and the softest is the white line. When the corium is damaged, it cannot produce healthy horn and hence it may predispose the claw to conditions that cause lameness. Therefore, when a cow has healthy corium it means the claws are likely to be healthy but diseased corium means the horn is also likely to have disorders (Telezhenko, 2009). The commonest causes of lameness in dairy cows are predisposed by damaged corium. The periople corium forms the perioplic horn and the new horn of the heel bulb. The coronary corium produces new horn to the wall of the hoof, which grows downward from the coronary band at about 5 mm per month. The laminar corium produces the laminar horn that attaches the abaxial, dorsal and a small part of the axial wall to the pedal bone. Therefore, the pedal bone is firmly attached and suspended inside the normal hoof. The laminar corium also produces most of the white line. The solear corium produces the solear horn (Beteg *et al.*, 2007).

The dimensions that represent the shape and conformation of the claw have been described by Vermunt and Greenough (1995) as shown on Fig. 1 below. Toe angle is at the junction of the dorsal wall and the sole, claw length is from the coronet to the end of the toe along the dorsal wall, the claw height is from the cranial most point of the coronet to the sole perpendicularly. The heel height is from the highest point of the heel perpendicularly to the level of the sole, claw diagonal is from distal end of the dorsal wall (tip of the toe) to the highest point of the heel, and the claw width is transverse at the widest part of the sole.

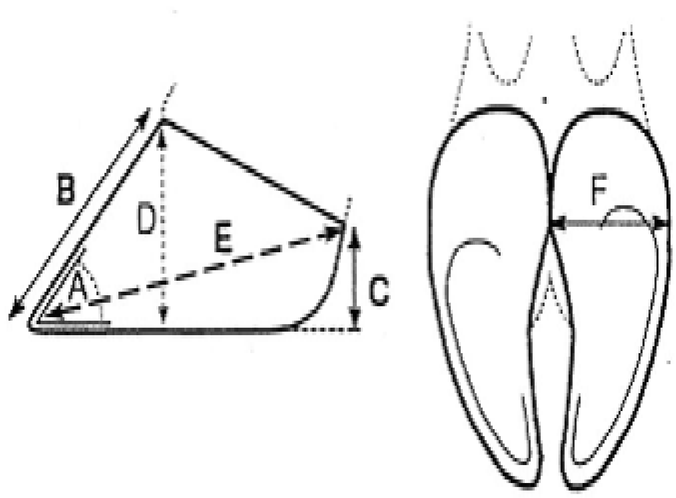

Figure 1. The names of various claw dimensions measured used to describe claw shape and conformation. A = claw angle; B = toe length; C= heel height; D = claw height; E = diagonal; F = claw width. (Adapted from Vermunt and Greenough, 1995)

2.3 Locomotion Scoring Systems

Locomotion scoring is done for assessment of the gait of cattle in an attempt to make early diagnosis of lameness or in locomotion research. It requires keen observation and experience particularly in early stages of lameness when symptoms are not obvious. There are subjective and objective locomotion or lameness scoring systems.

2.3.1 Subjective locomotion scoring systems

Subjective locomotion scoring systems are observational. The initial locomotion scoring system included a nine-point score that describe minor locomotion changes (Manson and Leaver, 1988). Later, four or five-point locomotion score systems were described (Sprecher *et al*., 1997; Whay *et al*., 1997; Juarez *et al*., 2003; Amory *et al*., 2006). The most reliable and frequently employed locomotion scoring system was described by Sprecher *et al*., (1997). This locomotion scoring system is based on the observation of back posture which can be either flat or arched when the cow is standing and when walking. The scoring is made on a 5-point locomotion score system. The assessment of locomotion is done on a flat, non-yielding and non-slippery ground. However, it is subjective because individuals may differ in their observations and in their conclusions depending on experience.

2.3.2 Objective locomotion scoring systems

The objective locomotion scoring systems are quantitatively assessed and more accurate compared to the subjective systems (Keegan *et al*., 1998). They are automated computerized systems with quantitative numerical values corresponding to the type of gait of the cow (Tasch and Rajkondawar, 2004; Pastell *et al.*, 2008). Other researchers have developed kinematic gait assessment systems that are reliable (Clayton and Schamhardt, 2001).

Kinematic gait assessment systems describe the geometry of animal movement, the force applied to the body, body mass distribution as well as dimensions and changes in the position of body parts during specified locomotion time. Kinematic locomotion studies have been carried out using chronophotography, videographic or optoelectronic systems consisting of integrated hardware and software components as well as electromechanical film which can detect only dynamic forces (Clayton and Schamhardt, 2001; Pastell *et al*., 2008). Although these objective methods are more reliable and sensitive, their practical and clinical application is limited by cost and applicability of the equipment in dairy farming.

2.4 Factors influencing locomotion in cattle

2.4.1 Claw and limb conformation

The shape of the claw may be influenced by both heritable and acquired characteristics. The shape of the claw is largely determined by the changes that occur on the horn capsule. These changes are influenced by animal-level and farm-level factors, particularly the housing factors (Nocek, 1997). The toe angle for a normal claw should be 45^0 to 55^0 but in a claw with abnormal conformation and those with disorders, toe angle can be as low as 35^0 (DEFRA, 2003).

The "hock angle" is critical for the gait of cattle and is always assessed from side view. The optimal angle at the hocks should measure 150^0 to 155^0. When the angle is bigger than optimal, the hocks are too straight, and when the angle is lower than optimal, the hind limb becomes sickled. The hock position is assessed from the rear in relation to a line from the hocks to the cleft of the claw. In normal hock position, these lines will be parallel to each other. When the hocks are close to each other, the toes of the claws are abducted. Normal conformation of the limb and the claws allows for even weight distribution between the limbs and between the claws, but uneven distribution occurs with poor conformation (Fig. 2).

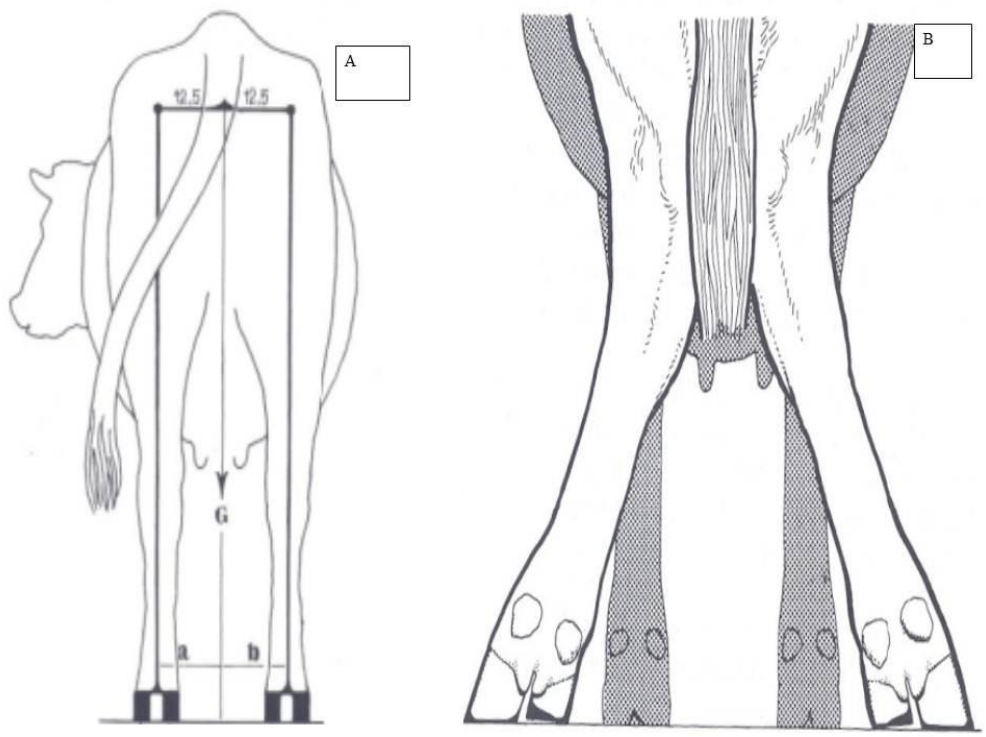

Figure 2: Different hind limbs conformation. **A**: represents normal hind limb conformation that has even weight distribution on the claws. **B**: represents abnormal conformation with uneven weight distribution on the claws. The picture is adapted from Brahman News Issue 170 (2011)

2.4.2 Claw trimming

When cows spend long hours standing on confined hard concrete floors, claws are exposed to higher pressures that predispose them to excessive local loading which trigger accelerated horn production subsequently enlarging the claws (van der Tol *et al*., 2003). The outer claws of the hind limbs are relatively more loaded and enlarged than the inner claws (Mülling *et al*., 2006).

Horn production is counter-balanced by regular claw trimming (Nacambo *et al*., 2004; Mülling *et al*., 2006). Functional claw trimming is performed to restore natural claw conformation that provides proper anatomical weight distribution between the claws. However, unskilled claw trimming could over-shorten the walls and cause excessive thinning of the sole, leading to lameness (Blowey, 2002). These problems can be avoided by trimming to redirect pressure on the abaxial claw walls which are the strongest parts of the claw (van der Tol *et al*., 2004). It has been shown that trimming of the claws reduces development of some claw conditions as well as incidence and degree of lameness in cattle (Manske, 2002). However, trimming the claws twice rather than once per year may increase the incidence of lameness conditions (Barker *et al*., 2007).

There are two basic types of hoof trimming methods: subjective and objective. The Dutch and White Line Methods are subjective methods in which determination of normal sole thickness from anterior to posterior part is based on using average values of dorsal wall length and heel height. In the hind feet, the medial claw is used as a guide for how much the lateral claw should be trimmed (Blowey *et al.*, 2004). These methods are subjective because the average values cannot adequately address the problem of individual claw variations.

The Kansas Method is an objective method in which determination of normal sole thickness is based on trimming-off the physical overgrown horn of the sole. The sole is trimmed until the overgrown horn of the sole is seemingly shed-off or just short of disappearance. This is an objective way to gauge if the sole has been returned to its normal thickness. This method can be used to return the overgrown bovine hoof to normal (Ladd and Eureka, 2005).

2.4.3 Floor type

Solid unyielding floors such as concrete may on one hand stimulate claw horn overgrowth thereby creating unbalanced weight bearing between the claws and on other hand it may cause abrasiveness that leads to excessive wear of the horn of the sole resulting in thin soles that predispose claws to ease of occurrence of lesions on the weight-bearing surface (Telezhenko, 2009). When the concrete is wet, the horn of the sole becomes softer resulting in increased sole abrasion, thereby enhancing rate of wear and consequently predisposing the claws to ease of lesion development and penetration by foreign bodies. This softening of the horn of the sole allows ground pressure against the weight of the cow to easily reach and damage the corium (Van der Tol *et al*., 2004). Floors with more friction provide cows with better ground grip that improves locomotion (Rushen and de Passille, 2006; Flower *et al*., 2007). However, when provided with hard ground and soft ground, cows prefer the soft to hard ground for standing and walking on (Telezhenko *et al*., 2007). Locomotion studies in dairy cows have been done on good standardized solid concrete, slatted concrete and rubber floors (Fjeldaas *et al*., 2011).

2.4.4 Slurry accumulation

Slurry quickly accumulates on the floor of the dairy cow unit. Its main effect on the claws is softening of the horn, which makes it easily penetrated by foreign objects. Softened horn of the sole allows the ground pressure to also penetrate easily thus causing a damaging effect on the underlying corium (Borderas *et al*., 2004; Nguhiu-Mwangi *et al*., 2008a; Jo Speed, 2010). Slurry also damages the intercellular matrix of the claw horn, thus reducing its health and integrity. Due to the softening effect on the horn of the claw, slurry enhances sole bruising and its unhygienic nature provides an environment for growth and transmission of bacteria that are likely to invade the claw particularly the heel (Nguhiu-Mwangi *et al*., 2008a; Jo Speed, 2010). To maintain optimal claw health, slurry must be removed frequently and the floor in the cow unit must have adequate slope gradient to allow drainage of water and urine (DEFRA, 2003).

2.4.5 Nutrition

Feeding and nutrition of the dairy cow are primary areas of interest when attempting to reduce lameness problems. Laminitis and various claw disorders share a close relationship with metabolic disease disorders, which are often linked to nutrition and/or feeding of dairy cows (Shearer and Van Amstel, 2000). Nutrition has a role in predisposing the occurrence of non-infective claw disorders that involve the horn capsule.

Feeding of cows with rations high in non-structural carbohydrates results in lowered pH of the rumen. This changes the population of rumen micro-flora from predominantly gram negative to predominantly gram-positive lactic acid producing bacteria. The death of gram-negative bacteria releases endotoxins from their cell walls. Acid-damaged rumen mucosa enhances absorption of lactic acid and, endotoxins, which further trigger release of vasoactive agents such as histamine, serotonin and bradykinin into blood circulation. These products through alternate vasoconstriction and vasodilation disrupt effective blood flow to the corium, thus interfering with horn production and hence predisposing to development of claw disorders (Nocek, 1997; Shearer and Van Amstel, 2000; Belge and Bakir, 2005).

One of the macro-minerals of greatest interest relative to claw horn integrity is calcium. The differentiation of keratinocytes in claw horn epithelium requires Calcium for proper function of enzymes in biochemical pathways that ultimately result in proper keratinization of horn cells (Nocek, 1997). Any deficiency that may occur, such as hypocalcaemia during the peripartum period, would have the potential to negatively influence on the normal maturation of keratinocytes and thus affect the integrity of the horn produced during this period (Mulling *et al*., 2006). The trace minerals zinc and copper play important roles in the process of keratinization.

