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Chapter 3

Indicators of Poor Welfare in Dairy Cows Within Smallholder Zero-Grazing Units in the Peri-Urban Areas of Nairobi, Kenya

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Additional information is available at the end of the chapter

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1. Introduction

Animal welfare lacks a good universal definition and a satisfactory distinction from the term "well being". However, a consensual definition is essential for practical, legislative and scientific purposes. Without a clear definition, animal welfare cannot be effectively studied or conclusively assessed to provide remedial measures to its violation [1-3]. Animal welfare is therefore defined as the ability of an animal to interact or cope comfortably with its environment, resulting in satisfaction of both its physical and mental state [4-6]. This satisfaction enhances expression of normal behavioural patterns by the animal [7,8].

In the context of welfare, "environment" refers to internal factors (within the animal) and external factors (in the animal's physical environment) to which the animal responds with its physiological and psychological systems [6,9]. In contrast, animal "well being" is defined as the animal's perception of its state in trying to cope with its environment [1,5]. Concisely, animal "well-being" refers to the current state of the animal, but animal welfare is a more general term referring to past, present and future implications of the animal's state [10].

The assessment of animal welfare is base on the provisions of five freedoms, which include:

a. Freedom from hunger and thirst, availed through provision of ready access to water and a diet to maintain health and vigour,

b. Freedom from pain, injury and disease, availed through disease prevention and treatment,

c. Freedom from fear and distress, availed through avoidance of conditions that cause mental suffering,

d. Freedom to have normal behaviour patterns, availed through provision of sufficient space and appropriate physical structures,

e. Freedom from thermal or physical discomfort, availed through provision of a comfortable environment.

Knowledge of animal physiology, animal behavior and animal needs based on the five freedoms is paramount in assessing as well as enforcing animal welfare. Animals need to be provided with amble comfort related to these five freedoms. They should be kept in housing or environments that will minimize adverse climatic variations or exposures to extremes of cold or heat, rain, strong continuous winds and direct solar exposures. Appropriate conditions minimizing trauma, development of lesions and disease outbreaks are essential. Continuous availability of water and provision of adequate wholesome feeds, which consist of balanced constituent rations supplying specific nutritional needs to the body, is required. Animals should be provided with housing conditions and environments that allow them to display natural behavior such as unhindered movement, free expression of oestrus or heat symptoms necessary for mating or insemination in order to have continued sustainable reproduction, social relationships that include animal-to-animal and animal-to-human cordial interactions; and finally minimizing or preventing any causes of suffering as much as possible [11].

Smallholder dairy farming occupies a vast proportion of agricultural production and the main livelihood of the people in most developing (third world) countries particularly in Africa, Asia and South America. In Kenya, smallholder zero-grazing dairy units contribute about 80% of the national commercial dairy herd [12] and over 70% of all the marketed milk [13-16]. Each of the Kenyan smallholder zero-grazing dairy units has 2 to 10 milking cows most of which are exotic breeds (Friesian, Ayrshire, Guernsey, Jersey or crosses of these exotic breeds). Some smallholder farmers, who have better financial resources, manage to have up to 20 or more cows. The cows are raised on small plots of land measuring between 0.25 to 2 acres. Only few smallholder farmers would have land measuring a maximum of 5 acres. The Kenyan smallholder zero-grazing dairy units are unique because they have varied designs and management practices. They vary in housing designs, nutritional and management protocol from unit to unit to the extent that they can correctly be referred to as zero-grazing "subunits" that are devoid of a consistent production system. The nutritional regimes and management practices not only vary from unit to unit, but also within the same unit from time to time [17]. The cows in these units are invariably zero-grazed [13,18] and have sub-optimal production [14,18,19], which is attributed to a number of constraints such as inadequate feeding, poor nutrition, substandard animal husbandry, lack of proper dairy farming facilities that include inadequate space to move and interact freely. All these factors predispose the cows to diseases and other stressful conditions [14,20,21].

A high number of smallholder zero-grazing dairy units are concentrated in the peri-urban areas owing to availability of ready market for milk and milk products among city and town residents [13,18]. The high and rapid population growth in developing countries has led to a reduction of agricultural lands that support the livelihood of the people. This has triggered a shift from fewer large-scale farms to numerous intensified smallholder production units in an endeavor to maximize economic profits [22]. The resulting low income following land subdivision to smallholder enterprises, affects the livelihood of majority of the citizens in the involved countries [16,21]. The low income poses financial challenges that make it difficult to afford adequate dairy farming facilities, hence the progressively deteriorating husbandry standards that precipitate stressful conditions, which further exacerbate poor welfare of the dairy cattle in these smallholder units. These interacting multiple factors, cause a vicious circle of events that eventually have negative effects on physiology, behavior, disease susceptibility and productivity of the dairy cows [23,24]. The welfare of food animals has become a major concern to consumers of animal products in many parts of the world. Consumers of products such as meat and meat products, milk and eggs are demanding to know how the animals from which these products have been obtained are handled with respect to animal welfare ethics [25,26].

