P-ISSN: 2304-3075; E-ISSN: 2305-4360

International Journal of Veterinary Science

www.ijvets.com; editor@ijvets.com

Research Article

Disorders of the Claw and Their Association with Laminitis in Smallholder Zero-grazed Dairy Cows

Nguhiu-Mwangi J[*1], Mbithi PMF[2], Wabacha JK[3] and Mbuthia PG[4]

[1]University of Nairobi, Faculty of Veterinary Medicine, Department of clinical studies, P.O. Box 29053-00625, Nairobi; [2]Office of the Vice Chancellor, University of Nairobi, P.O. Box 30197-00100, Nairobi; [3]African Union-IBAR-Nairobi, P.O. Box 30786-00100, Nairobi; [4]University of Nairobi, Faculty of Veterinary Medicine, Department of Veterinary Pathology, Microbiology and Parasitology, P.O. Box 29053-00625, Nairobi

***Corresponding author:** jamesnguhiumwangi@gmail.com

Article History: Received: January 25, 2017 Revised: February 10, 2017 Accepted: February 22, 2017

ABSTRACT

A cross-sectional study was carried out in which 300 zero-grazed dairy cows from 32 smallholder dairy units were examined for claw lesions in the peri-urban areas of Nairobi, Kenya. The objective of the study was to determine the characteristics of claw disorders and their association with laminitis. Lameness for each cow was determined by assessing the locomotion score through a prescribed locomotion scoring system. Each cow was restrained in a crush and the claws thoroughly washed and examined for any external claw lesions or disorders including signs of laminitis. About 1-2 mm thickness of the horn of the sole for each claw was trimmed to confirm laminitis by presence of sole haemorrhages. Data was analyzed using Genstat statistic software. Prevalence of laminitis was 70.3% out of which 49.3% was subclinical laminitis and 21.0% was chronic laminitis. Claw deformities found to be strongly associated with chronic laminitis were claw overgrowth ($\chi^2 = 96.69$, r = 0.6, P<0.0001), horizontal grooves ($\chi^2 = 61.27$, r = 0.5, P<0.0001), concave claws ($\chi^2 = 59.39$, r = 0.4, P<0.0001), flat claws ($\chi^2 = 57.87$, r = 0.5, P<0.0001), presence of sole haemorrhages ($\chi^2 = 50.16$, r = 0.4, P<0.0001), double soles ($\chi^2 = 42.57$, r = 0.4, P<0.0001) and white line separation (χ^2=37.78, r=0.4, P<0.0001), while sole bruising was moderately associated with chronic laminitis (χ^2=11.02, r = 0.2, p = 0.0009). Sole haemorrhages were the only lesions strongly (χ^2=89.45, r=0.6, P<0.0001) associated with subclinical laminitis. It was therefore concluded that chronic laminitis was strongly associated with deformity types of claw disorders coupled with diffuse sole haemorrhages, while subclinical laminitis was strongly associated with sole haemorrhages only.

Key words: Lameness, Sole haemorrhages, Claw deformities, Subclinical laminitis, Chronic laminitis

INTRODUCTION

The physiological function of the bovine claw and the pathogenesis of non-infectious claw disorders depend on the state of pododermal microvasculature (Hirschberg and Plendl, 2005). Biologically, laminitis is a systemic disease syndrome that primarily manifests in the claws, hence rightly being referred to as "claw horn disruption" (CHD), which is a term that more appropriately describes its main effects on the claws (Hoblet and Weiss, 2001). Impairment of the corium microvasculature resulting from altered systemic pH, as well as the action of circulating endotoxins and vasoactive substances trigger processes that lead to laminitis (Nocek, 1997; Cook *et al.*, 2004). Laminitis initially develops as insidious subclinical form with delayed manifestation of the clinical symptoms. By the time it gets to the phase of clinical manifestation, the disruptive changes within the claw may already be irreversible (Greenough, 1987; Nocek, 1997; Belge and Bakir, 2005; Nguhiu-Mwangi, 2007; Nguhiu-Mwangi *et al.*, 2008). Apart from causing lameness directly in cattle, laminitis through claw-horn disruption (Hoblet and Weiss, 2001) is also incriminated as a significant contributor to the occurrence of other non-infectious claw disorders such as white line separation, sole ulcers, heel erosion, sole bruising, double soles and sole haemorrhages (Smilie *et al.*, 1991; Nocek, 1997; Belge and Bakir, 2005).