The occasional feeding of concentrates, minerals and vitamins or their total absence from the dairy cows in the Kenyan smallholder dairy zero-grazing units may have a role in influencing the occurrence of lameness (Nguhiu-Mwangi *et al*., 2008a).

2.5 Common claw horn disorders in cattle

Laminitis is diffuse aseptic inflammation of the corium of the claw. It is mainly caused by interference with microcirculation of the corium, which leads to hypoxia and diminished nutrient supply that subsequently compromises horn production (Bergsten, 2003). Mechanical stretching of the attachment between the inner and outer laminar structures of the claw wall brought about by laminitis may cause the distal phalanx to rotate and sink inside the horn capsule. Depending on severity of laminitis, irreversible changes could ensue (Bergsten, 2003). Laminitis can be acute, chronic or subclinical. Acute laminitis is a rare occurrence and is usually due to a single, gross metabolic insult such as grain overload or diseases such as acute metritis or mastitis. It develops rapidly and causes severe signs of acute pain, but does not produce lesions that are visible in the hoof (Berry *et al.,* 2010). Subclinical laminitis is believed to be caused by several factors, with lesions first visible about six to eight weeks after distinct insults while chronic laminitis develops from continuous or repeated insults that cause lesions which may affect the shape and function of the feet and eventually locomotion (Berry *et al.,* 2010). Ossent and Lischer (1998) examined claws at post mortem in cattle with clinical laminitis and found a range of lesions that included; impaired horn production with diffuse softening, discoloration and hemorrhages in the horn of the sole, heel and white line, development of double soles, heels and walls with white line fissures and eventually sole, toe and heel ulcers. In chronic cases, the whole claw becomes deformed.

Claw overgrowth is one of the common disorders that lead to discomfort in cows when walking (Blowey *et al.*, 2004). It is a natural consequence of feeding and housing conditions common in intensive dairy production. Overgrowth is manifested primarily by elongation of the toes. The horn of the wall is harder and the rate of wear is less at the toe. In contrast, horn of the heel is softer and the rate of wear is faster than other parts. The result is a lengthening and curving of the toe upwards with a corresponding lowering of the heel (Shearer and Van Amstel, 2000). This leads to an elevation of the toe, rotating the claw backwards. The angle of the anterior wall changes from a normal of 45º to a lowered slope of 30º and this applies additional weight on the heel. Cows with overgrown claws have poorer gait and walk with significant discomfort compared to well-trimmed animals. The effect of hoof overgrowth is overloading and instability (Shearer and Van Amstel, 2000).

Sole ulcer is an opening through the horn of the sole that exposes the corium. The typical site is the rear middle part of the sole, which corresponds to the flexor process of the pedal bone. The prognosis for sole ulcers depends on the damage to the horn-producing tissue that determines the length of regeneration of the horn to cover the defect on the horn. The primary cause of a sole ulcer is a pinching of the corium between the flexor tuberosity of the pedal bone above and the hard horn of the sole beneath, which causes bleeding and weakening of the horn. Compression and damage to the corium can be so severe that horn formation is completely disrupted, leading to complete breakage through the horn of the sole with subsequent corium protrusion (Blowey and Nazhvani, 2007).

Cracks or fissures in the hoof wall are also common in cattle. Those which run in a vertical direction (from the coronet towards the weight-bearing surface) are referred to as vertical wall cracks or sandcracks, while those that run in a horizontal direction (parallel to the coronet) are referred to as horizontal wall cracks. It is believed that trauma, dehydration, laminitis, or vitamin and/or trace mineral deficiencies may be contributors to occurrence of fissures in many herds (Shearer and Van Amstel, 2000). These claw horn disorders manifest with pain and hence lameness.

Interdigital necrobacillosis is the commonest occurring infective condition. The bacteria most commonly isolated from this infection are *Fusobacterium necrophorum* acting in synergy with *Porphyromonas levii* (Berg and Franklin, 2000). The primary signs are fissures and caseous necrosis of the interdigital skin and diffuse and symmetrical digital swelling. Pain usually causes moderate to severe lameness. A characteristic, fetid odor is present due to presence of *Fusobacterium necrophorum*. A possible sequel of interdigital necrobacillosis is deep digital sepsis (Reinohl-DeSouza *et al*., 2004).

Interdigital dermatitis may occur as acute or chronic superficial dermatitis of the interdigital skin (van Amstel and Bemis, 1998; Blowey *et al.*, 2004). *Dichelobacter nodosus* and *Fusobacterium necrophorum* may be primary or contributory pathogens (Guard, 1995; van Amstel and Bemis, 1998; Blowey *et al.*, 2004). Lesions are usually painful to touch but often do not cause lameness. The lesions occur on all areas of the interdigital skin, but more commonly on the rear feet.

Other infective conditions that invariably influence locomotion scores in dairy cows include digital dermatitis and slurry heel (Berry *et al.*, 2010).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Geographical study area

The study was carried out in Kikuyu District (Fig. 3), Kiambu County of Kenya, between June and August 2013. Kikuyu District is a peri-urban area of Nairobi, the capital city of Kenya. The district occupies an area of 236 square kilometers with an approximate population of 265,829 and 77,045 households. It has a high number of smallholder dairy production units prompted by enhanced market for milk by the vast peri-urban and urban population. The study area was divided into 4 zones, which were designated as North, South, West and East from which smallholder zero-grazing dairy units were selected and data collected.

3.2 Sample Size Determination

At least 161 dairy cows were needed in this study. The sample size was determined using the formula by Martin *et al.* (1987). Sample size= $n = Z^2PQ/L^2$. Where n = the required sample size. Z =1.96 = the normal deviation at 5% level of significance. P = the estimated prevalence (in percentage), which is 88%. Q = 1-p and L= the precision of estimate which is considered to be 5% = 0.05

3.3 Study Design and Selection of the smallholder zero-grazing dairy units

This was a cross-sectional study in which each selected smallholder zero-grazing dairy unit was visited once and each selected cow within the smallholder zero-grazing unit was examined only once during the period of data collection. A total of 100 smallholder zero-grazing dairy units were included in the study. For purposes of this study, a smallholder zero-grazing dairy unit was one with a minimum of 2 and a maximum of 10 adult dairy cows. With the help of the local veterinarians and animal health assistants, 25 zero-grazing units were purposively selected from each zone. The purposive selection was done for logistical reasons, mainly willingness of the farmers to allow their dairy units to be used in the study and the challenges of getting units that met the study smallholder zero-grazing unit criteria.

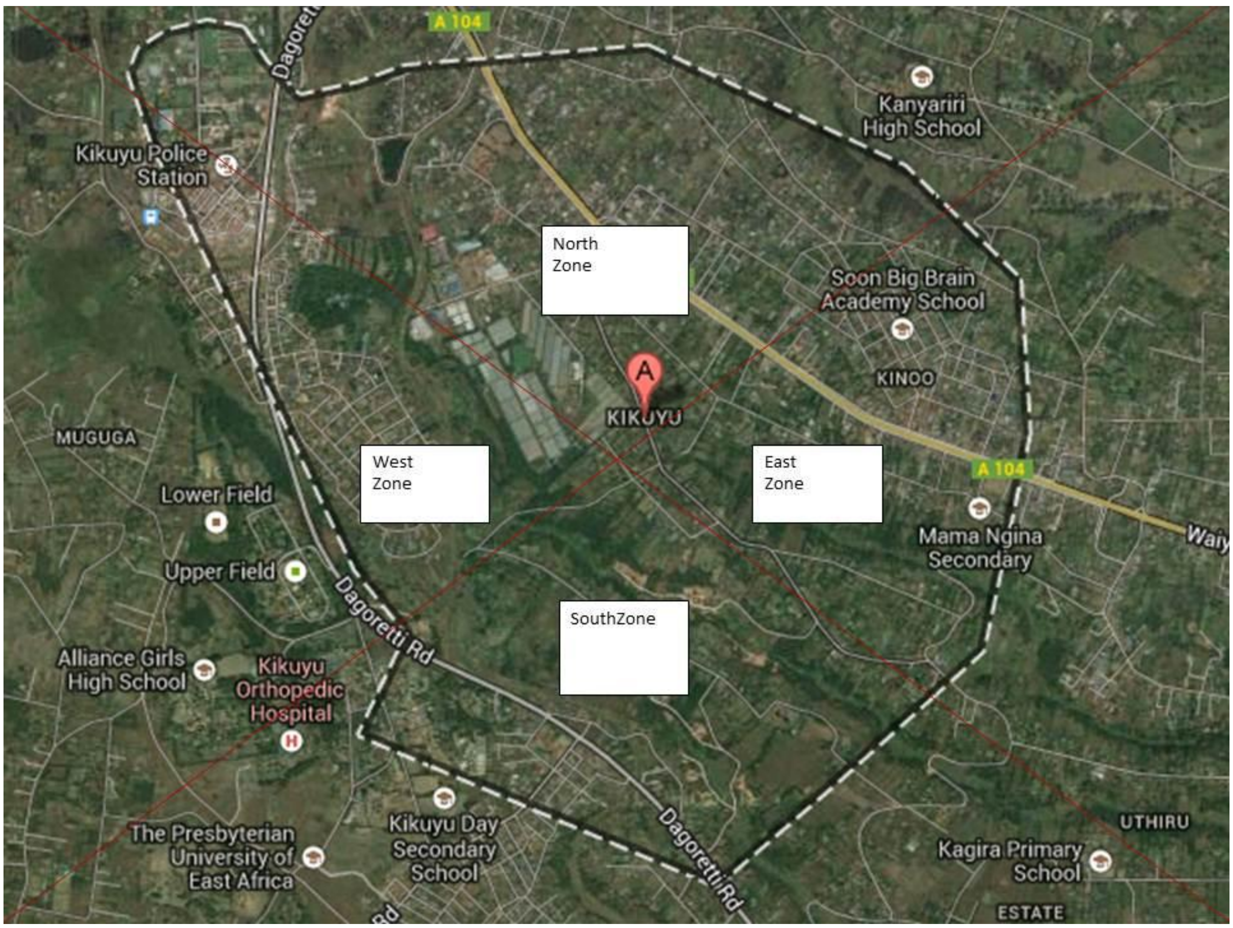

Figure 3: Map of Kikuyu district showing the 4 zones that were visited during the study of evaluation of locomotion scores in dairy cows from smallholder zero-grazing dairy units between June 2013 and August 2013.

3.4 Animal selection in each smallholder zero-grazing dairy unit

The criteria for inclusion of an animal into the study were an adult dairy cow that had calved at least once, whether currently lactating or dry. In the smallholder zero-grazing dairy units that had three or less cows that met the criteria for inclusion into the study population, all the cows were examined. In the smallholder zero-grazing dairy units that had more than three cows meeting the criteria for the study, three cows were selected by simple random method for examination. In such zero-grazing units, the cows were assigned numbers randomly, which were written on pieces of paper. Each piece of paper with a specific number written on it was folded and put in a small box in which they were all mixed properly by shaking the box, followed by picking any three. Only the cows whose assigned numbers corresponded to the ones written on the three pieces of paper were included in the study and examined. A total of 161 cows were selected for the study.

3.5 Evaluation of locomotion scores

Each cow that was selected had its gait assessed by observation as she stood without movement and as she walked on the walk-alley of the zero-grazing unit. The gait was evaluated using the conventional locomotion scoring system, which is based on the back posture as well as limb placement on the ground while the animal is standing without motion and then as the animal walks as described by Sprecher *et al.,* (1997). The locomotion scoring system is described in Table 1.

Table 1: Locomotion scoring system that was used to evaluate the gaits of cows in the smallholder zero-grazing dairy units in Kikuyu district, Kiambu County, Kenya between June 2013 and August 2013 (described by Sprecher *et al.*, 1997)

Locomotion score	**Gait**	**Description**
1	Normal	• Stands and walks normally. • All feet placed with purpose. • Back posture standing: flat. • Back posture walking: flat.
2	Mild lameness	• Stands with flat back, but arches when walking. • Gait is slightly abnormal. • Back posture standing: flat. • Back posture walking: arched. • Normal strides
3	Moderate lameness	• Stands and walks with an arched back. • Short strides with one or more legs. • Back posture standing: arched. • Back posture walking: arched.
4	Lame	• One or more limbs favored but partially weight bearing. • Back posture standing: arched. • Back posture walking: arched. • Careful strides
5	Severe lameness	• Refuses to bear weight on one limb. • May refuse or have great difficulty moving from lying position. • Back posture standing: arched more. • Back posture walking: arched more degree.

3.6 Evaluation of claw dimensions, conformation and disorders

Each cow was restrained in a standing posture in a crush. The claws were washed thoroughly with soap and water while scrubbing with a brush. Claw dimensions were measured while the cow stood with the foot firmly placed on a flat ground. A wooden plunk was used as an alternative to provide a flat surface in situations where the crush floor surface was uneven (Fig. 4). The dimensions included: claw angle in degrees, and the others such as toe length, claw height, claw diagonal and sole length were in centimeters. These claw dimensions were measured using a pair of vernier caliper, a pair of divider, ruler and adjustable protractor. After measurement of the claws, the limbs were raised off the ground one at a time by tying and fastening with a rope to an overhead pole. The soles of the claws were thoroughly washed with brush, soap and water. The claw width was measured with the foot raised off the ground. The horn and weight-bearing surface of the claw were examined for any gross lesions. The lesions were recorded in data collection sheets. Each claw with a lesion or deformity was photographed using a digital camera (Sony DSC-W630, 16.1 Mega Pixels). After measurement of the claws when all the limbs were properly bearing weight firm on the ground, the conformation of each claw was determined by observing the way they bear weight. Any abnormal conformation or deformity was recorded in the data collection sheets. Those that were excessively overgrown were trimmed using hoof trimmer and hoof knife as a remedy. In all 161 cows, only the hind limbs were examined, which added up to 332 claws. The hind limbs were preferred for logistic reasons, which included difficulties of accessing the forelimbs when a cow is restrained in the available restraint structures of the zero-grazing units (Fig. 4). It was easier to examine the claws of hind limbs and impossible to examine the forelimbs in the zero-grazing unit restraint structures.