Dairy cattle housing should provide the animal with protection from harsh environmental extremes [27]. Good housing systems are those that are well designed for ease of management and maintenance at all times [27-29]. It is proposed that all confinement for animals should be constructed and operated to meet the legal requirements for protection of the animal as well as maintain high quality animal products [30]. Good animal housing systems are those that enhance provision of all the five freedoms that an animal should have to satisfy its welfare [28,31]. If these basic needs cannot be met in the animal house, then health, welfare and production of the animal will be compromised. These concerns are particularly critical in the smallholder zero-grazing systems, in which dairy cows are confined throughout their growth and production life. Naturally, cattle are grazing animals and therefore pasture-grazing is a more welfare-friendly system because it allows free expression of normal animal behavior compared to the restricted indoor zero-grazing systems. Conversely, high yielding dairy cows may not get all their nutritional demands from grazing only, and this may compromise their welfare with regard to nutrition. This means that both zero-grazing and pasture-grazing systems have positive and negative effects on the welfare of dairy cattle [32]. However, zero-grazing systems demand more articulate precision in design, construction and management because they have a higher inclination to compromising welfare of the housed dairy cattle. Although pasture-grazing allows free expression of normal cattle behavior and provides sufficient comfortable lying space, the pasture forage has lower nutritional value than the high plane feeding of the zero-grazing units and therefore cattle in pastures may spent long hours grazing depending on the quality and amount of forage in the pasture, hence less time resting, which influences the resting aspect of welfare negatively [33]. In comparison, indoor housing systems provide high level feeding and increase intake rates, thus fulfilling nutritional requirements faster, reducing eating times, leaving more time for cattle to rest and ruminate [34]. However, indoor housing systems have limited space allowance, which increases competitive aggressive behavior within the herd [35], restriction of natural foraging behavior and opportunity to feed selectively [36], negative effects on the cow comfort [33], and high incidence of diseases such as lameness and mastitis

[37,38]. All these factors in the indoor housing have adverse effects on the welfare of cattle. In Kenya, the practice of zero-grazing dairy production is inevitable owing to the reduced land sizes. Hence, the importance of drawing reliable direct indicators of poor welfare existing in these zero-grazing systems in order to introduce corrective remedial measures, particularly in relation to designing of the construction of welfare-acceptable and cow-comfortable zero-grazing units no matter how simple or cheap.

Improvements of animal welfare may be achieved through (a) assessment of animal welfare, (b) identification of risk factors potentially leading to welfare problems and (c), interventions in response to the risk factors. Improvements can be enhanced by directly dealing with the risk factors of animal welfare within the farming unit. Therefore, there must be good reliable way of measuring or assessing whether or not poor animal welfare exists within the practiced farming systems. In this process the animal based parameters help us to identify the animal's response to the system, and therefore indicating the negative impact of the potential risk factors existing within the farming system [39]. Traditionally, farm animal welfare assessment has focused on the measurement of resources provided to the animal such as housing-and-housing design criteria [40,41]. Although such indirect resource-based welfare assessment criteria are quick, easy and have some degree of reliability, basing the welfare verdict solely on their findings may not necessarily mean that the welfare of the animals is good or poor. Other husbandry aspects that affect animal welfare are management practices and the human-animal relationship, but their measurement may be more difficult. However, the provision of good management and environmental resources does not necessarily result in a high standard of animal welfare. Direct animal-level parameters such as health or behavior can be taken as indicators of the animals' feelings and a measure of bodily state of the animal. These are more reliable because they indicate how the animal has been affected by some factors existing within the proximate environment or housing system of the animal and how it has responded to these factors. Welfare assessment should therefore be based primarily on such animal-related parameters. In practice, resource or management-based parameters should also be included in an on-farm assessment protocol when closely correlated to animal-associated measurements and because they can form the basis for the identification of causes of welfare problems [39]. It is however challenging to select and develop reliable and at the same time feasible measurements for on-farm assessment protocols. Attempts to create an operational welfare assessment protocol primarily relying on animal-related parameters have mainly been made with regard to dairy cows [42-45].

Animal-level indices for on-farm welfare assessment can be divided into ethological or behavioural and pathological or health parameters; physiological indicators are mostly unavailable for feasibility reasons. Ethological parameters include individual animal behavior, animal-to-animal interaction, human-animal interaction, agonistic behavior and other abnormal behavior. The commonest animal health indicators of cattle welfare are lameness, external body injuries, disease incidence, body condition score and body cleanliness. The main welfare health problem in cattle is lameness, particularly caused by lesions resulting from disruptions of the horn of the claw predisposed by factors such as concrete floors, zero-grazing systems and uncomfortable stalls [45,46]. One of the main shortcomings that exacerbates welfare problems of lameness in cattle and this would even be more prevalent in zero-grazing systems in developing countries, is the lack of valid and reliable lameness diagnostic methods. There is generally lack of sensitive methods of recognizing early change in the gait of lame cattle [44,47,48]. The most reliable and sensitive way of detecting early changes in gait for diagnosis of lameness is the use of automated gait-scoring computer aided systems, which are very scarcely used all over the world [49]. Moreover, these automated facilities are expensively unaffordable to the poor smallholder farmers in developing countries such as Kenya. Claw disorders particularly those related to laminitis are highly prevalent in smallholder zero-grazing dairy units and subunits in the peri-urban areas of Nairobi, Kenya and probably in other parts of Kenya with similar production systems [50]. These have been found to be highly associated with housing and management factors within the zero-grazing units [17,50]. This high prevalence of claw lesions together with a high prevalence of injuries or signs of injuries in specific parts of the body as well as soiling and body condition scores of dairy cows in the smallholder zero-grazing units in the peri-urban areas of Nairobi, Kenya [51,52] was thought to be reliable indicators of the state of welfare of dairy cattle particularly when correlated with the prevailing zero-grazing conditions.