Laminitis may not drastically reduce productivity in dairy cows. However, due to its effects on the quality of the horn of the claws that predispose to the occurrence of other claw disorders and the irreversible damage within the claws, it may eventually have long-term effects on the

Cite This Article as: Nguhiu-Mwangi J, Mbithi PMF, Wabacha JK and Mbuthia PG, 2017. Disorders of the claw and their association with laminitis in smallholder zero-grazed dairy cows. Inter J Vet Sci, 6(2): 64-69. www.ijvets.com

performance of the dairy cow that may subsequently result in the culling of the animal (Nocek, 1997; Belge and Bakir, 2005).

Chronic laminitis in cattle causes gross misshaping of the claw that can easily be mistaken as mere hoof deformity (Rhebun and Pearson, 1982; Greenough, 1987). The claw horn becomes more elongated, flattened, widened and the dorsal wall concave (Greenough, 1987; Nocek, 1997), while horizontal ridges on the dorsal surface of the claw become deeper and more prominent, giving it a rippled appearance (Weaver, 1993; Nocek, 1997). Some of the lesions associated with laminitis can be evident externally, but others are more discernible only after trimming the horn over the sole and the white line (Nocek, 1997; Belge and Bakir, 2005).

It has been stated that laminitis could be the cause or result of some of the non-infectious claw disorders affecting dairy cows (Smilie *et al*., 1999; Nocek, 1997; Belge and Bakir, 2005), but its association with these claw disorders has not been presented in any literature. The purpose of this paper is therefore to show how subclinical and chronic phases of laminitis are associated with other non-infectious claw disorders in dairy cows.

MATERIALS AND METHODS

The study Area

The study was carried out in the urban and peri-urban areas of Nairobi County, Kenya. Nairobi is the capital city of Kenya with an area estimated at 696 square kilometers and a population of over 3.1 million people. It lies between 01°18´S and 36º45´E. It is 1798 meters above the sea level and has an annual rainfall estimated at maximum of 765 mm and minimum of 36 mm with two distinct seasons of March to June and October to December. Nairobi and its surroundings has a high concentration of smallholder zero-grazed dairy units due to its ready market for milk and related milk products.

Selection of the Smallholder dairy Units

A purposive selection of 32 smallholder zero-grazing dairy units was done. Each had 5-20 adult dairy cows. The median number of cows to the units was 10. Purposive selection method was used because of the difficulties from farmers being hesitant to allow their animals to be used for the study; hence it was based on their willingness to participate and to allow their cows to be used. The farms were selected with the assistance of local veterinarians and veterinary paraprofessional workers with whom the farmers were acquainted.

Selection of the cows

A total of 300 dairy cows were selected for the study from the 32 smallholder zero-grazing dairy units. A cow qualified to be recruited into the study population if she had calved at least once. Among the cows that were selected, 40% had 1 or 2 parities and 60% had 3 or more parities. Lame and non-lame cows were included in study. They included the four main dairy breeds, which were Friesian, Ayrshire, Guernsey and Jersey or their cross breeds.

The cows were selected using simple systematic sampling method in which the cows that met the selection criteria in each smallholder zero-grazing unit were serially tagged with numbers 1, 2, 3,-- n, where n was the serial number of the last cow that met the selection criteria in the unit. The assigning of the serial numbers to the cows was randomly done by a farm-worker who was not aware of the research objectives in order to avoid being biased. The investigator then did the systematic sampling of the serially numbered cows in each unit by selecting every alternate cow within the serial numbers. For example cow numbers 1, 3, 5, 7-- n or 2, 4, 6, 8-- n until the last cow within the smallholder zero-grazing unit. Therefore the cows within a zero-grazing unit that met selection criteria were either all picked from only even numbers or only odd numbers. For any smallholder zero-grazing unit that had a total of 5 eligible cows or less, all of them were included in the study, while systematic sampling was done only for units with more than 5 eligible cows.