3.7 Data collection on cow-level factors

Some of the cow-level factors such as breed and body condition were collected through observational method. The heart girth was measured by the investigator. Other data such as parity and lactation stage were obtained through a questionnaire, which was administered by the investigator as the interviewer to the farmers or stockmen as respondents. These data were obtained after the cows were selected for the study, but before examination of the claws was carried out. All the data were recorded in the data collection sheets.

3.8 Data collection on floor factors and slurry removal

During visitation of each of the 100 smallholder zero-grazing dairy units, data on floor factors and management of slurry were obtained. Data on type and state of the floor as well as the current state of the slurry in each zero-grazing unit was obtained through observation by the investigator. But data on frequency of slurry removal was obtained as part of the questionnaire that was administered by the investigator. All these data were recorded in the data collection sheets.

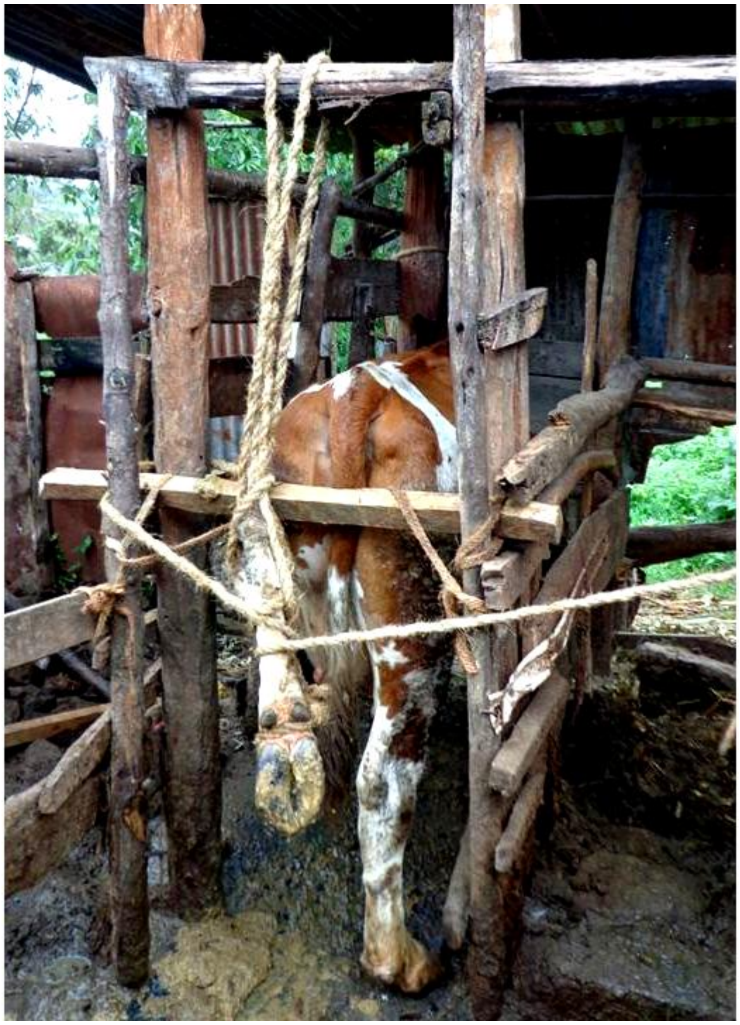

Figure 4: A cow in a crush of one of the smallholder zero-grazing dairy units that was included in the study carried out to evaluate the locomotion scores. The cow is restrained with one of the hind limbs raised from the ground for claw examination and trimming. Notice the impossibility of accessing the forelimbs, hence the choice of only hind limbs.

Figure 5: A cow's foot placed on a wooden plunk (bold arrow) to provide a flat surface when the floor surface of the crush is uneven (dotted arrow). This was done during evaluation of locomotion scores of dairy cows in the smallholder zero-grazing dairy units in Kikuyu district, Kiambu County, Kenya.

3.9 Evaluation of farmer awareness, perspective and the practice of claw trimming in smallholder zero-grazing dairy units.

Data on whether the smallholder zero-grazing dairy farmers were aware of the need for claw trimming and their perspective on its practice as well as whether claw trimming was being carried out in these zero-grazing units, were obtained through a questionnaire administered by the investigator as interviewer to farmers or stockmen who were the respondents. The questions were structured such that the responses expected from the questionnaire were "*Yes*, *No* and *I don't know",* to avoid subjective data from the respondents. The questionnaire is presented in the Appendices 1, 2, 3 and 4.

3.10 Data management and analysis

The data collected from this study were entered and stored in Microsoft Office Excel 2007. Entry of the data into spreadsheets was done by use of codes representing each parameter for ease of analysis. Data was verified and validated as per the data entries in the record sheets. It was then imported into SAS (Statistical Analytical System) © 2002 – 2003 (SAS Institute Inc., Cary, NC, USA).

Descriptive statistics were generated and tests for simple associations were done using Chi-square (χ^2) statistics at $p<0.05$ significance level. These tests for simple associations helped to determine the relationship between locomotion scores and claw dimensions, claw conformation and claw lesions; as well as the relationship between the findings on the claws and whether or not claw trimming is done in the zero-grazing dairy units. Chi-square (χ^2) values were determined using 2×2 contingency tables constituting 2 rows and 2 columns. In these associations, the chi-square (χ^2) calculations were determined by evaluating claw dimensions, conformation and claw lesions (all as variables) against each locomotion score (outcomes) on the cows. Also evaluated was whether or not claw trimming in the zero-grazing dairy units is done (variables) against claw dimensions and deformities (outcomes). The degrees of freedom (df) in each case was standard, being calculated by [(rows-1) (columns-1)], hence [(2-1) x (2-1) =1]. Therefore, df was 1 for each association test. Simple one-way ANOVA was used to determine whether there are any significant differences between the means of claw dimensions in the three levels of locomotion scores.

Multiple logistic regression were done through backward elimination in which the associated factors that made the least variation to the prevailing locomotion scores were eliminated one at a time through the consideration of their odds ratios and the corresponding P-values. The effects of confounders were dealt with in the analysis model, but they were minimal because of the similarities of management within the smallholder farms.

CHAPTER FOUR

4.0 RESULTS

4.1 Descriptive statistics for the zero-grazing dairy units and the cows examined

In this study, 100 zero-grazing dairy units were visited for evaluation of unit conditions, as well as examination of the claws and locomotion scores in the dairy cows within these units. Of these zero-grazing units, 52.8 % (85) had between 6-10 cows, 44.1% (71) had between 1-5 cows and the remaining 3.1% (5) had over 10 cows. The average number and the median number of cows in the 100 zero-grazing units were 6 and 7 respectively. A total of 161 dairy cows in the 100 zero-grazing dairy units were examined for locomotion scores and claw disorders. The breeds of the cows were Friesian 53.4% (86), Ayrshire 26.7% (43), Guernsey 6.2 % (10) and the crosses of these dairy breeds were 13.7% (22). Among the cows, 23.60 % (38) had calved once, 21.74% (35) had calved twice, 21.74% (35) had calved thrice and 32.92% (53) had calved four or more times. These animals were also at different stages of lactation with 22% (39) being dry, 32.92% (53) between 1 to 90 days post-partum, 24.84% (40) between 90 to 180 days post-partum, while 18.01% (29) were over 180 days post-partum. Heart girth measurements also varied in which 23.60% (38) of the animals had heart girth size below 170 cm, 57.76% (93) had heart girth size between 170 cm and 180 cm while 18.63% (30) had heart girth of over 180 cm.

4.2 Farmers' knowledge and perceptions on claw trimming

The responses of the questionnaire from the farmers are presented in Table 2. Among the farmers, 94% (94) agreed that claw trimming was essential for cows, but 6% thought it was not essential. Only 43% (43) of the farmers reported that claw trimming had been done at least once in the last one year in their zero-grazing units. Of these 43 farmers, 65.1% (28) said their cows had claws trimmed once per year, 30.2% (13) said they were trimmed twice per year and 4.7% (2) said trimming was done more than twice per year. In the 43 zero-grazing units, for which claw trimming was reported to have been done, it was done by either a veterinarian or an animal health assistant. Among the farmers in these 43 zero-grazing units, 69% (30) of them said claw overgrowth was the reason for trimming, while 30.2% (13) of them said that lameness from other causes was the reason for trimming. All the farmers from the 94% of the zero-grazing units in which claw trimming had been done at least once, were informed of its necessity by either a veterinarian or an animal health assistant. All the farmers in the 100 zero-grazing units indicated willingness to have claws of their cows trimmed regularly.

4.3 Summary of the locomotion scores among the 161 dairy cows examined

Among the 161 dairy cows examined, 68.3% (110) had locomotion score 1, 30.4% (49) had locomotion score 2 and 1.3% (2) had locomotion score 3. The average locomotion score for the 161 dairy cows was 1.3.

4.4 Claw dimensions of hind limbs of the 161 dairy cows examined

In the 161 dairy cows examined, dimensions of the claws were measured only in the hind limbs. The total number of hind limbs was 322, and the claws were 644. Means of different claw dimensions measured are as presented in the Table 3 and Table 4. Lateral claws had relatively longer dimensions than medial claws.

4.5 Claw disorders and the percentages of their occurrences in the 161 dairy cows examined

A summary of the various claw disorders found among the 161 dairy cows examined and the percentages their occurrences in percentage are presented in Table 5.

4.5.1 Claw overgrowth

Various forms of claw overgrowth were observed in this study, which included moderate to extreme elongation of the toes, thickened and widened soles and walls (Fig. 6 and 7). Other claws manifested with overgrowth with various levels of deformities (Fig. 8) that led to varying degrees of abnormal gait. Claw overgrowth was found in 66.5% (107) of the cows examined out of which, 59.8% (64) had a locomotion score of 1, 38.3% (41) had a locomotion score of 2 and 1.9% (2) had a locomotion score of 3.

Table 2: Responses from a questionnaire on awareness and practice of claw trimming in cows within the smallholder zero-grazing dairy units in Kikuyu district, Kenya.

Questions asked to the farmer		Responses in % (number of respondents)
Is claw trimming important?		
	Yes	94^{*} (n = 94)
	No	6 (n = 6)
Claw trimming ever been done?		
	Yes	43^{*} (n = 43)
	No	57 (n = 57)
Frequency of claw trimming?		
	Once per year	65.1^{**} (n = 28)
	Twice per year	30.2 (n = 13)
	More than twice per year	4.7 (n = 2)
Reasons for claw trimming?		
	Claw overgrowth	69^{**} (n = 30)
	Other causes of lameness	30.2 (n = 13)
Who did the claw trimming?		
	Veterinarian/animal health assistant	100^{**} (n = 43)
Who informed you about claw trimming?		
	Veterinarian/animal health assistant	100^{***} (n =94)

Table 3: Means of various claw dimensions measured in the hind limbs of 161 dairy cows whose locomotion scores were evaluated in the smallholder zero-grazing units in Kikuyu District, Kiambu county, Kenya between June 2013 and August 2013

	Claw Mean ± Standard Deviation (SD)	
Claw Dimension	**Lateral**	**Medial**
Claw angle (^{o})	38.44 ± 6.90	38.15 ± 7.23
Toe length (cm)	8.52 ± 2.17	8.30 ± 2.05
Heel height (cm)	2.95 ± 1.08	2.47 ± 0.65
Claw height (cm)	5.94 ± 1.02	5.45 ± 0.92
Claw diagonal (cm)	13.65 ± 2.35	12.92 ± 2.53
Claw width (cm)	5.00 ± 0.84	4.46 ± 0.74
Sole length (cm)	11.77 ± 2.50	11.47 ± 2.63

Table 4: Means of various claw dimensions at different locomotion scores in 161 dairy cows examined from 100 smallholder zero-grazing dairy units in Kikuyu District, Kenya between June 2013 and August 2013**.**

Locomotion score	Claw dimension	Number of cows	Mean ± Standard Deviation
1	Claw angle (◦)	110	39.55 ±5.39
	Toe length (cm)	110	7.91 ±1.89
	Heel height (cm)	110	2.75±0.83
	Claw height (cm)	110	24.99±7.40
	Claw diagonal (cm)	110	18.80 ±2.38
	Claw width (cm)	110	13.61±2.42
	Sole length (cm)	110	15.04±2.98
2	Claw angle (◦)	49	36.12±8.78
	Toe length (cm)	49	9.41±2.07
	Heel height (cm)	49	2.65±0.63
	Claw height (cm)	49	24.94±8.51
	Claw diagonal (cm)	49	18.18±3.27
	Claw width (cm)	49	13.82±2.86
	Sole length (cm)	49	14.92±3.60
3	Claw angle (◦)	2	32.50±0.00
	Toe length (cm)	2	10.88±0.11
	Heel height (cm)	2	2.04±0.76
	Claw height (cm)	2	26.98±3.50
	Claw diagonal (cm)	2	18.10±0.66
	Claw width (cm)	2	14.50±0.82
	Sole length (cm)	2	15.40±1.05

Table 5: Various claw disorders and the percentages of their occurrences in the 161 dairy cows examined and evaluated for locomotion scores in the smallholder zero-grazing dairy units in Kikuyu district, Kenya between June 2013 and August 2013.