Parameters used to assess animal welfare should be able to inform us about the state of welfare. Three requirements are essential for parameters or indicators used to assess animal welfare. These include: “validity”, which asks the question, “what does the parameter in consideration tell us about the animal’s welfare state?”; “reliability”, which considers inter-observer reliability and asks the question, “do different observers see the same thing?” and the third requirement is “feasibility”, which considers the practical aspects of doing the recordings, asking the questions, “how easy is it to record the parameter?, how long does it take to assess the parameter?, and what equipment is needed for measuring the parameter?” [39].

There is a high likelihood among farmers with zero-grazed dairy cows to focus more on whatever it takes to cause their cows produce as much milk as possible at the expense of the health and welfare considerations of the animal. High milk yielding cows often develop a compromise of energy-balance deficits, which infringes on their welfare. As a result of energy deficit stress, these dairy cows become easily susceptible to metabolic and reproductive problems [53]. The uniqueness of the zero-grazing systems in Kenya which consists of subunits that are inconsistently varied in designs, in feeding regimes in relation to feed types, quality and quantity, as well as substandard management practices makes them a rich source of information on management of welfare of cattle. Information acquired from studies in these smallholder zero-grazing subunits will serve to demonstrate how animal-level parameters can be useful in indicating the welfare state of the dairy cattle and how these indicators are associated with the housing design, feeding and management practices in these varied and substandard zero-grazing units and generally suggest possible remedial welfare improvement measures.

The intent of this paper is to present the results from two studies carried out at different times with collection of data from some of the zero-grazing units in the same area but looking at separate objectives. These studies dealt with assessment of the state of welfare of dairy cattle in those units and the prevalent risk factors for poor welfare. In particular, it was planned 1) to determine the role of claw lesions in predicting the welfare of zero-grazed dairy cows with respect to housing designs, floor type, feeding and management practices in the peri-urban areas of Nairobi Kenya; 2) and to determine the role of body injuries, body soiling and body condition scores in predicting the welfare of zero-grazed dairy cows with respect to housing designs, floor type, feeding and management practices in the peri-urban areas of Nairobi Kenya.

2. Material and methods

2.1. Assessment of animal welfare

Assessment of animal welfare can be done using both animal-based and environmental-related parameters (which includes housing factors and management factors) [40,44,54]. These parameters can be evaluated using indicators that show the state of the animal such as production performance, physiological, pathological, ethological and integrated factors [3,55].

2.1.1. Production performance as an indicator of welfare

The production performance indicators of animal welfare are growth rate, productivity, reproductive output and duration of productive life of an animal [1,56]. Many researchers have stated that if the welfare of an animal is good, then production will be optimal [1,57,58]. However, high productivity may not necessarily be an indicator of good welfare, nor low productivity an indicator of poor welfare [46]. For example, dairy cows with high milk production are likely to be predisposed to increased lameness, mastitis, damaged udder ligaments, infertility and problems at parturition [59,60]. It has been suggested that milk yield can be used as an on-farm indicator of animal welfare [44].

2.1.2. Physiological indicators

The main physiological indicators of welfare are hormone levels from the pituitary and adrenal glands and the changes induced on target organs by these hormones such as tachycardia, blood pressure, hyperglycaemia, lymphocytosis and eosinopaenia [3]. The advantages of physiological indicators of animal welfare are that their measurements use reliable analytical methods [61,62] that are less invasive within the body [6]. Cortisol levels indicate the degree of stress experienced by an animal [63]. However, other normal activities such as mating, can lead to an increase in stress hormone levels. Moreover, results of different studies on stress hormones have been inconsistent and hence their reliability as indicators of animal welfare is doubtful [64]. In spite of these arguments, the use of stress hormone response as a welfare indicator has gained credibility because it can easily be measured [65].

Methods used as welfare indicators should not be generalized to all species but rather considered within species, and the search for more reliable methods should be intensified [66]. It has been shown that heart rate, adrenal function, brain biochemistry, regulatory responses

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and the suppression of functions are the main physiological responses to short-term welfare problems [5]. Adrenocorticotropic hormone (ACTH) challenge technique and the immune response provide measurement of long-term welfare problems. In bovines, the heart rate has been found to be a suitable parameter for studying dairy cow response to stress [67,68].

2.1.3. Pathological indicators

Pathologic signs are widely accepted as indicators of poor welfare because they are a manifestation of current suffering of the animal [3]. Reduction in health could be a reflection of compromised welfare; hence animal-level parameters are likely to be the best welfare indicators [42,44]. Clinical signs of disease and injuries are the animal-level parameters associated with reduced health that may be useful indicators of poor animal welfare [5,44]. Lameness, skin injuries and measurement of immune function are the most commonly used pathological indicators of poor welfare in dairy cattle [3,44]. However, absence of injury and disease is not sufficient proof of good animal welfare [69]. Therefore, pre-pathological state of the animal which includes suppressed immunity (hence increasing vulnerability to diseases), reduced ability to reproduce and cessation of normal growth, tend to suggest that the animal is already suffering and these factors could be used as indicators of poor welfare [70,71]. Assessment of pre-pathological immunity state is based on white cell counts in blood or milk [72]. However, results obtained from such studies have been inconsistent [63]. Some of the short comings of these studies are that pre-pathological conditions do not necessary lead to adverse effects on animals [3] and also animal welfare may be impaired at the time of pre-pathological assessment [66].