Examination of the Selected Cows

Each of the selected cows was assessed for lameness using a locomotion scoring system adapted from Sprecher *et al*. (1997). This was followed by each cow being restrained in a crush for examination of claw disorders. In most of the smallholder zero-grazing units, the restraint facilities were poor and therefore only the hind limbs were examined because of the difficulties of accessing the forelimbs while the cows were within these facilities. Moreover, it is clearly known that a higher percentage of claw disorders in cattle affect mainly the hind limbs (Tranter *et al*., 1993), hence examining the hind limb would be a reliable indicator of the claw disorder status.

With the cow well restrained in a crush, each hind limb claw was evaluated on the dorsal surface for signs of laminitis and other disorders. Each limb was raised off the ground by fastening it with a rope tied to an overhead cross-bar, thoroughly washed and the sole examined for any gross lesions. About 1-2 mm thickness of the horn of the sole was trimmed-off using a quittor knife in order to expose any underlying lesions. Trimming was non-invasive because it did not reach the level of the corium, hence no pain was caused to the cows. Foot anaesthesia using 2% lignocaine hydrochloride was applied when examining any cow with painful claw lesions.

Each claw lesion was pre-coded with a specific code number and recorded in designated data entry forms using a simple numerical system. Numerical "1" was used for presence of subclinical laminitis, chronic laminitis or a claw disorder, while numerical "0" for absence of claw disorders (i.e. when the claw was normal). The "1" or "0" entries made it easier and convenient to import the data into computer analysis software. Diagnosis of laminitis was mainly based on presence of haemorrhages occurring on the weight-bearing surfaces of the claws as red or yellow discolourations. The haemorrhages would either be on one or more zones of the weight-bearing surface and would either occur alone or concurrently with other non-infectious claw lesions such as sole bruising, sole ulcer, heel erosion, white line separation and double soles (Nocek, 1997; Belge and Bakir, 2005). Normal-looking claws but with sole haemorrhages were diagnosed as having subclinical laminitis, but those with sole haemorrhages concurrently with other claw disorders/ deformities were diagnosed as having chronic laminitis.

Those with no sole haemorrhages were diagnosed as having only the manifesting disorder.

Location of each lesion on the weight-bearing surface of the claws was classified according to the 6 conventional zones as described by Greenough and Vermunt (1991) as shown in Figure 1.

The distribution of haemorrhages on the weight-bearing surfaces of the claws was categorized according to 5 conventional haemorrhage scores also described by Greenough and Vermunt (1991), which is presented in Table 1.

Data management and analysis

The data were stored in Microsoft Office Excel 2003 (Microsoft Corporation, 2003) spread sheets. They were cleaned, verified and validated to be correct as per the entries from the record sheets. The data were imported into SAS© 2002-2003 (SAS Institute Inc. Cary, NC, USA). Descriptive statistics were computed for each claw disorder per cow and then for the entire study population. The prevalence rate of each claw disorder was calculated independent of other claw disorders. It was calculated as the number of cows (CL) affected by the specific claw disorder divided by the total number of cows (300) examined multiplied by 100 to give the percentage (%).

$$\text{Prevalence (\%)} = \frac{CL \times 100}{300}$$

After descriptive statistics, the test of association between laminitis and the non-infectious claw disorders and the manifesting symptoms was done in three stages. The first stage was Chi-square (χ^2) statistics to test for unconditional associations as well as strength of those associations between laminitis and the other claw disorders at the 5% significant level (P<0.05) and also the correlation coefficient (r) for direction of the associations. The second stage was multiple logistic regression models that factored all the claw disorders against subclinical and chronic phases of laminitis. These also revealed both the strength and direction of the associations using β-estimate (β-e) and odds ratio (O.R.). The third stage was stepwise logistic regression models, which revealed the claw disorders that were invariably associated with the two phases of laminitis. The effects of confounding among the claw disorders in contributing to the associations were dealt with in the analysis through the stepwise selection of the factored claw disorders.