Claw disorder	**Number of cows (n=161)**	**Percentage**
Claw overgrowth	107	66.5
Underrun/ double sole	73	45.3
White line separation	60	37.3
Horizontal grooves	50	31.1
Horizontal cracks	25	15.5
Vertical cracks	3	1.9
Corkscrew claw	18	11.2
Sole erosion	29	18.0
Heel erosion	67	41.6
Splayed claw	27	16.8
Sole ulcer	5	3.1
Chronic laminitis	10	6.2
Foot rot	8	5.0
Traumatic pododermatitis	4	2.5
Scissors shaped	2	1.2

Figure 6: Claw overgrowth showing **A**: moderate toe elongation (arrow), **B**: extreme toe elongation curving upwards (arrow), **C**: thickened sole (double-headed arrow) and widened dorsal wall (dotted arrow), **D** widened sole (double-headed arrow). These claw disorders were seen in some of the dairy cows evaluated for locomotion scores in the smallholder zero-grazing units in Kikuyu District, Kiambu county, Kenya between June 2013 and August 2013.

Figure 7: Claw overgrowth showing **A**: widened sole (double-headed arrow) and **B**: normal claw without overgrowth. These claw disorders were seen in some of the dairy cows evaluated for locomotion scores in the smallholder zero-grazing units in Kikuyu District, Kiambu county, Kenya between June 2013 and August 2013.

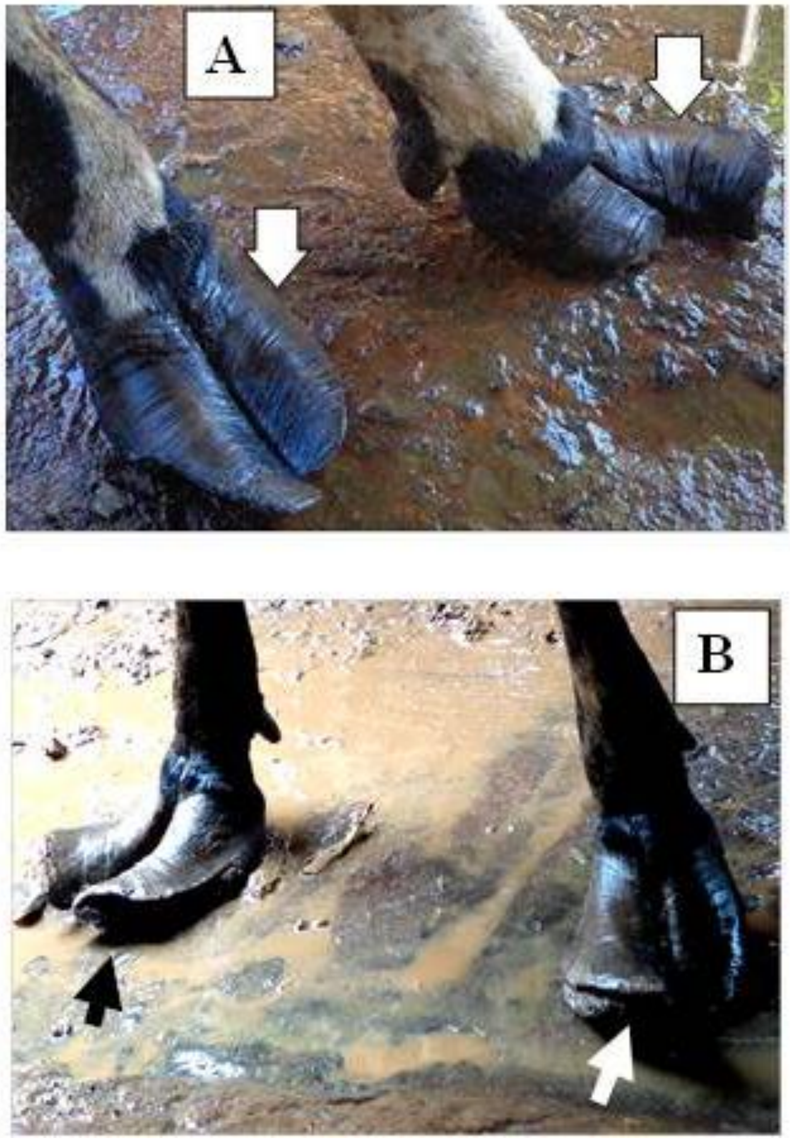

Figure 8: A and **B**: Claws with extreme overgrowth to the extent that they are deformed (arrows) and may have chronic laminitis since they show prominent horizontal grooves (arrows). Such claw disorders were observed in some of the dairy cows evaluated for locomotion scores in the smallholder zero-grazing units in Kikuyu District, Kiambu county, Kenya between June 2013 and August 2013.

4.5.2 Double/Underrun sole

Presence of double (underrun) soles (Fig. 9) was evident only after thorough washing of the claw in which dung was seen beneath the superficial sole. Confirming of the double soles was made by trimming the horn of the sole, which revealed presence of a separate underlying thin layer of horn. Out of the 161 dairy cows examined, 45.3% (73) had double soles, among which 45.2% (33) had locomotion score 1, 53.4% (39) had locomotion score 2 and only 1.4% (1) had locomotion score 3.

4.5.3 White line separation

White line separation was seen after washing of the claws as evidenced by presence of a gap between the horn of the sole seen and the vertical wall of the claw. In all the cases with white line separation, dung was found stuck in the avulsed white line (Fig. 10). A total of 37.3% (60) of the dairy cows examined had white line separation. The separations did not extend deep but were only superficial. Among the 60 cows showing superficial white line separation, 46.7% (28) had locomotion score 1 while 53.3% (32) had locomotion score 2.

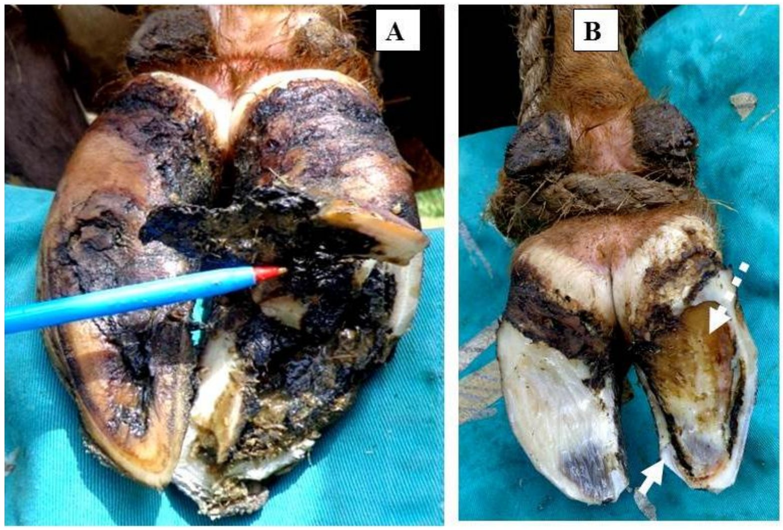

Figure 9: **A**: Claw with double soles (pen-pointer) before trimming and **B**: after trimming, the sole that was underlying is clearly seen (dotted arrow) and the margins where the superficial sole overlay is still seen soiled with dung (bold arrows). These features were found in 73 out of the 161 dairy cows evaluated for locomotion scores in the smallholder zero-grazing units in Kikuyu District, Kiambu county, Kenya between June 2013 and August 2013.

Figure 10: Claws with superficial abaxial (bold arrow) and axial (dotted arrow) white line separations, which were found in some of the dairy cows evaluated for locomotion scores in the smallholder zero-grazing units in Kikuyu District, Kiambu county, Kenya between June 2013 and August 2013.

4.5.4 Horizontal grooves

Claws with prominent (slight to moderately deep) horizontal grooves (Fig. 11) were found in 31.1% (50) of all the dairy cows that were examined. Some of the cows with prominent horizontal grooves, 48% (24) had locomotion score 1, 48% (24) had locomotion score 2 and 4% (2) had locomotion score 3. Some grooves were deep indicating that they were developing into horizontal cracks. Other features of the claws with prominent horizontal grooves was extremely rippled appearance with obvious rough texture of the horn of the dorsal wall. The areas of the horn with such rippling and texture also changed colour to dark-brown appearance (Fig. 11). Some of the cows with prominent horizontal grooves were also observed with overgrown claws.

4.5.5 Horizontal cracks

Horizontal cracks appeared transverse on the dorsal wall of the claw in a plane parallel to the coronary band. They ranged from superficial cracks that did not penetrate the full thickness of the horn to deep cracks that completely detached the toes from the claws. The horizontal cracks occurred at different levels of the claw; mostly at the level of coronary band and towards the distal aspect of the toe. One of the deep horizontal cracks was at the junction of the horn of the lateral wall of the claw and the skin at the coronary band (Fig. 12). A total of 15.5% (25) of the dairy cows that were examined had varying level of development of horizontal cracks. Out of these, 44% (11) had a locomotion score 1 and 56% (14) had a locomotion score 2.

4.5.6 Vertical cracks

Vertical fissures appeared in a longitudinal plane of the dorsal wall of the hoof. The fissures observed in this study were minutely superficial and at the uncommon sites located closer to the latero-ventral aspect of the abaxial wall (Fig. 13). None of the vertical cracks were complete through the thickness of the horn of the wall in any of the cows that were positive. Only 3 of the dairy cows examined had vertical cracks, of which one had a locomotion score 1 while the other 2 had a locomotion score 2.

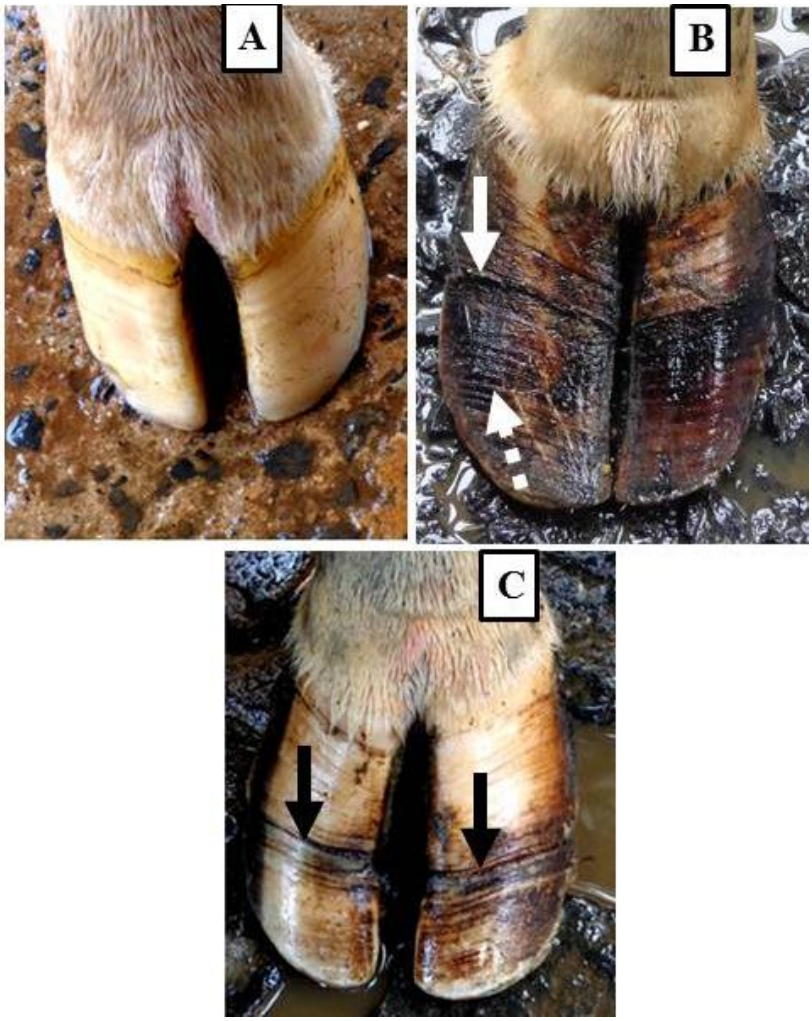

Figure 11: A: Normal claws with smooth-looking dorsal wall for comparison with **B**: which shows dorsal claw walls with prominent horizontal grooves giving the horn surface rippled appearance and dark-brown color (dotted arrow) and a deep wide groove (bold arrow) similar to the ones in **C** that are likely to penetrate full horn thickness and become horizontal hoof cracks. These types of grooves were seen in 50 out of 161 dairy cows evaluated for locomotion scores in the smallholder zero-grazing units in Kikuyu District, Kiambu county, Kenya between June 2013 and August 2013.