2.1.4. Ethological indicators

Behaviour is an important indicator of animal welfare. It can be measured and recorded with minimal animal disturbance [73]. However, the main difficulty is the understanding of animal's normal, natural or ideal behavior in order to quantify abnormal behaviour [74]. Behavioural indicators of poor welfare include the inability of the animal to carry out normal behaviour and the exhibition of a persistent undesirable action by a minority of the population that could be termed as abnormal behaviour [3,61]. Abnormal animal behaviour is classified into five categories which include: detrimental behaviour that causes injury, sham behaviours that are performed in the absence of adequate substrate or environmental stimuli, apathetic behaviour that is a reduced attentiveness towards external stimuli, escape behavior that manifests as a desire to leave the confined environment and redirected behaviour that may ritualize into stereotypes [75]. Abnormal behaviour is damaging to the animals [76]. Expression of abnormal behaviour is a sign that an animal has problems adapting to its environment [3]. It may be an expression of the level of distress that the animal is experiencing [6].

2.1.5. Bovine ethology

Cattle are referred to as group animals because they express synchronized behaviour within the herd [73]. On daily basis, cows confined and housed spend 5-6 hours eating, 4-9 hours ruminating and 11-11.5 hours lying down [3,77,78]. However, the behavioural patterns may vary according to the type of housing system in which they are [79,80]. Friesian cows under cubicle system were found to have lying time of 13.7 hours/day compared to 6.5 hours/day in open out-door systems [81]. Reduced lying time has been found to exacerbate the incidence of claw lesions [82]. Prolonged standing causes cows to expend more energy and exposes hooves to longer periods on slurry, which may increase incidence of lameness [17,83]. Eating behaviour is the most characteristic indication of the state of comfort in animals, that is, the degree to which the biological requirements of animals are met [84]. It has been observed that feeding cows with smooth quality fodder and high concentrates is very beneficial compared to rough fodder. The explanation here is that reduced eating time reduces standing time of the animals [84]. Increased milk yield has been observed in cows with longer lying times. This is thought to be due to increased blood supply to the udder through the milk vein, increasing nutrient supply to the udder [86,87].

2.2. Study procedures

2.2.1. Study area

The study was carried out in the peri-urban areas of Nairobi, Kenya. Nairobi is the capital city of Kenya with an area of 696 square kilometers and a population of over 2.1 million people. It is surrounded by a fertile peri-urban agricultural region lying between 01º 18′S and 36º 45′E, and 1798 meters above sea level. It has an annual rainfall estimated at 765 mm maximum and 36 mm minimum in two distinct seasons (March to June, and October to December). The rest of the months of the year are moderately dry. The cold months are beginning of July to the end of August with temperatures ranging from 18º C to 21ºC at day time and 11ºC to 15ºC at night time. The North-Western side of Nairobi is the coolest with high humidity, while the Eastern side is the warmest with very low humidity. The region has a high concentration of zero-grazed smallholder dairy units owing to its ready market for milk and milk-related dairy products.

2.2.2. Study design

Study 1 – Can claw lesions be used for predicting welfare of zero-grazed dairy cows?

The study consisted of a cross-sectional study in which each zero-grazing unit was visited once and each cow included in the study was examined only once. Even when a zero-grazing unit was visited more than once, no cow was examined twice. Thirty-two smallholder zero-grazing dairy units were purposively selected from those with median cow number of 10 (ranging from 5 to 20 adult cows). It was difficult to get enough farmers allowing their cows to be used for the study, hence another major criteria for inclusion of the zero-grazing dairy units was the willing smallholder farmers. Selection of the zero-grazing dairy units was facilitated by local veterinarians and animal health technicians with whom the farmers were more acquainted. A total of 300 dairy cows that included Friesians 76% (n=228), Ayrshires 20% (n=60) and 4% (n=12) being Guernsey and Jersey crosses were recruited from the 32 smallholder zero-grazing units. Cows that were included in the study had calved at least once, from which 40% were in their first and second parities and 60% in their third and fourth parities. Both lame and non-lame cows of any of the breeds were included in the study group. Selection of the cows meeting the inclusion criteria was performed as previously described [50]. Briefly, in each smallholder unit, cows that met the selection criteria were isolated from the rest and serially numbered as 1, 2, 3, to S, where S was the last serial number depending on the total number of cows isolated in that unit. To avoid biased sampling, a farm worker numbered the isolated cows. From the serially numbered cows, the investigator, starting with either serial number 1 or 2, systematically selected every second cow in the series. For example in the series S1, S2, S3, S4, S5, S6, S7, S8, S9, and S10, if the first cow selected was S1 the next one selected serially would be S3, S5, S7 and S9 respectively, thus all odd serial numbers. But if the first cow selected was S2, then the next ones selected serially would be S4, S6, S8 and S10 respectively, thus all even serial numbers. If the first cow selected in one smallholder unit was serial number S1, then in the next smallholder unit, the first cow selected would be serial number S2. This selection of the first cow was alternated between odd and even numbers from one smallholder unit to the other until investigation in all the 32 units was completed. Therefore, the cows selected in any individual smallholder unit were either all with odd or all with even serial numbers.