RESULTS

The results of this study revealed that the dairy cows in the smallholder zero-grazing units in the urban and peri-urban areas of Nairobi had a 70.3% prevalence of laminitis of which 49.3% was subclinical and 21% was chronic. There were also relatively high percentages of occurrence of claw disorders other than laminitis, such as haemorrhages (52%), sole bruising (45%), overgrown claws (30.3%), heel bruising (27%), white line separation (18%), horizontal ridges (17.8%), double (underrun) soles (17%) and flattened claw (12%). Claw infections had low percentage (4.7%). The percentages of occurrence of these claw disorders are summarized in Table 2.

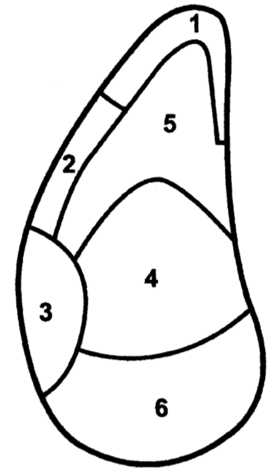

Fig. 1: Zones of the weight-bearing surface of the claws of cattle (Greenough and Vermunt, 1991). **Key to Figure 1:** Zone 1- white zone at the toe, Zone 2 - abaxial white zone, Zone 3 - abaxial wall-bulb junction, Zone 4 – sole-bulb junction, Zone 5 – apex of the sole, Zone 6 – heel bulb.

Table 1: The 5-score scale of sole haemorrhages that occur on the weight-bearing surface of the claws of cattle (Greenough and Vermunt, 1991).

Score	Description
0	No haemorrhages
1	Slight discolouration
2	Moderate discolouration
3	Severe haemorrhages
4	Exposed corium

Table 2: Prevalence of laminitis and the non-infectious claw disorders that were found during prospective cross-sectional study in dairy cows in 32 smallholder zero-grazing units in urban and peri-urban areas of Nairobi, Kenya

Claw disorders	Number of cows (n = 300)	Prevalence (%)
Subclinical laminitis	148	49.3
Chronic laminitis	63	21.0
Sole haemorrhages	156	52.0
Sole bruising	135	45.0
Overgrown claws	91	30.3
Heel erosion/bruising	82	27.3
White line separation	54	18.0
Horizontal ridges on dorsal wall surface	53	17.8
Double (underrun) soles	51	17.0
Flattened claws	36	12.0
Concaved claws	15	5.0
Corkscrew claws	14	4.7
Sole ulcer	8	2.7

NB: Some of the cows had more than one claw disorder per claw, hence the reason for total number adding to more than 300 and prevalence of all claw disorders adding to more than 100%.

Correlation coefficient (r) and chi-square (χ^2) statistics indicated that subclinical laminitis has significant positive and strong association with sole haemorrhages (r = 0.5, χ^2 = 89.45, P<0.0001). The haemorrhages associated with subclinical laminitis were invariably observed in zone 4 of the weight-bearing surface of the claw and this was significant (r = 0.3, χ^2 = 22.83, P<0.001) and occasionally but significantly in zone 6 (r = 0.1, χ^2 = 5.87, P = 0.0154) (Table 3).

Table 3: Correlation between subclinical laminitis and non-infectious claw disorders in dairy cows examined during the prospective cross-sectional study in 32 smallholder zero-grazing units in urban and peri-urban areas of Nairobi, Kenya

Claw disorders	Number of cows with each claw disorder (n =300)	χ^2	r-value	p-value	Direction of association
Sole haemorrhages	156	89.44	0.6	< 0.0001	Positive
Sole haemorrhages in zone 4	104	22.84	0.3	< 0.0001	Positive
Sole haemorrhages in zone 6	42	5.87	0.1	0.0154	Positive
Overgrown claws	91	15.94	-0.2	< 0.0001	Negative
Concaved claws	15	15.37	-0.2	< 0.0001	Negative
Flattened claws	36	14.62	-0.2	< 0.0001	Negative
Corkscrew claws	14	14.30	-0.2	0.0002	Negative
Horizontal grooves	53	6.09	-0.1	0.0136	Negative

NB: Some of the cows had more than one claw disorder per claw, hence the reason for total number adding to more than 300.