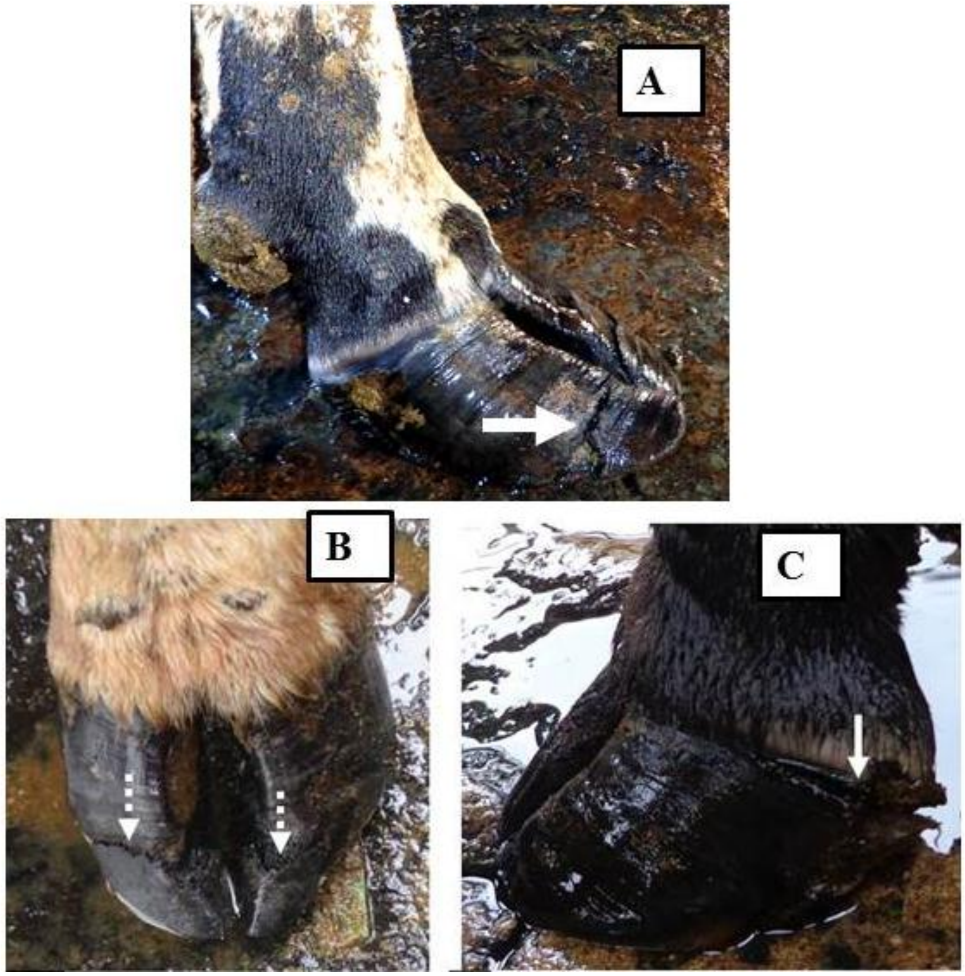

Figure 12: A and **B**: Claws with relatively deep horizontal cracks near the distal aspects of the toes of both claws in the same limb in each case appearing almost as thimbling (bold and dotted arrows respectively) in **C**: a claw with deeper horizontal crack at the level of coronary band (bold arrow). These were seen in some claws among the 25 of the 161 dairy cows that were evaluated for locomotion scores in the smallholder zero-grazing dairy units in Kikuyu District, Kiambu county, Kenya between June 2013 and August 2013.

Figure 13: Claw with hardly superficial appearing vertical fissure at the latero-ventral aspect and whose ends are shown by bold and dotted arrows. This claw also shows apparently prominent horizontal grooves (arrow head). Such vertical fissures were observed in 3 out of the 161 dairy cows evaluated for locomotion scores in the smallholder zero-grazing dairy units in Kikuyu District, Kiambu county, Kenya between June 2013 and August 2013.

4.5.7 Corkscrew claws

The corkscrew claws observed in this study appeared to have several features (Fig. 14). One of the features was elongation of one claw simply spiraling towards the other claw of the same foot. Another feature was one claw rotating upwards while the other claw on the same foot looking normal. One more feature was elongation in which the axial wall of one of the claws spiraled dorsally with part of the abaxial wall turning towards the tread surface. All these features of corkscrew claws result in slight to extreme deformities of the claws and consequent gait of affected cows ranging between locomotion score 1 to score 3 depending on the extent of claw deformity. Corkscrew claw disorder was observed in 11.2% (18) of the 161 dairy cows evaluated for locomotion scores. Out of the cows with corkscrew claws, 16.7% (3) had a locomotion score 1, 72.2% (13) had a locomotion 2 and only 11.2% (2) locomotion score 3.

4.5.8 Sole erosion

Sole erosion presented as roughened dark necrotic-like areas of the sole and some areas seeming to have compromised thickness of the horn of the sole (Fig. 15). A total of 18% (29) of the cows examined had claws with sole erosion out of which 51.7% (15) had a locomotion score of 1 while 48.3% (14) had a locomotion score of 2.

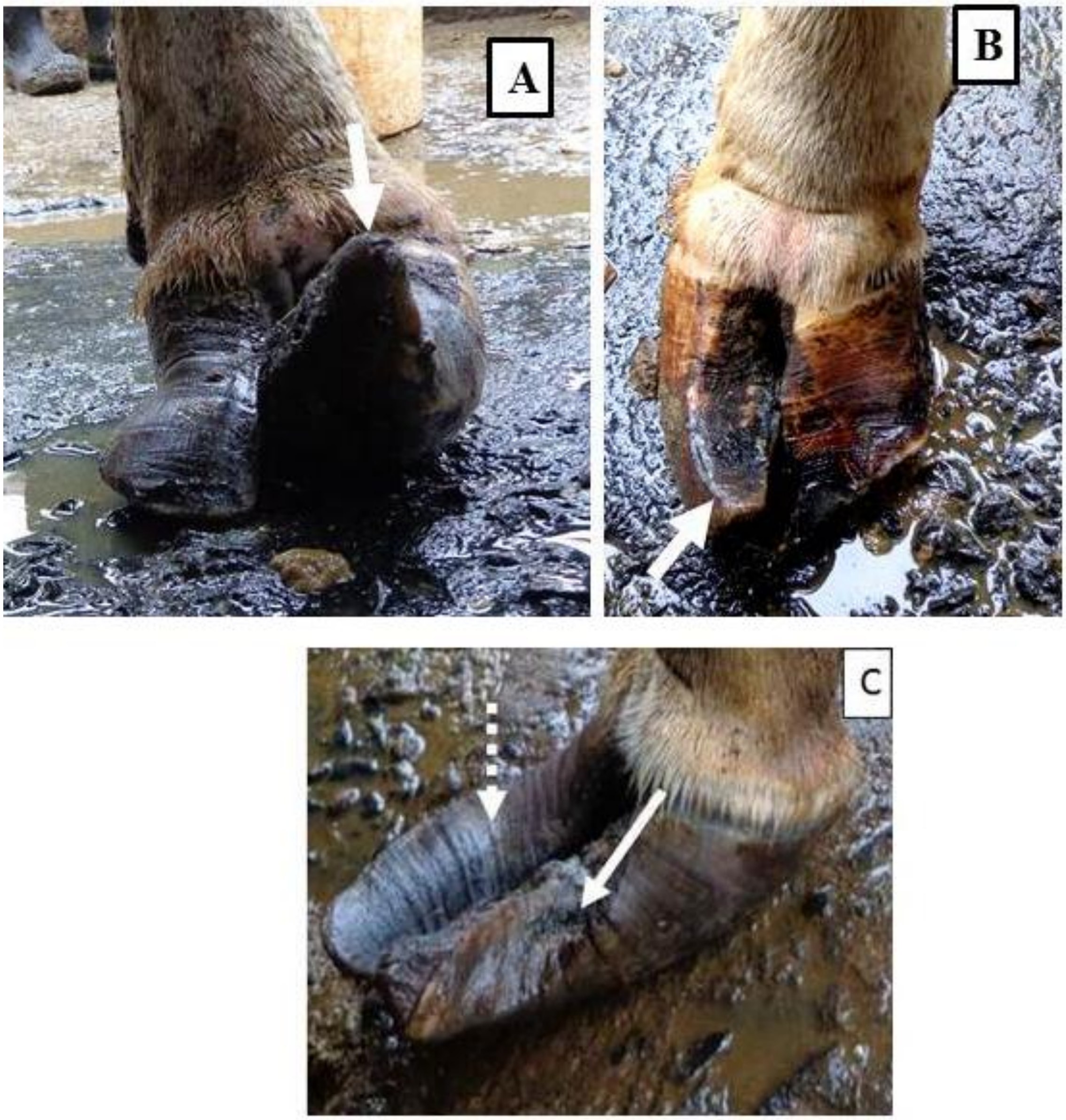

Figure 14: Claws showing various features of corkscrew appearance. **A**: Corkscrew is characterized by upward rotation of one claw (arrow), **B**: corkscrew is characterized by spiraling of one claw toward the normal claw (arrow) and **C**: both claw are elongated, but the axial wall of one claw rotates dorsally (bold arrow) while the axial wall of the other claw remains normal (dotted arrow). Such corkscrew claws were observed in 18 of the 161 dairy cows evaluated for locomotion scores in the smallholder zero-grazing dairy units in Kikuyu district, Kiambu county, Kenya between June and August 2013.

Figure 15: Claws in **A** show almost entire soles having darkened necrotic-like areas (dashed arrows), which represent horn erosions and destruction. In **B**, the reduced thickness of the horn of the eroded areas of the sole (bold arrows) is demonstrated by the horn of the walls projecting above the eroded areas on the axial and abaxial margins (dotted arrows). These were seen in 29 of the 161 dairy cows evaluated for locomotion scores in the smallholder zero-grazing dairy units in Kikuyu district, Kiambu county, Kenya between June 2013 and August 2013.

4.5.9 Heel erosion

Heel erosion appeared as darkened necrotic-like areas similar to sole erosion except it occurred on the heel bulb (Fig. 16). Heel erosion was found in 41.6% (67) of the 161 dairy cows examined. Among those with heel erosion, 58.2% (39) had locomotion score 1 and 41.8% (28) had locomotion score 2.

4.5.10 Splayed claws

Splaying of the claws with excessive toe separation (Figure 17) was found in 16.8% (27) of the 161 dairy cows evaluated for locomotion scores. A total of 70.4% (19) of the cows with splayed claws had locomotion score 1 and the other 29.6% (8) had locomotion score 2.

4.5.11 Sole ulcer

Sole ulcers became more clearly seen after washing and trimming the horn of the sole, which revealed small localized areas of exposed corium at the site of the ulcer. The ulcers were small varying between 2-6mm in diameter (Fig. 18). In this study, the exposed corium in each case was still below the level of the horn of the sole. 5 out of the 161 dairy cows examined had a sole ulcer all of which were located close to the sole-heel bulb junction close to the axial aspect. Only one cow had locomotion score 1, while the other 4 had locomotion score 2.

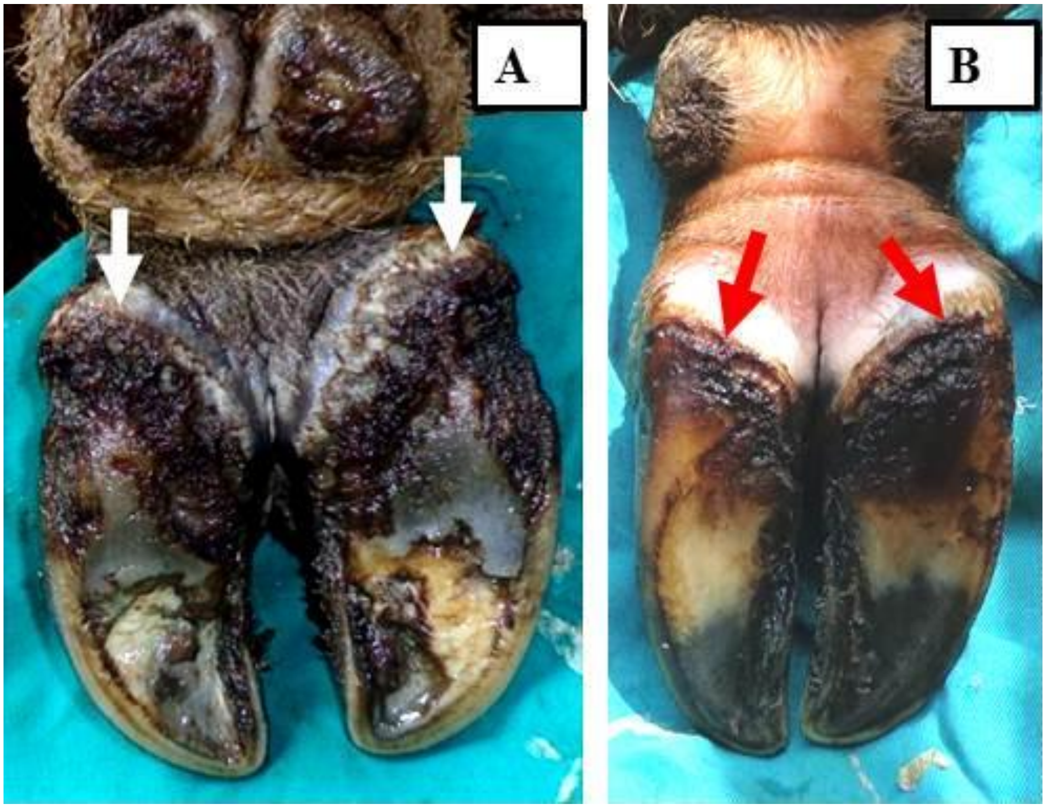

Figure 16: A and **B**: show claws with heel erosion demonstrated by darkened and rough-appearing horn of the heel bulb extending to the sole-heel junction (arrows). This was observed in 67 of the 161 dairy cows evaluated for locomotion scores in the smallholder zero-grazing dairy units in Kikuyu district, Kiambu county, Kenya between June 2013 and August 2013.