Data on claw disorders were collected by examining only the hind claws of each cow, due to poor restraint facilities that make it difficult to examine the fore limbs. General observation of gait for signs of lameness was done first. The floor state and small sizes of the units made the examination for lameness quite restrictive, and it needed an experienced veterinarian to conclude on whether a cow was lame or not, particularly when mildly lame. Each cow was restrained in a standing posture in the crush or the sleeping cubicle. Lifting of one hind limb at a time was done using a rope tied to an overhead pole or cross-bar. After washing with soap and water, claws were examined for any lesions, particularly on the weight-bearing surface. About 1-2 mm thickness of the horn of the sole was trimmed-off using a sharp quittor knife to expose any underlying lesions. Trimming did not reach the level of the corium and therefore was non-invasive and non-painful to the cows. In case of painful claw condition, local analgesia using 2% lignocaine hydrochloride and a tourniquet at mid-metatarsus was applied. The lesions found on each cow were recorded.

Data on cow-level factors were collected by the first author (as interviewer) administering questionnaires either to farmers, or the stockmen managing the cows in the zero-grazing units (as respondent interviewees) before examination of the cows. The data which included breed, parity, milk yield per day, and lactation stage were pre-coded and recorded in the questionnaires. The questionnaires were structured simple "Yes" and "No" and "I do not know" responses to minimize variations and information bias from the respondents. Data on farm-level factors were collected during visitation to each of the 32 farms. Some data (housing and stall design, presence and number of cubicles, type of cubicle bedding and floor, presence or absence of a curb, and lunging space, and adequacy of feeding space) were collected through observation. Other data such as kerb height were collected through measurements, while the rest (frequency of concentrate feeding, mineral supplementation, type of fodder, and frequency of slurry removal from the walk-alleys were collected by the first author interviewing the farmer, or stockmen. All the information collected from the zero-grazing units by measurements and by interview on the questionnaires was recorded in data collection sheets in codes allocated for each parameter.

Study 2 - Are body injuries, body soiling or body condition scores useful in predicting the welfare of zero-grazed dairy cows?

In this cross-sectional study each zero-grazing smallholder unit (defined as one with a minimum of 3 and a maximum of 16 adult dairy cows) was visited once for the whole study period. A total of 80 smallholder zero-grazing dairy units were included in the study (It is important to note that apart from these zero-grazing units being in the same area as those in study 1, none of them was included in both studies). Selection of the 80 zero-grazing units to include in study 2 was performed as for study 1. Furthermore, for logistical reasons units were also chosen based on the farmers' willingness to co-operate and to allow their dairy units to be used in the study.

The animals included for examination were adult dairy cows, whether in milk or dry. In any smallholder unit that had 5 or less adult cows, all the adult females were selected for examination. In those having more than 5 adult cows, only 5 were selected for examination. The five were selected using a simple systematic sampling method, similar to the one used in study 1. In all the 80 smallholder units, a total of 306 dairy cows were selected for examination.

In each unit, the selected cows were closely examined for signs of external body injuries. Injuries were recorded according the body regions on which they occurred. These body regions were mainly those that were prone to injury from housing structures and they included the neck, brisket, carpal joint area, rib-cage area, area over the tuber coxae, ischial area, hock joint area, teats and udder. The main signs that were considered as indicators of body injuries included external presence of raw wounds, ulcerations, swellings, scars, localized hair loss and skin hyperkeratosis/callus-like formation.

2.2.3. Evaluation of housing and animal management

Some of the factors of housing design and the quality of construction finishes were evaluated only by visual observation while others were assessed by taking actual measurement of the dimensions. Those factors that were evaluated only by visual observation included types and state of roofing, walls, and floor (mainly at the walk alleys and cubicles), as well as types and adequacy of feed bunks/troughs, presence or absence of neck-bars over the feed bunks and presence or absence of cubicles. Presence and type of cubicle bedding was also observed. Those housing factors that were evaluated by measuring actual dimensions included height of neck-bar from the upper edge of the feed bunk, width of the walk alleys from the rear edge of the cubicles to the front (near edge) of the feed bunk as well as width and length of the cubicles. Besides the physical aspects of the facilities, other animal-related aspects were also evaluated. The stocking density was evaluated by calculating cows to cubicle ratios. Presence of slurry on the walk alleys and gross body soiling of the cows was noted. Frequency of slurry removal was obtained through questionnaires. The individual body condition score (BCS) was evaluated on a simple scale of 1 to 5, which included half points that separated between the unit body condition scores. BCS 1 meant poor body condition, BCS 2 represented moderate body condition, BCS 3 represented good body condition, BCS 4 meant a fat cow, and BCS 5 represented a very fat cow. The farmers' and stockmen's perspective or knowledge on animal welfare was evaluated through interviewing them as respondents. All the data were recorded in data collection sheets.

2.2.4. Data management and analysis

The data representing each parameter information was coded with a specific numerical code for each parameter for the purposes of entry into Microsoft Office Excel sheets. The data were imported into SAS© 2002-2003 (SAS Institute Inc., Cary, NC, USA). Descriptive statistics were computed for cow-level and farm-level factors. From study 1, the prevalence rate of each claw disorder was calculated independent of other claw disorders. The prevalence of each claw disorder was calculated as the number of cows (CL) affected by the specific claw disorder divided by the total number of cows (300) examined, then multiplied by 100 to make it a percentage.