Table 4: Results of multiple logistic regression models on associations between subclinical laminitis and non-infectious claw disorders in dairy cows examined in a prospective cross-sectional study in 32 smallholder units in urban and peri-urban areas of Nairobi, Kenya

Claw disorders	β-estimate (β-e)	S.E (β)	Odds ratio (O.R.)	95% C.I.	χ^2	p-value
Sole haemorrhages	3.672	1.367	39.33	2.70-573.14	7.22	0.0072
Sole ulcer	-2.213	1.105	0.11	0.01-0.95	4.02	0.0451
Horizontal grooves	-1.559	0.469	0.21	0.08-0.53	11.07	0.0009
Sole bruising	0.821	0.315	2.27	1.22-4.22	6.77	0.0093
Heel bruising	0.820	0.334	2.27	1.18-4.37	6.05	0.0139

NB: S.E (β) = standard error of β, CI = confidence interval

Table 5: Correlation between chronic laminitis and non-infectious claw disorders in dairy cows in a prospective cross-sectional study in 32 smallholder zero-grazing units in urban and peri-urban areas of Nairobi, Kenya

Claw disorders	Number of cows with each type of claw disorder	χ^2	r-value	p-value	Direction of association
Overgrown claws	91	96.69	0.6	< 0.0001	Positive
Horizontal grooves	53	61.27	0.5	< 0.0001	Positive
Concaved claws	15	59.39	0.4	< 0.0001	Positive
Flattened claws	36	57.87	0.4	< 0.0001	Positive
Corkscrew claws	14	45.71	0.4	< 0.0001	Positive
Double (underrun) soles	51	42.57	0.4	< 0.0001	Positive
White line separation	54	37.78	0.4	< 0.0001	Positive
Sole bruising	135	11.02	0.2	0.0009	Positive
Sole ulcers	8	4.16	0.1	0.0412	Positive
Sole haemorrhages	156	50.16	0.4	< 0.0001	Positive
Haemorrhages zone 2	38	18.23	0.2	< 0.0001	Positive
Haemorrhages zone 3	43	23.45	0.3	< 0.0001	Positive
Haemorrhages zone 4	104	11.05	0.2	0.0009	Positive
Haemorrhages zone 5	26	5.23	0.1	0.0222	Positive
Haemorrhages zone 6	42	4.48	0.1	0.0343	positive

The degree of haemorrhages associated with subclinical laminitis was slight to moderate (score 1 and 2) as described in Table 1. However, through multiple logistic regression and stepwise logistic regression models, it was found that the only claw disorders having significant strong positive association with subclinical laminitis were the occurrence of sole haemorrhages (β-e = 3.672, O.R. = 39.33, p = 0.0072), particularly in zone 4 (β-e = 1.399, O.R. = 4.05, P<0.0001) as shown in Tables 4.

The claw disorders that had weak positive significant association with subclinical laminitis were sole bruising (β-e = 0.821, O.R. = 2.27, p = 0.0093) and heel bruising (β-e = 0.820, O.R. = 2.27, P = 0.0139) (Table 4). The rest of the claw disorders observed were negatively associated with subclinical laminitis as shown by correlation coefficient and β-estimate values (Tables 3 and 4). Overgrown claws, horizontal grooves on the dorsal surfaces of the claws, concave shape of the dorsal wall of the claw, flattened claws, corkscrew claws, double (underrun) soles, white line separation, sole bruising and presence of haemorrhages on the weight-bearing surfaces of the claws were all found to have strong positive significant association with chronic laminitis (Table 5). Unlike in subclinical laminitis, the sole haemorrhages associated with chronic laminitis were found to be severe (scores 2 and 3), which was significant (χ^2 = 50.16, P<0.0001). These haemorrhages were widely distributed in most zones on the weight-bearing surface of the claws and had varied strength of associations with chronic laminitis as follows: zone 2 (χ^2 = 18.24, P<0.0001), zone 3 (χ^2 = 23.45, P<0.0001), zone 4 (χ^2 = 11.05, p = 0.0009), zone 5 (χ^2 = 5.23, p = 0.0222) and zone 6 (χ^2 = 4.48, p = 0.0304) as shown in Table 6. Sole ulcer was weakly but significantly associated (r = 0.1, χ^2 = 4.16, p = 0.0412) with chronic laminitis. Although multiple regression models showed that all these claw disorders were significantly associated with chronic laminitis, stepwise logistic regression models indicated the only claw disorders that were invariably significant with chronic laminitis were overgrown claws (β-e = 3.006, O.R. = 10.93, P<0.0001) and deep horizontal grooves on the dorsal wall of the claws (β-e = 2.196, O.R. = 12.30, P<0.0001).