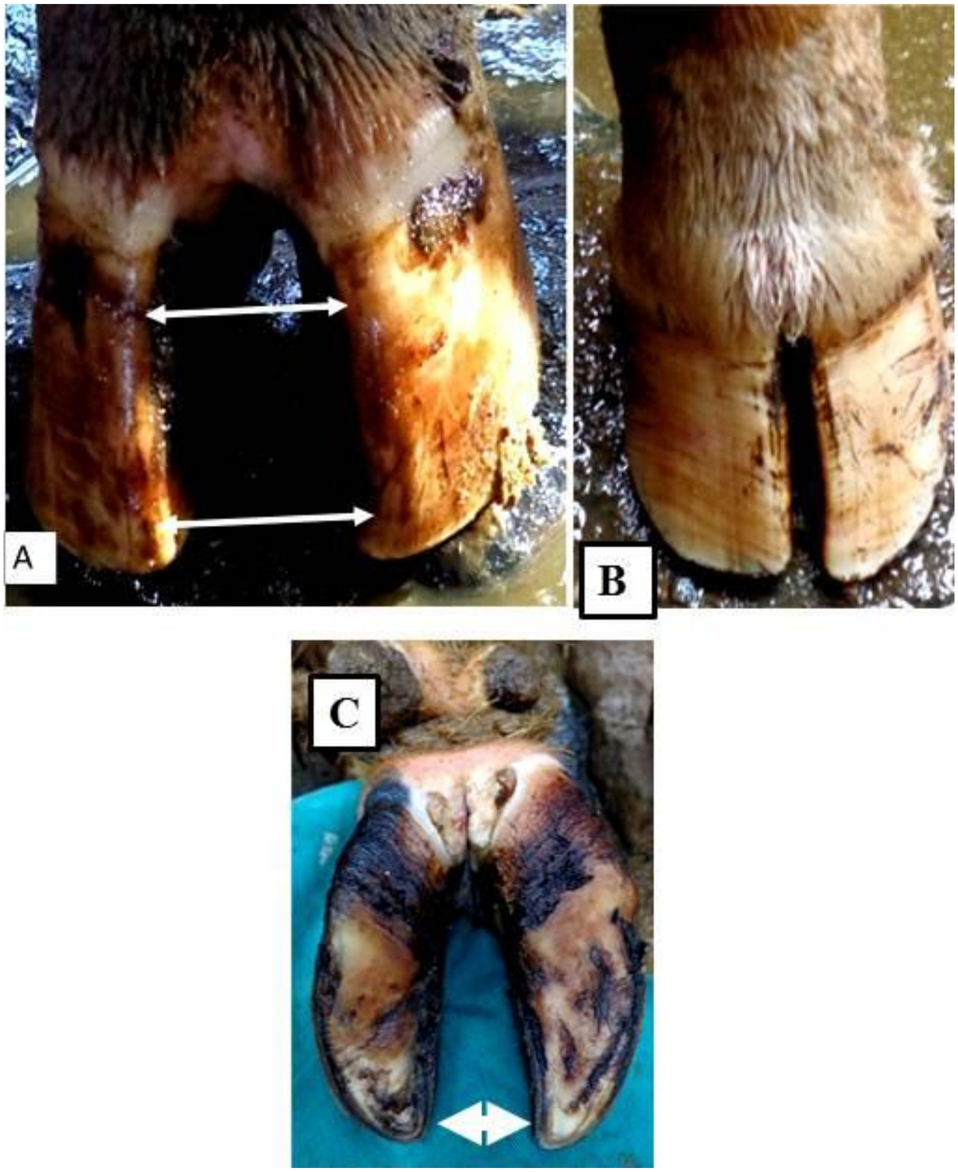

Figure 17: Splayed claws with varying degrees of separation of the toes causing widening of the interdigital space (double-headed arrows) are seen in **A** and **C**. These can be compared to normal claws in **B**, in which the toes are close to each other and the interdigital space is small. Splayed claws were observed in 27 out of the 161 dairy cows evaluated for locomotion scores in the smallholder zero-grazing dairy units in Kikuyu district, Kiambu county, Kenya between June 2013 and August 2013.

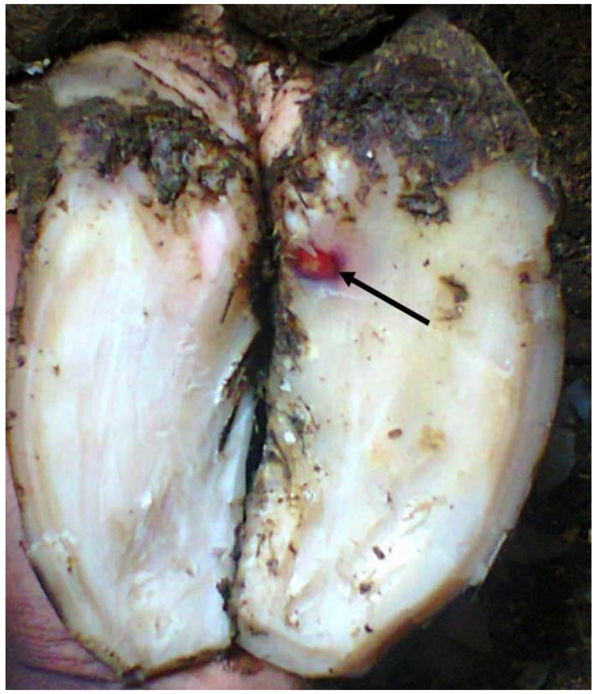

Figure 18: A claw with a developing small sole ulcer near the sole-heel junction close to the axial side (arrow). Such lesions were observed in 5 out of the 161 dairy cows evaluated for locomotion scores in the smallholder zero-grazing dairy units in Kikuyu district, Kiambu county, Kenya between June 2013.

4.5.12 Chronic laminitis

Chronic laminitis with irreversible deformities of the claws was found in 6.2% (10) of the 161 dairy cows examined. It was manifested by extreme elongation, broadening and unusually twisted claws that cannot be reclaimed by trimming. The toe ends were also unusually thickened with appearance of crumbling horn at the distal ends (Fig. 19). One out of the 10 cows had a locomotion score of 1, 80% (8) had a locomotion score of 2 while the remaining one cow had a locomotion score of 3.

4.5.13 Interdigital necrobacillosis (Foot rot)

Cases of interdigital necrobacillosis were encountered in only 5% (8) of the dairy cows examined in this study. The foot rot lesions varied from mild to moderate in severity. Among the cows with foot rot, 4 had a locomotion score of 1 the other 4 had a locomotion score of 2.

4.5.14 Traumatic pododermatitis

Lameness resulting from trauma through the horn and the pododerm with subsequent pododermatitis was found in 2.5% (4) of the 161 dairy cows examined in this study. The traumatic lesions were obvious at the heel bulb or sole-heel junction (Fig. 20). All the 4 cows had a locomotion score of 2.

4.5.15 Scissors claws

Only 1.2 % (2) of the dairy cows examined in this study had scissor claws in which the toes were excessively elongated resulting in overlapping over each other at the distal ends (Figure 21). The 2 affected cows had a locomotion score of 2.

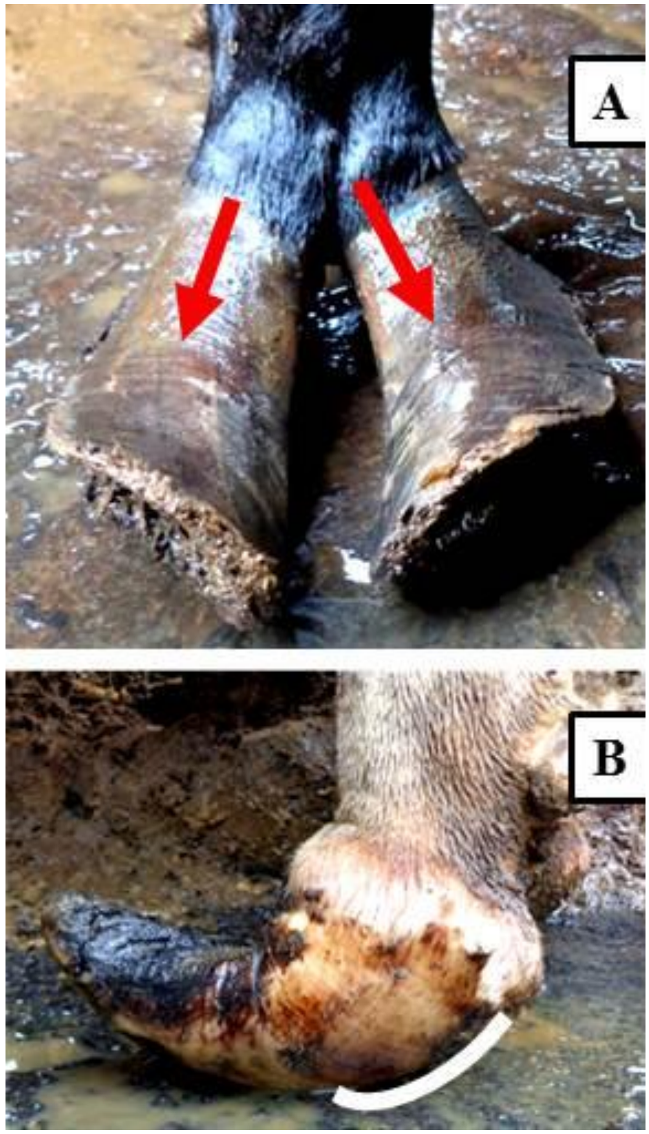

Figure 19: Elongated, broadened and deformed claws because of chronic laminitis. In **A**, both claws are deformed by rotating towards the axial side (arrows). In **B**, the claws are deformed by concave turning of the dorsal wall of the claw and convex shape of the weight-bearing surface resulting in treading at the heal (arc). Both types of deformities may not be remedied effectively by trimming. These types of deformities signifying chronic laminitis were seen in 10 out of the 161 cows evaluated for locomotion scores in the smallholder zero-grazing dairy units in Kikuyu district, Kiambu county, Kenya between June 2013 and August 2013.

Figure 20: Traumatic lesion at the proximal part of the heel bulb (arrow) leading to pododermatitis . Traumatic lesions with subsequent pododermatitis were found in 4 of the 161 dairy cows examined in the smallholder zero-grazing dairy units in Kikuyu district, Kiambu county, Kenya between June 2013 and August 2013.

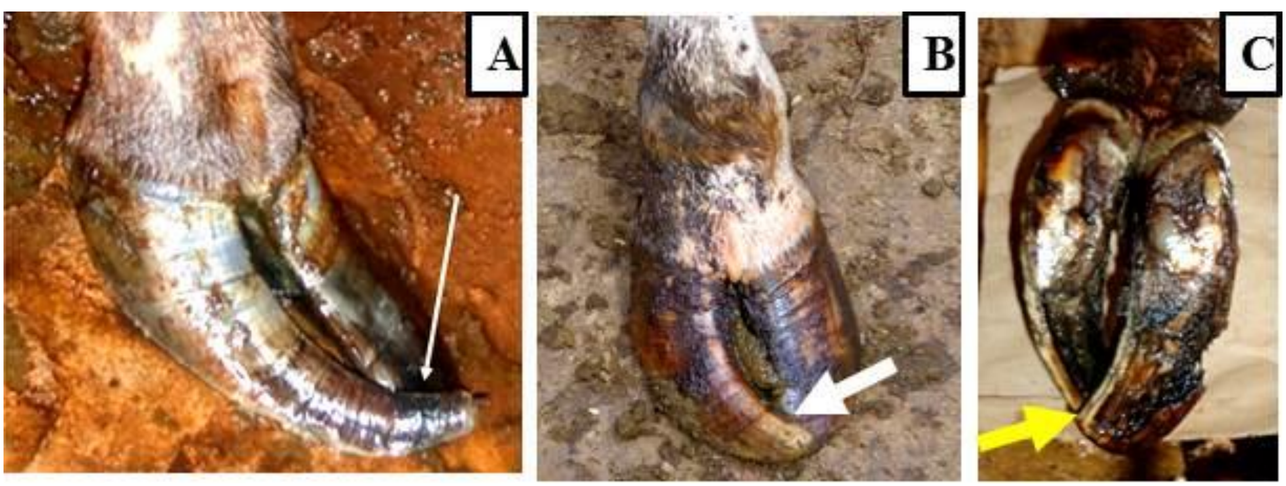

Figure 21: **A** and **B** show overlong toes overlapping with a tendency to forming scissor claws (arrow) and in **C**, the toe overlap is seen from the underside of the claw. These tendencies to scissor feet were observed in only 2 of the 161 dairy cows evaluated for locomotion scores in the smallholder zero-grazing dairy units in Kikuyu district, Kiambu county, Kenya between June 2013 and August 2013.

4.6 Floor type characteristics

Among the 100 smallholder zero-grazing dairy units evaluated, 92% (92) had concrete floors and the other 8% (8) had earthen floors. Of the 92 zero-grazing units with concrete floors, 38% (35) of them had intact well-finished concrete, 57.6% (53) had poorly constructed or worn-out concrete with holes and loose stones and 4.4% (4) had excessively smooth concrete floors. Six out of the remaining 8 zero-grazing units had bare earth floors, but the other 2 had straw and grass overlaid on the earthen floor. Various types of floors observed in the study are shown in Figure 22. Animals in zero-grazing units with overly smooth concrete floors recorded higher mean locomotion scores while those on earthen floors recorded the least locomotion scores (Table 6).