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

Chi-square (χ^2) statistics were used to determine unconditional associations between all risk factors and the claw lesions. An association was considered significant at the level of $P<0.05$. Multiple logistic regressions were done through a step-down regression in which the risk factors that made the least variation to the occurrence of the claw lesions were eliminated one at a time through consideration of their odds ratios. Only the factors that were found to influence the occurrence of claw lesions significantly were retained in the model. The effects of confounding the risk factors were dealt with in the analysis but they were minimal because of some similarities of the management in the smallholder farms.

From study 2, prevalence of body injuries were calculated as simple percentages of occurrences of lesions, injuries and the risk factors. By use of SAS (Statistical Analytical System) descriptive statistics were generated and tests of simple associations between zero-grazing unit-level and animal-level factors were done using Chi Square (χ^2) statistics at $p<0.05$ significance level. Chi Square values were determined using 2x2 contingency tables. In these associations, the Chi Square calculations were determined by evaluating each risk factor (variable) against each welfare predictor (outcome) on the animal. 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.

3. Results and discussion

3.1. Lameness and claw disorders as indicators of welfare

A high prevalence of acquired claw disorders was encountered in the cows from both studies, but higher in the first than the second study. The difference can be attributed to the fact that in study 1 the claws were trimmed during evaluation, while in study 2 only observation for lameness was done without trimming for specific examination of the claws. In study 1, out of 300 cows the prevalence was 88% (n=264) of which 69% (n=182) were subclinical (the affected cows were not lame), the diagnoses being made through trimming of the claws; and 31% (n=82) were clinical (the affected cows were lame), with animals showing evidence of lameness. About 70% (n=211) of the cows had laminitis, which was either sublinical laminitis in 49% (n=148) diagnosed by presence of sole haemorrhages seen after trimming a thin layer of the horn of the sole, or chronic laminitis in 21% (n=63) diagnosed by presence of extensive diffuse sole haemorrhages coupled with various degrees of claw deformities. The Pictorial description of the claw lesions and the associated predisposing causes was detailed in a previous publication [50]. In study 2, lame cows were encountered in 73% (n=58) of the 80 zero-grazing units, for which the total prevalence was 35% (n=107) among the 306 cows examined. The lameness was caused by different claw disorders, which included various degrees of claw deformities ranging from moderate claw overgrowth to severe twisting of the claws. Lameness caused by lesions in proximal parts of the limbs (proximal to the claws) had very low prevalence of less than 2% in both studies; most of these lesions did not cause any lameness.

3.2. Body injuries as indicators of welfare

Injuries on body surface were found distributed in various body regions among the 306 cows that were examined from the 80 smallholder zero-grazed dairy units in study 2 (Table 1). These body regions included the neck, brisket, hock joint area, carpal joint area, tuber coxae, ischial and rib cage areas, teats and udder. These areas being protuberant were prone to be easily injuried by house structures. The protuberant areas of the body are the parts on which pressure is exerted the most when lying down, and therefore injuries in these areas indicate the comfort state of the lying places of the animal house, hence reflecting good or poor animal welfare with respect to lying comfort. Injuries on the mentioned body protuberances also serve as indicators of the traumatic tendencies of certain structural parts of the animal housing unit, and this in turn reflects good or poor animal welfare state of the housing unit.

In 65% (n=52) of the zero-grazed units, cows showed injuries in the dorsal part of the neck between the middle area and over the shoulders, which presented various signs such as hyperkeratosis and callus-like skin tissue, large patched hair loss, raw wounds, and scars (Figure 1). These affected 60.8% (n=186) of the 306 cows examined. Hyperkeratosis and callus-like skin tissue were the predominant lesions indicating chronic injuries to the skin and constituted 70% (n=130) of the cows with signs of neck injuries. Prevalence of hair loss and raw wounds or scars on the dorsal aspect of the neck as signs of injury was low, being 20% (n=37) and 10% (n=19) of the cows with signs of neck injuries respectively. Evaluation of the housing structures showed that only in 35% (n=28) of the zero-grazing units they were not the cause for trauma to the neck areas of the cows. The low level of neck-bars over the feed bunks was the main risk factor for injuries on the dorsal surface of the neck. Hyperkeratosis and callus-like skin in the dorsal surface of the neck are caused by constant friction against the neck-bar during the many hours of feeding at the feed bunks. A neck-bar is fixed over the feed bunk to prevent cattle from wasting feeds and placing their forelimbs into the feed bunks (Figure 2). Similar effects of neck-bars have been previously described [88]. The neck-bars over the feed bunks were present in 60% (n=48) of the zero-grazing units, and in 77.1% (n=37) of these units the neck-bars were fixed at less or up to 50cm of the top edge of the feed bunk, while in 22.9% (n=11) of the units they were more than 50 cm from the top edge of the feed bunk. When the level is too low, the dorsal surface of the neck would always scrap against the neck-bar as long as the animal is at the feed bunk feeding, and injuries are exacerbated by animals pushing one another and fighting at the feed bunks due to inadequate feeding space or social dominance molestation. All the neck-bars in these zero-grazing units were made of timber, some of which had side-facing sharp edges that contact the dorsal surface of the neck, precipitating the occurrence of injuries (Figure 2). Also, the width of some feed bunks was excessive that cows struggled to reach the feed on the far end and this predisposed them to more of the neck injuries.