Table 6: Results of multiple logistic regression models on associations between chronic laminitis and non-infectious claw disorders in dairy cows examined in a prospective cross-sectional study in 32 smallholder zero-grazing units in urban and peri-urban areas of Nairobi, Kenya

Claw disorders	β-estimate (β-e)	S.E. (β)	Odds ratio (O.R.)	95% CI	χ^2	p-value
Sole haemorrhages	4.397	4.056	0.3	0.03-2.45	39.92	< 0.0001
Haemorrhages zone 2	6.040	4.257	13.7	1.11-167.30	19.60	< 0.0001
Haemorrhages zone 3	6.132	4.178	24.8	1.89-327.21	23.63	< 0.0001
Haemorrhages zone 4	61.630	4.194	4.0	0.42-38.45	11.74	< 0.0001
Haemorrhages zone 5	4.990	4.087	7.06	0.60-83.35	5.99	0.0144
Haemorrhages zone 6	7.227	4.253	17.70	1.49-210.79	4.54	0.0332
Overgrown claws	2.402	0.817	11.04	2.23-54.74	93.55	< 0.0001
Flattened claws	3.543	1.037	34.56	4.53-263.74	93.55	< 0.0001
Horizontal grooves	2.553	0.705	12.84	3.23-51.07	60.62	< 0.0001
Sole ulcer	1.573	1.523	4.82	0.24-95.45	4.19	0.0406
Sole bruising	1.840	0.821	6.30	1.26-31.47	10.24	0.0014
White line separation	2.352	0.828	10.50	2.07-53.26	35.08	< 0.0001
Double (underrun) soles	3.035	0.856	20.80	3.88-111.33	39.70	< 0.0001

DISCUSSION

The high prevalence of laminitis and non-infectious claw disorders has been attributed to presence of cow-level and farm-level risk factors prevailing within the smallholder dairy systems in the zero-grazing units (Nguhiu-Mwangi *et al*., 2008). The low plane concentrate feeding in these smallholder dairy systems only predisposes to the occurrences of subclinical and chronic laminitis rather than acute laminitis, which is normally associated with high level of grain feeding.

The results of this study indicate that all cows with subclinical and chronic laminitis invariably had sole haemorrhages as previously documented (Nocek, 1997; Belge and Bakir, 2005). However, the severity of haemorrhages and the zones on the weight-bearing surface of the claw in which the haemorrhages were found varies between subclinical and chronic laminitis. Strong positive association between sole haemorrhages and laminitis could be attributed to changes in pododermal microvasculature that occurs in laminitis, which results in transvascular seepage of serum that manifests as haemorrhagic discolourations in the horn of the sole (Nocek, 1997; Hirschberg and Plendl, 2005). It has further been reported that a number of claw-horn lesions initially develop as haemorrhages of the sole or white line (Vermunt and Greenough, 1996).

The invariable association of haemorrhages in zones 4 and 6 with subclinical laminitis could be explained by the fact that the horn in these zones is thinner than the rest of the zones, hence the haemorrhages that occur in the corium would initially (during subclinical laminitis phase) show on the surfaces of these zones and then later in chronic laminitis phase appear on the surfaces of the zones with thick horn (Nguhiu-Mwangi *et al*., 2007). Furthermore, the initial pathogenesis of subclinical laminitis involves the process of extravascular seepage of blood components into the tubules of the horn of the sole and the heel bulb (Greenough and Vermunt, 1991), with haemorrhages gradually becoming visible on the surface of the sole as time continues, hence sole haemorrhages are a good indicator of subclinical laminitis (Shearer and van Amstel, 2000; Nguhiu-Mwangi *et al*., 2007). This explains the fact that by the time laminitis advances to chronic phase, the haemorrhages are widely spread to most zones of the weight-bearing surface of the claw. Moreover, the deformities that occur in chronic laminitis result in shifting of weight-bearing to the sole-heel junction area which is weaker. This exacerbates microvascular damage in the corium, leading to more severe and widespread sole haemorrhages in chronic laminitis than in subclinical laminitis (Greenough and Vermunt, 1991; Nocek, 1997).