4.7 Management of slurry

Out of the 100 smallholder zero-grazing dairy units evaluated, 36% (36) had scanty slurry on their floors at the time of the visit, 62% (62) had moderate amount of slurry and only 2% (2) had excess slurry. Slurry was considered to be scanty when there were alternating small patches of the slurry and parts of the floor devoid of slurry, Moderate slurry had slurry covering most of the floor with only minimal patches of floor without slurry and excessive slurry had complete floor cover with slurry (Fig. 23). Removal of slurry from the floor at least once per day was done in 41% (41) of the zero-grazing units, twice per day in 45% (45) of the units, while in 14% (14) of the zero-grazing units, slurry remained on the floor without being removed for long periods of at least more than one day. Average locomotion score was 1.32 for dairy cows kept on floors with scanty slurry, score 1.34 for those on floors with moderate slurry and score 1 for those on floors with excess slurry.

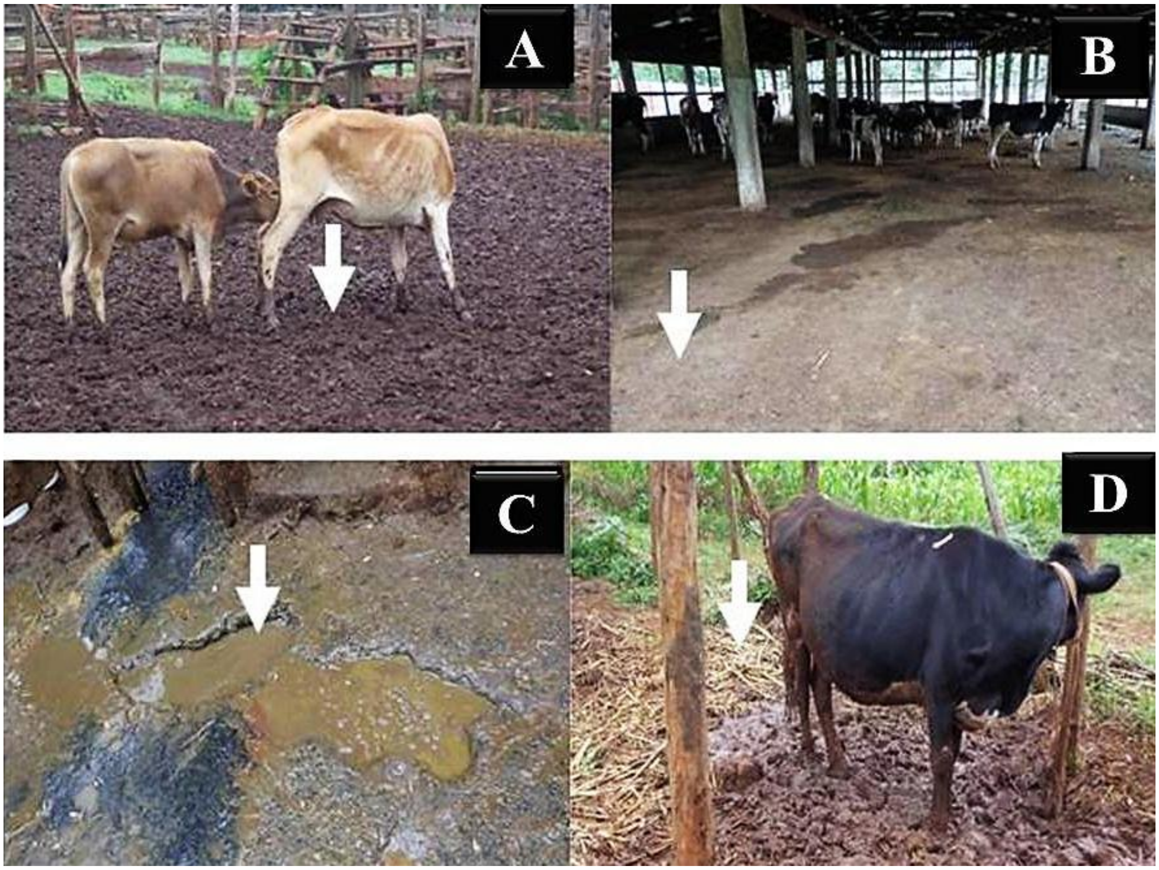

Figure 22: Different characteristics of floors in cattle houses. **A**: earthen floor on an open area (bold arrow), **B**: clean good quality concrete floor, **C**: cemented floor with large holes that retain slurry (bold arrow) and predisposes the cows to injuries, **D**: Grass and straw on earthen floor (bold arrow) on an open area where the cow is tied on a pole. These were observed in 27 of the 161 dairy cows evaluated for locomotion scores in the smallholder zero-grazing dairy units in Kikuyu district, Kiambu county, Kenya between June 2013 and August 2013.

Figure 23: Different characteristics of slurry on different floors in cattle houses. **A**: Excess slurry accumulation (bold arrow), **B**: Moderate slurry accumulation (bold arrow), **C**: Scarce slurry with a single patch of cow dung (bold arrow) and **D**: excess slurry accumulation to the level where the farmer used a rope (dashed arrow) to keep the animal for long duration in the cubicle. These were observed in 27 of the 161 dairy cows evaluated for locomotion scores in the smallholder zero-grazing dairy units in Kikuyu district, Kiambu county, Kenya between June 2013 and August 2013.

Table 6: Means of locomotion scores for the 161 dairy cows on various floor types as was found during evaluation of the locomotion scores in the 100 smallholder zero-grazing dairy units in Kikuyu District, Kenya between June 2013 and August 2013.

Floor Type	**Average Locomotion Score**
Overly smooth concrete	1.75
Straw/ Grass covered	1.40
Concrete with holes/ Loose stones	1.34
Good concrete	1.32
Earthen	1.17

4.8 Simple Associations between animal- and farm-level factors and locomotion scores

4.8.1 Association between claw dimensions and locomotion scores

The levels of statistical associations between various claw dimensions and locomotion scores in the dairy cows examined in the smallholder zero-grazing dairy units are presented in Table 7. Locomotion score was found to be strongly associated with toe length [$F(2, 158)=11.77$, $p < 0.0001$)] and the claw angle [$F(2, 158)= 5.41$, $p = 0.0054$)]. Cows with excessively elongated toes and e low claw angles had high locomotion scores.

4.8.2 Association between claw disorders and locomotion scores

Levels of association between claw disorders and locomotion scores in all the dairy cows examined in this study are presented in Table 8. Presence of various claw disorders was significantly associated ($p < 0.05$) with locomotion scores of the cows examined in this study. Some of the claw disorders had strong association with locomotion scores. These included: corkscrew claws (O.R.=1.3, $\chi^2 = 35.43$, $p < 0.0001$), underrun (double) soles (O.R.=1.1, $\chi^2 = 33.67$, $p < 0.0001$), white line separation (O.R.=1.1, $\chi^2 = 24.23$, $p < 0.0001$), overgrown claws (O.R.=1.1, $\chi^2 = 10.90$, $p = 0.0043$), traumatic pododermititis (O.R.=1.7, $\chi^2 = 9.38$, $p = 0.0092$) and horizontal hoof wall cracks (O.R.=1.2, $\chi^2 = 9.29$, $p = 0.0096$). Other claw disorder was weakly associated with locomotion scores. This was sole ulcer (O.R.=1.1, $\chi^2 = 5.99$, $p = 0.0490$).

Table 7: Associations between claw dimensions and locomotion scores in the 161 dairy cows examined in the smallholder zero-grazing dairy units in Kikuyu district, Kenya between June 2013 and August 2013.

Claw dimension	F-value	P-value
Claw angle (^{0})	5.41	0.0054*
Toe length (cm)	11.77	<0.0001*
Heel height (cm)	1.03	0.3598
Claw height (cm)	0.07	0.9553
Diagonal length (cm)	0.68	0.5064
Claw width (cm)	0.21	0.8089
Sole length (cm)	0.04	0.9626

*Significant association at p>0.05

Table 8: Associations between claw disorders and locomotion scores in 161 dairy cows examined in the smallholder zero-grazing dairy units in Kikuyu district, Kenya between June 2013 and August 2013.

Claw disorder	Chi square (χ^2)	P-value
Claw overgrowth	10.90	0.0043*
Underrun (double) soles	33.66	<0.0001*
White line separation	24.23	<0.0001*
Horizontal hoof wall grooves	0.50	0.7110
Horizontal hoof wall cracks	9.29	0.0096*
Vertical hoof wall cracks	1.90	0.3859
Corkscrew claws	35.43	<0.0001*
Sole erosion	5.57	0.0619
Heel erosion	1.50	0.4140
Splayed claws	0.43	0.8066
Sole ulcer	5.99	0.0490*
Chronic laminitis	3.52	0.1640
Interdigital necrobacillosis	1.58	0.4545
Traumatic pododermatitis	9.38	0.0092*
Scissor claws	0.94	0.6253

*Significant association at $p < 0.05$

4.8.3 Association between animal-level factors and locomotion scores

The levels of association between some animal-level factors and locomotion scores are presented in Table 9. The animal-level factors that were evaluated and found to be significantly associated with locomotion scores of the cows examined were breed of the cow (O.R.=1.2, $\chi^2 = 18.55$, $p = 0.0026$), parity (O.R.=1.2, $\chi^2 = 14.20$, $p = 0.0060$) and stage of lactation (O.R.=1.1, $\chi^2 = 10.84$, $p = 0.0367$). Higher locomotion scores were observed in the Friesian breed, in cows with parity >3 and in cows with lactation stage less than 180 days

4.8.4 Association between farm-level factors and locomotion scores

The farm-level factor that was found to be strongly associated with locomotion scores among those that were evaluated in the smallholder zero-grazing dairy units was the type of floor (O.R.=1.5, $\chi^2 = 40.47$, $p = 0.0016$). Higher locomotion scores were observed in cows that were in zero-grazing units with excessively smooth floors and in those units that generally had concrete floors, while lower locomotion scores were observed in cows that were in units with earthen floors. Although the level of slurry did not influence locomotion scores, it nevertheless had a significant influence when combined with the type of floor.

4.8.5 Association between claw trimming practice and locomotion scores

Statistically, the frequency of claw trimming was the only factor which was strongly associated (O.R. =1.3, $\chi^2 = 30.21$, $p = 0.0112$) with locomotion scores. The level of awareness on claw trimming had no significant association with locomotion scores. The dairy cows that were frequently hoof-trimmed recorded lower locomotion scores.

Table 9: Association between animal-level factors and locomotion scores in 161 dairy cows examined in the smallholder zero-grazing dairy units in Kikuyu district, Kenya between June 2013 and August 2013.

Animal-level factor	Chi square value	P-value
Breed	18.55	0.0026*
Parity	14.20	0.0060*
Body condition score	9.66	0.5598
Heart Girth	4.23	0.3145
Lactation stage	10.84	0.0367*

*Significant association at $p < 0.05$

CHAPTER FIVE

5.0 DISCUSSION

The results of this study have generally shown that there is association between locomotion scores of dairy cows in the smallholder zero-grazing units with claw disorders, claw dimensions, parity and lactation stage of the cows; as well as the type of floors in the zero-grazing units and the claw trimming practices that are common in these units. The study showed that the average locomotion score in these zero-grazed dairy cows was 1.3, which indicates that a higher percentage of the cows in these zero-grazing units had between normal gait and mild lameness. The study also revealed that although claw trimming was not applied in many of the smallholder zero-grazing units evaluated, most smallholder farmers were nevertheless aware that claw trimming as a practice can be performed.

The current study established that there was a strong and significant association between breed and locomotion scores. The association of the friesian breed with higher locomotion scores is probably an incidental finding simply due to the fact that more than 50% of the dairy cow population examined in this study were Friesians. The significant association between locomotion scores and parity in the dairy cows that have calved more than three times is similar to previous findings in most lameness cases (Sogstad *et al*., 2005) and in those with chronic laminitis (Nguhiu-Mwangi, *et al*., 2008a). The significant association between locomotion scores and lactation stage less than 180 days in dairy cows as found in this study agrees with previous reports. These reports suggest that the type of prepartum feeding and the stress of high milk yield during early postpartum period may contribute to physiological changes that trigger development of subclinical laminitis, which subsequently predisposes to chronic laminitis and other claw disorders (Rowlands *et al*., 1983; Nocek, 1997; Donovan *et al*., 2004; Vermunt, 2004; Nguhiu-Mwangi, *et al*., 2008a). The large udder in the early stages of lactation may also interfere with the gait of the cow, hence higher locomotion scores (Boelling and Pollott, 1998).

In the current study, awareness of claw trimming by a high percentage of smallholder farmers may be attributed to the fact that the smallholder zero-grazing units evaluated were in the practice area served by the veterinary ambulatory clinic of the University of Nairobi. However, embracing of routine claw trimming practice by only a few of the smallholder zero-grazing dairy units in the study area may have been influenced by several factors including reluctance by the veterinarians and animal health assistants to perform the procedure owing to difficulties exacerbated by poor restraint facilities in these units as previously reported (Nguhiu-Mwangi *et al*., 2008b). Other reasons could be resistance by farmers, due to fears emanating from costs of the procedure and reduced milk yield on the day of trimming, which follow the struggle that the cows undergo during restraint. Nevertheless, it is surprising that all the farmers expressed willingness to have their cows trimmed. However, it is positive to note that in those zero-grazing units where claw trimming had been done, it was performed by veterinarians and animal health assistants and not by the farmers themselves. The reason the farmers do not perform claw trimming on their own is probably due to lack of trimming equipment. They should nevertheless be discouraged from performing it on their own because when unskilled persons do claw trimming, it may result in more lameness (Blowey, 2002). However, smallholder farmers should be instructed that claw trimming is inevitable for balancing continuous horn production in order to reduce the risk of developing claw lesions (Nacambo *et al*., 2004; Mülling *et al*., 2006). It should therefore be done regularly as needed, but nevertheless by skilled professional personnel.