	Zero-grazing units with cows showing surface body injuries		Cows with surface body injuries	
Body region	**n**	**%**	**n**	**%**
Carpal joint	77	96	230	75.16
Hock joint	76	95	260	85.00
Rib cage area	76	95	228	74.51
Tuber coxae	72	91	204	66.70
Ischial area	61	76	124	40.52
Neck	52	65	186	60.78
Brisket	51	64	134	43.79
Teats / udder	50	63	89	29.10

Table 1. Distribution of injuries on various parts of the body surface as found among 306 cows examined in the 80 smallholder zero-grazed dairy units evaluated for welfare of dairy cattle in the peri-urban areas of Nairobi, Kenya.

Inadequate feeding space per animal at the feed bunk was a common finding in these smallholder zero-grazing dairy cattle units. This led to increased competitiveness and aggressive behavior of the cows toward each other and particularly toward the subordinate cattle during feeding times. Such behavior is likely to result in physical injuries not only in the neck area but also in other regions of the body, and to reduce feeding time as well, a fact that also infringes partly on freedom from hunger (one of the five freedoms of animal welfare).

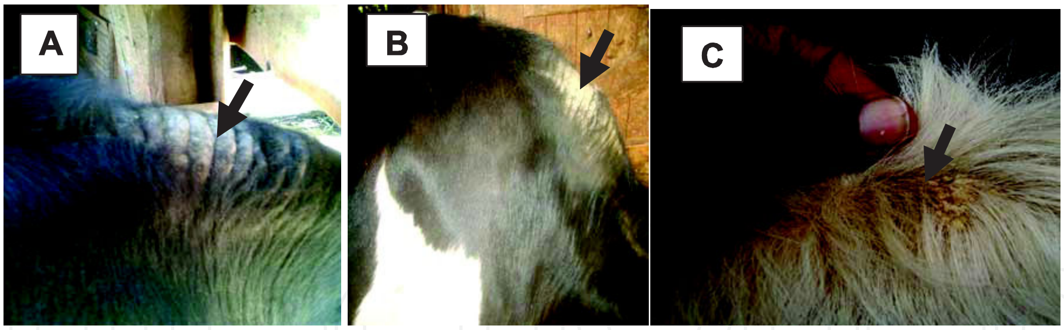

Figure 1. Signs of injuries on the dorsal surface of the neck in some of the cows among the 80 farms evaluated for welfare of dairy cattle in the smallholder zero-grazing units in the peri-urban areas of Nairobi, Kenya. Picture A shows severe hyperkeratosis, callus-like skin with complete hair loss (arrow), Picture B shows moderate hyperkeratosis and a patch of hair loss (arrow), and Picture C shows beginning of hair loss with skin crust (arrow).