Association of sole bruising and heel erosion with subclinical laminitis may result as a cascade of processes. In these processes, subclinical laminitis causes production of weak horn that is easily bruised or eroded at the sole and the heel. Bruised and eroded horn of the sole and heel become excessively thin, allowing easy transmission of pressure to the corium from the weight of the animal against treading ground particularly in zones 4 and 6 (Shearer and van Amstel, 2000). This causes microvascular damage within the corium, which predisposes to occurrence of subclinical laminitis, subsequently leading to production of weak horn. This cascade cycle continues.

Claw deformity disorders shown to have positive strong association with chronic laminitis can probably be attributed to the disruption of the growth of keratinized horn during laminitis, which subsequently alters the shape of claws, thus making them longer, flattened and broadened (Nocek, 1997). The dorsal angle becomes markedly reduced, while the dorsal wall becomes shaped to concave (Weaver, 1993). It is this misshaping of the claws that makes chronic laminitis be mistaken for claw deformity (Rhebun and Pearson, 1982; Greenough, 1987) with the affected cow developing abnormal gait and lameness. Presence of any of these claw shapes concurrently with characteristic rippled appearance of the dorsal surface due to prominent horizontal grooves (Weaver, 1993; Nocek, 1997), could positively indicate presence of chronic laminitis. Moreover, laminitis is incriminated as a predisposing cause for development of claw deformities (Greenough, 1987; Weaver, 1993). Conversely, the resulting misshaping of the claws enhances more laminitis by altering the treading angle with more weight-bearing on the softer parts of the sole towards the heel, which in turn leads to transmission of pressure into the underlying corium that can result to trauma.

The association of some claw conditions such as double (underrun) soles, white line separation, sole bruising, white line separation, sole ulcer and heel erosion with chronic laminitis is probably related to the fact that chronic laminitis is reported to be a predisposing cause to these conditions (Nocek, 1997; Smilie *et al*., 1999; Belge and Bakir, 2005). Severe microvascular haemorrhages in the corium leads to accumulation of blood/serum between the corium and the horn of the sole. This eventually causes separation of the horn from the underlying corium. The new inner horn produced by the corium is separate from the old outer horn and this results in double soles with outer old horn and inner new thin horn (Nocek, 1997). The formation of double soles is a process that occurs in chronic laminitis and not in subclinical laminitis, which explains its strong association with chronic laminitis.

Similarly, the white line zone is naturally the weakest point of impact on the weight-bearing surface of the claws and easily succumbs to avulsion under pressure of the weight of the animal against the treading ground (Baggott and Russell, 1981). During laminitis, the white line zone becomes even more vulnerable to avulsions owing to softening and impairment of the horn, which is more prevalent in chronic laminitis (Nocek, 1997; Smilie *et al*., 1999; Belge and Bakir, 2005).

The cows found with sole ulcers in this study had very advanced laminitis. It has been reported that in chronic laminitis, the pedal bone changes its configuration and drops distally, compressing the corium towards the horn of the sole. The horn then gives way at the axial part of zone 4 and 5, hence resulting in sole ulcer that exposes the corium to protrude externally, which explains how sole ulcer is associated with chronic laminitis (Baggott and Russell, 1981; Hull, 1993; Nocek, 1997).

It is therefore concluded from the findings of this study that non-infectious claw disorders in cattle are strongly associated with laminitis. The subclinical phase of laminitis being strongly and invariably associated with sole haemorrhages particularly in zones 4 and 6 of the weight-bearing surface of the claw, while chronic laminitis being strongly associated with deformities that cause disorders of the claws. However, laminitis can be the "cause" or the "effect" of non-infectious claw disorders. The main risk factors of laminitis and non-infectious claw disorders in the dairy cows in the smallhoder zero-grazing units are comprehensively described in a previous publication (Nguhiu-Mwangi *et al*., 2008).