The mean locomotion score of 1.3 found in these smallholder zero-grazed dairy herds in the current study compares closely to locomotion score 1.26 reported by Olechnowicz and Jaskowski (2010). However, it is lower than locomotion score of 1.77 reported by Barker *et al*. (2007). This low mean locomotion score in the current study can probably be explained by the fact that a higher percentage of the claw lesions and disorders found in these cows, either caused no lameness at all (score 1) or caused mild lameness (score 2). Similar higher percentages of non-lame dairy cows were reported previously in the small scale-farming units in some peri-urban areas of Nairobi, Kenya (Gitau *et al*., 1996; Nguhiu-Mwangi, *et al*., 2009). The types of floor and design of the smallholder zero-grazing dairy units in the study area may lower the sensitivity of locomotion scoring system particularly for cows with lesions that have higher pain threshold or with lesions that do not cause pain at all, hence judged as having low locomotion scores. The lesions or disorders may also not cause sufficient discomfort to change the gaits of the cows (Tadich *et al.,* 2010). However, the use of locomotion scoring is pertinent for identifying and recording of lameness for early remedial treatment and control.

In the current study, animals with reduced claw angle and increased toe length had higher locomotion scores. There was also a strong association between locomotion score and reduced claw angle and increased toe length in the dairy cows that were examined. This finding is in agreement with previous observations that reported increased lameness and locomotion scores with similar changes in these claw dimensions (Olechnowicz and Jaskowski, 2010; Mohamadnia and Khaghani, 2013). Increased toe length results in flattening of the claw, with subsequent reduced claw angle as has been described in cases of chronic laminitis (Greenough, 1987; Weaver, 1993; Nocek, 1997). Consequently, the cow shifts weight-bearing more from the sole to the heel thus altering the gait, hence higher locomotion scores (score ≥ 2). The finding of greater dimensions of the lateral claws compared to those of the medial claws as found in the current study, was similar to previous reports (Mohamadnia and Khaghani, 2013). This is probably explained by the fact that anatomically the outer claw of the hind limb is more loaded with weight bearing than the inner claw and therefore has more horn production (van der Tol *et al*., 2003). This further suggests that in functional claw trimming of the hind limbs, it is prudent to trim the outer claw first because it is longer and wider, hence it sets the level of trimming the inner claw (Mülling *et al*., 2006).

Although many lesions found on the claws caused low locomotion scores, the high prevalence of claw lesions in this study is consistent with the findings of previous researchers (Manske, 2002; Nguhiu-Mwangi *et al*., 2009). This is probably attributable to the fact that claw lesions are by far the most common cause of lameness in cattle (Clarkson *et al*., 1996; Weaver, 2000). The high prevalence of claw lesions could further be attributed to interactive varied factors such as floor type, stocking rate, slurry, parity, and lactation stage and long hours cows that stand in confinement of the zero-grazing units without ever being released to open yards (Mulling *et al*., 2006, Nguhiu-Mwangi *et al.*, 2008a). This confinement provides suitable underfoot environment in which multiple interactive factors favor development of claw lesions (Clarkson *et al.*, 1996; Cook *et al.*, 2004). The high percentage of the cows that had claw lesions without showing lameness (locomotion score 1), was probably due to the lesions being in the subclinical phase. Similar findings have been reported in the study of laminitis in which cases of subclinical laminitis manifests an insidious course that eventually contributes to the development of more severe future lameness episodes as long as the predisposing factors persist (Nocek, 1997; Belge and Bakir, 2005; Nguhiu-Mwangi, 2007).

In the current study, claw overgrowth and the underrun (double) soles were the most prevalent claw disorders. These claw disorders are associated with claw trimming, hence lack of regular claw trimming predisposes their occurrence. Since almost all the cows with claw disorders or lesions in this study were found to have locomotion scores 1 or 2, it could imply that either the claw conditions did not cause any pain/discomfort or caused mild pain/discomfort, hence locomotion scores 1 and 2 respectively. It may also mean that the evaluation of locomotion scores is not sensitive enough to distinguish between mild and moderate discomfort (score 2 and 3) but could easily distinguish the extreme cases of absence of limb discomfort (score < 2) and severe pain (≥ 3). This agrees with the explanation given by Tadich *et al*., (2010) that presence of hoof lesions may not necessarily mean association with increasing locomotion scores. The strong association between locomotion scores and some of the claw conditions such as overgrown claws, corkscrew claws and double soles can probably be attributable to claw deformations that result from these conditions as well as their possible association with laminitis (Rebhun and Pearson, 1982; Greenough, 1987; Nocek, 1997; Nguhiu-Mwangi *et al.*, 2008b). Other disorders such as horizontal hoof wall cracks and traumatic pododermatitis may be strongly associated with locomotion scores due to possibility of pain caused when these lesions involve the deep parts of the claw such as the corium. This is closely consistent with previous findings (Dyer *et al.*, 2007). All the claw conditions showing strong association with locomotion scores are likely to cause severe lameness in the affected cows. In contrast to previous findings of sole ulcers being strongly associated with higher locomotion scores (Nguhiu-Mwangi, 2007; Tadich *et al*., 2010), sole ulcers in the current study were found to be weakly associated with locomotion scores. This may be attributable to the fact that the prevalence of sole ulcers in the current study was low. Moreover, the ulcer lesions in this study were below the surface of the horn of the sole in which case the sensitive tissue did not tread directly on the ground, hence less pain and low locomotion scores.

The fact that 92% of the smallholder zero-grazing dairy units had concrete floors despite some of them having floor defects and some being overly-smooth, shows a tendency of adopting cleanable floors for improvement of hygiene in these units. However, ignorance of the effects of the state of floors on dairy cow claw health was manifested by more than 50% of the zero-grazing units having concrete floors that were poorly constructed, worn out with holes and loose stones. Although it is easier to maintain hygiene on concrete floors, their abrasiveness to the claws and long hours that cows stand on such hard ground are some of the factors that predispose to claw lesion development (Vokey *et al*., 2001; Somers *et al*., 2003). These floor types and associated defects may be some of the factors contributing to high prevalence of claw disorders seen in the cows in the smallholder zero-grazing dairy units in the current study. Overly-smooth concrete floors were associated with higher mean locomotion scores most likely due to slipperiness of the floor that results in unstable gait. The slipperiness of over-smooth floors has been reported to result in smaller movement amplitude of cows' proximal joints and reduced walking velocity (Phillips and Morris, 2000) as well as shorter strides (Telezhenko *et al*., 2009). Conversely, earthen floors were associated with lower locomotion scores possibly due to better ground grip, which improves the gait. The findings also agree with those of previous researchers who found the gait of cattle to be impaired on hard floors, hence affecting the locomotion score (Telezhenko *et al*., 2009).

The finding in the current study, of more than three quarters of the smallholder zero-grazing dairy units with scanty or moderate slurry may be attributable to the fact that in 41% and 45% of all the units, slurry was removed once and twice per day respectively. This may also explain the reason why the amount of slurry in this study had no influence on locomotion scores. It may also explain the low prevalence of infective claw conditions owing to improved hygiene of the floors in the zero-grazing dairy units. This is in contrast to previous findings in which slurry being left to accumulate more than one day without removal from the zero-grazing unit predisposed to development of laminitis, hence influencing locomotion score (Borderas *et al*., 2004; Vermunt, 2004; Nguhiu-Mwangi, *et al*., 2008a). However, although slurry in this study did not influence locomotion scores, as stated in previous reports, it causes slipperiness of the floor that affects gait. Subsequently, the cows lack treading confidence, hence affect their natural locomotion behavioral activities (Phillips and Morris, 2000). In the current study, the slipperiness was probably minimized by the excessive roughness of worn out concrete floors that existed in these zero-grazing units.

The strong and significant association between locomotion score and the frequency of claw trimming could be attributable to the even weight-bearing distribution between the claws after appropriate trimming. Regular trimming (at least once per year) corrects balance of weight bearing and improves the gait of the cows for several months. It also exposes underlying lesions, thus enhancing their healing. It therefore means the cows not subjected to regular claw trimming are likely to have higher locomotion scores. This is consistent with previous findings, which state that claw trimming reduces chances of development of claw lesions as well as the incidences and degree of lameness (Manske, 2002). Claw trimming is also a crucial procedure for balancing out horn production to maintain sound anatomical tread between all the claws and all the limbs of a cow (Nacambo *et al*., 2004; Mülling *et al*., 2006).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusions

From this study, it is concluded that:

a) The farmers in these smallholder zero-grazed dairy units were aware that claw trimming is done in cattle, but only few of them had it done on their cows. This had an influence on the disorders that were found on the claws of dairy cows in these units.

b) The average locomotion score of dairy cows in these smallholder zero-grazing units was 1.3. Therefore, although there was a high prevalence of claw disorders in dairy cows in these units, most of the disorders did not cause clinical lameness or caused only mild lameness.

c) The disorders and factors that were found to have a strong association with locomotion scores and therefore influence gait of the cows included: overgrown claws, corkscrew claws, double soles, hoof cracks and traumatic pododermatitis. Others were overly-smooth floors, concrete floors, frequency of claw trimming, reduced claw angle and increased toe length. All these result in higher locomotion scores and poorer gait.

6.2 Recommendations

There is need to train smallholder dairy farmers on the importance of maintaining good claw health through proper management of dairy cows, which includes claw trimming and proper housing design, user friendly floor and slurry removal.

6.3 Areas of further research

a) It essential to design a study to evaluate the sensitivity and challenges of applying locomotion scoring systems in the smallholder zero-grazing units in Kenya.

b) A study on the methods used to make diagnosis of lameness by Kenyan veterinarians should be done and evaluated against locomotion scoring systems.

CHAPTER SEVEN

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APPENDICES

Appendix 1: Data collection sheet on Animal level factors

Farm No:………………………………… Animal no:………………Date:…………………….

1. Animal breed:
   (1)Friesian (2) Ayrshire (3)Guernsey(4)Jersy (5)Crosses
2. Body condition score: _________
3. Heart girth (cm):
   (1) <170 (2) 170-180 (3) >180
4. Parity:
   (1) first (2)second (3)third (4)>three
5. Lactation stage:
   (1) dry (2)1-90days (3) 90-180 days (4)>180 days
6. Locomotion score:
   (1)Normal (2) mild lameness (3) moderate lameness (4)lame (5) severe lameness
7. Claw Lesions/deformity:
   (1) None
   (2) Claw overgrowth
   (3) Double/Underrun sole
   (4) Whiteline separation
   (5) Horizontal grooves
   (6) Horizontal cracks
   (7) Vertical cracks
   (8) Corkscrew cracks
   (9) Sole erosion
   (10) Heel erosion
   (11) Splayed claws
   (12) Sole ulcer
   (13) Flattened claw
   (14) Foot rot
   (15) Traumatic Injury (Heel bulb)- Traumatic pododermatitis
   (16) Scissors shaped

Appendix 2: Data collection sheet on Farm Level Factors

Farm No:________________________ Date________________________

8. Herd size:
   (1)1-5 (2) 6-10 (3)11-20

1. Floor types:

(1) Good concrete

(2) Concrete with holes/loose stones

(3) Over smooth concrete

(4) Wooden

(5) Earthen

(6) Straw/grass

(7) Others (specify):______________________________

2. Description of slurry:

   (1) Scanty (2) Moderate (3) Excess

3. Frequency of slurry removal:

(1) Once per day (2) Twice per day (3) Remains unremoved more than a day (4) Occasional (specify):___________________

Appendix 3: Questionaire on Farmer Perception On Foot Trimming And Lameness.

Farm No:____________________ Date____________________

1. Do you think claw trimming is important for cattle?
   (1) Yes (2) No
2. Has claw trimming ever been done in your farm:
   (1) Yes (2) No
   If yes,
3. Frequency of trimming (per year):
   (1) Once (2) Twice(3) More than twice
4. Who did hoof trimming:
   (1) Vetenarian/ Animal Health Assistant (2) Farm personnel (3) Farmer
5. Why was hoof trimming done in your farm?
   (1) Claw overgrowth (2) Cow lame
   (2) Other reasons (Specify)____________________
6. Who informed you about claw trimming?
   (1) Veterinarian (2) Animal health worker (3) Another farmer (4) No one
7. Would you like your animals trimmed regularly?
   (1) Yes (2) No

Appendix 4: Data collection sheet for Hoof Measurement.

Farm No:______________ Animal No:______________ Date_____________

		Code 1 Right Lateral	Code 2 Right Medial	Code 3 Left Lateral	Code 4 Left Medial
	Claw Angle (A)				
	Toe Length (B)				
	Heel Height (C)				
	Claw Height (D)				
	Diagonal (E)				
	Claw Width (F)				
	Sole Length (G)				

		Code 1 Right Lateral	Code 2 Right Medial	Code 3 Left Lateral	Code 4 Left Medial
	Claw Angle (A)				
	Toe Length (B)				
	Heel Height (C)				
	Claw Height (D)				
	Diagonal (E)				
	Claw Width (F)				
	Sole Length (G)				

		Code 1 Right Lateral	Code 2 Right Medial	Code 3 Left Lateral	Code 4 Left Medial
	Claw Angle (A)				
	Toe Length (B)				
	Heel Height (C)				
	Claw Height (D)				
	Diagonal (E)				
	Claw Width (F)				
	Sole Length (G)				