Acknowledgements

The authors are grateful to the Deans Committee of the University of Nairobi for financial support to carry out this study. We also appreciate the farmers who gave permission for data collection from their smallholder zero-grazing units.

REFERENCES

Baggott DG and AM Russell, 1981, Lameness in cattle. Brit Vet J, 137: 113-132.

Belge A and B Bakir, 2005, Subclinical laminitis in dairy cattle: 205 selected cases. Turk J Vet Sci, 29: 9-15.

Cook NB, KV Nordlund, and GR Oetzel, 2004, Environmental influences on claw horn lesions associated with laminitis and subacute ruminal acidosis in dairy cows. J Dairy Sci, 87: E36-E46.

Greenough PR, 1987, An illustrated compendium of bovine lameness. Part I. Modern Vet Prac, 68:6-9.

Greenough PR and JJ Vermunt, 1991, Evaluation of subclinical laminitis in a dairy herd and observations on associated nutritional and management factors. Vet Rec, 128: 11-17.

Hirschberg RM and J Plendl, 2005, Pododermal angiogenesis and angioadaptation in the bovine claw. Microsc Res Tech, 66: 145-155

.Hoblet KH and W Weiss, 2001, Metabolic hoof horn disease. Claw horn disruption. Vet Clin North Amer. Food Anim Prac, 17:111-127.

Hull BL, 1993, Sole abscesses, vertical wall cracks, horizontal wall cracks, Rusterholz ulcer. In: Current Veterinary Therapy 3. Food Animal Practice. Howard JL (ed.). WB Saunders, Philadelphia, pp: 864-866.

Nguhiu-Mwangi J, 2007, Characteristics of laminitis and associated claw lesions in dairy cows in Nairobi and its Environs. PhD Thesis, University of Nairobi.

Nguhiu-Mwangi J, PMF Mbithi, JK Wabacha, and PG Mbuthia, 2007, Prevalence of sole haemorrhages and its correlation with subclinical and chronic laminitis in dairy cows. Bull Anim Hlth Prod Africa, 55: 232-242.

Nguhiu-Mwangi J, PMF Mbithi, JK Wabacha, and PG Mbuthia, 2008, Factors associated with the occurrence of claw disorders in dairy cows under smallholder production systems in urban and peri-urban areas of Nairobi, Kenya. Vet Arhiv, 78: 343-355.

Nocek JE, 1997, Bovine acidosis: implications on laminitis. J Dairy Sci, 80: 1005-1028.

Rhebun WC and EG Pearson, 1982, Clinical management of bovine foot problems. J Amer Vet Med Assoc, 1982: 181: 572-579.

Shearer JK and S van Amstel, 2000, Lameness in dairy cattle. In: Proceedings of 2000. Kentucky Dairy Conference. Lexington. pp: 1-11. http://www.uky.edu /Ag/AnimalSciences/dairy/dairyconference/dc07

Smilie RH, KH Hoblet, WP Eastridge, WP Weiss, GL Schnitkey and M L Moeschberger, 1999, Subclinical laminitis in dairy cows: use of severity of hoof lesions to rank and evaluate herds. Vet Rec, 144: 17-21.

Sprecher DJ, Hostetler JB and JB Kaneene, 1997, A lameness scoring system that uses posture and gait to predict dairy cattle reproductive performance. Theriogenology, 47: 1179-1187.

Tranter WP, RS Morris, IR Dohoo and NB Williamson, 1993, A case-control study of lameness in dairy cows. Prev Vet Med, 15: 191-203.

Vermunt JJ and PR Greenough, 1996, Sole haemorrhages in dairy heifers managed under different underfoot and environmental conditions. Brit Vet J, 152: 57-73.

Weaver AD, 1993, Aseptic laminitis of cattle, interdigital and digital laminitis, interdigital phlegmon (interdigital necrobacillosis). In: Current Veterinary Therapy 3. Food Animal Practice. Howard, JL (ed.). WB Saunders. Philadelphia, pp: 867-870.