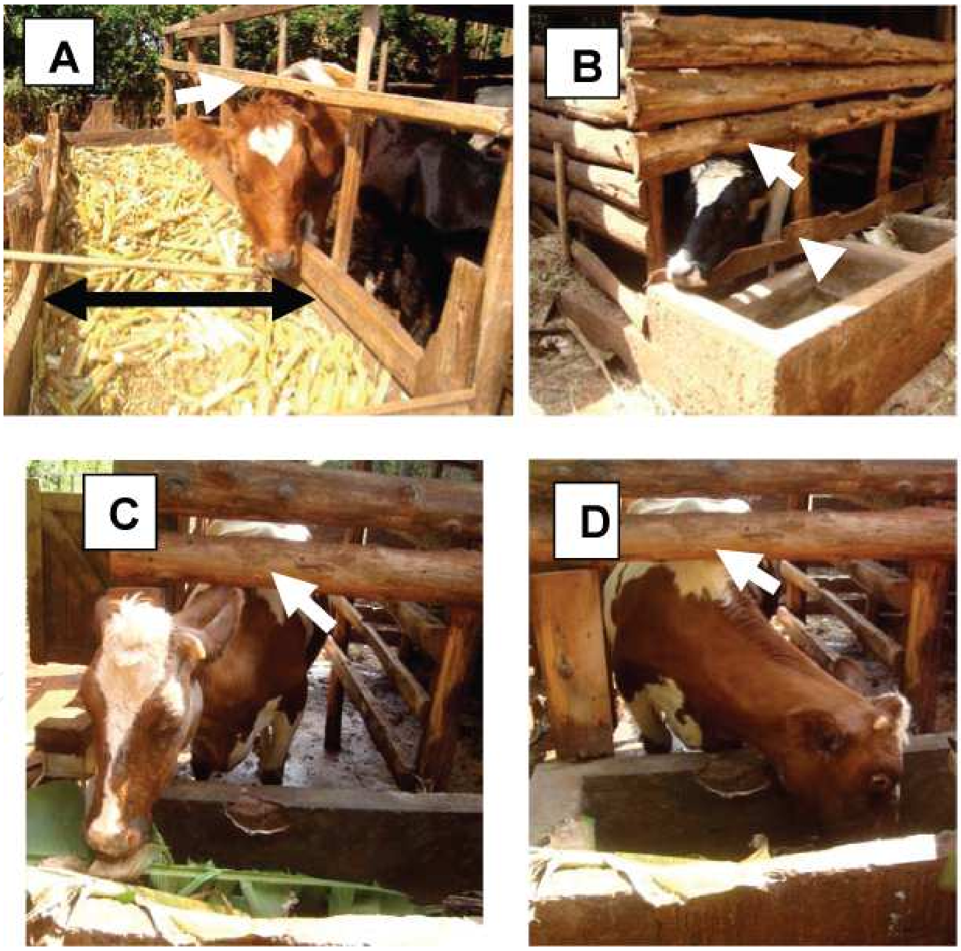

Figure 2. Position of the neck-bars in some of the zero-grazing units evaluated for dairy cattle welfare in the peri-urban areas of Nairobi, Kenya. Pictures A, C and D show low-level positioned neck-bars (arrow) that always rubs the dorsal surface of the cow neck whenever she feeds from the feed bunk; Picture A also shows excessively wide feed bunk (double-headed arrow) from which a cow struggles to reach feed in the far wide-end; Picture B shows a cow attempting to squeeze the head and the neck between a very low sharp-edged neck-bar (arrow) and a broken sharp-edged under-bar (arrow head).

Signs of injuries on the cranial surface of carpal joint area of the cows were observed in 96% (n=77) of the 80 units evaluated. These included healing wounds and scars, soft tissue swellings, hardening of skin in callus-like appearance and various degrees of hair loss. Out of the 306 cows examined, 75.2% (n=230) had signs of injuries in the carpal joint area. The main signs of injury in this area of the body were healing wounds and scars found in 75% (n=173) of the 230 cows with carpal area injuries, but soft tissue swellings and hair loss alone were found in 15% (n=34) and 10% (n=23) of the cows respectively. The high prevalence of signs of injuries on the cranial surface of the carpal joint area served as indicators of the rough and abrasive state of the floors where the cows lie on. It also meant that the cubicles in which the cows lay had inadequate or no bedding at all (Figure 3). Cattle get up from the lying posture by first kneeling on the carpus before extending the hind limbs to support their weight and finally stand up. This behavior predisposes cattle to likelihood of injuries to the carpal area every time the animal kneels on bare abrasive floor or bare concrete cubicle surfaces. Concrete or loose stone floors of the walk alley and cubicle lying surfaces were the commonest abrasive surfaces in these zero-grazing units. Repeated friction and contusion on such floors may cause injuries that will heal with time, leaving scars and hair loss. The repeated prolonged friction on the cranial surface of the carpus might eventually extend deep and lead to contusion of the underlying subcutaneous connective tissue with subsequent development of false pre-carpal bursa that consequently results into carpal hygroma (Figure 4). Inadequate lunge space and bob zone in the animal cubicle may exacerbate occurrence of injuries on the cranial surface of the carpus. All these traumatic signs indicate existence of poor animal welfare in the evaluated zero-grazing units.

In this study, floors were evaluated in the walk alleys where the cows spent most of their time standing during feeding times. In total, 28.8% (n=23) of the 80 studied units were earthen floors in the walk alleys, while the remainder 71.3% (n=57) had concrete or stoned floors. The concrete floors were grossly worn-out and pot-holed in 41.3% (n=24) of the 57 units with concrete walk alleys, while 26.2% (n=15) were smooth and slippery and 32.5% (n=18) were good and non-slippery (32.50%). In 53.75% (n=43) of the units there was no bedding material in the cubicles or animal resting areas, these areas were bare earth in 53.5% (n=23) and bare concrete in 46.5% (n=20). The bedding materials used in the rest of the zero-grazing units were wheat straw, saw-dust, wood-shavings, plastic mats or bare wooden slabs. The grossly worn-out or pot-holed concrete floors and bare concreted cubicles were the main causes of injuries and discomfort on the cranial surface of the carpal joint area whenever the cows rose up from the lying position. Slippery concrete on the walk alley poses a risk by increasing chances of slipping and falling, particularly in the presence of slurry on the floor, making of it an increased risk for poor animal welfare [28]. Considering that cows spend an average of about 12 hours per day standing even when provided with soft lying area [77,89], it makes it necessary to have soft, non-slip, smooth washable floor systems with adequate slope for drainage in order to enhance claw hygiene and health [28,31]. Such materials on floors would promote good animal welfare. The types and conditions of the floors in these studies predisposed the cows to poor claw health, hence the high prevalence of claw lesions subsequently precipitating to lameness [90,91]. Provision of comfortable bedding in the cubicles and resting areas of the cow housing unit influences cow resting behavior positively, by encouraging them to lie down frequently. Hence, by reducing the long hours of standing, which subsequently minimizes the risk of lameness from claw lesions [17,92], the cow welfare is enhanced. However, some of the bedding such as sawdust, which are used in these zero-grazing units owing to ease of their availability and cost, could be incriminated as risk factor for mastitis [93], but in the current studies, mastitis was not a problem.

Figure 3. Bare or damaged floors and cubicles without bedding, which predisposed the cows to injuries and poor welfare. Picture A shows a cow lying on bare floor of a cubicle that is fallen apart with wooden planks on the floor. Picture B shows a floor made of blocks of stone with gaps between them. Picture C shows cubicles with loose stones in them. Picture D shows a cow attempting to stand by kneeling, which injures the carpus if the cubicle or concrete floor is bare and lunge space small, note the neck is under a wooden cross-bar. Picture E is a damaged pot-holed concrete floor. Picture F shows cows lying on rubber mats.

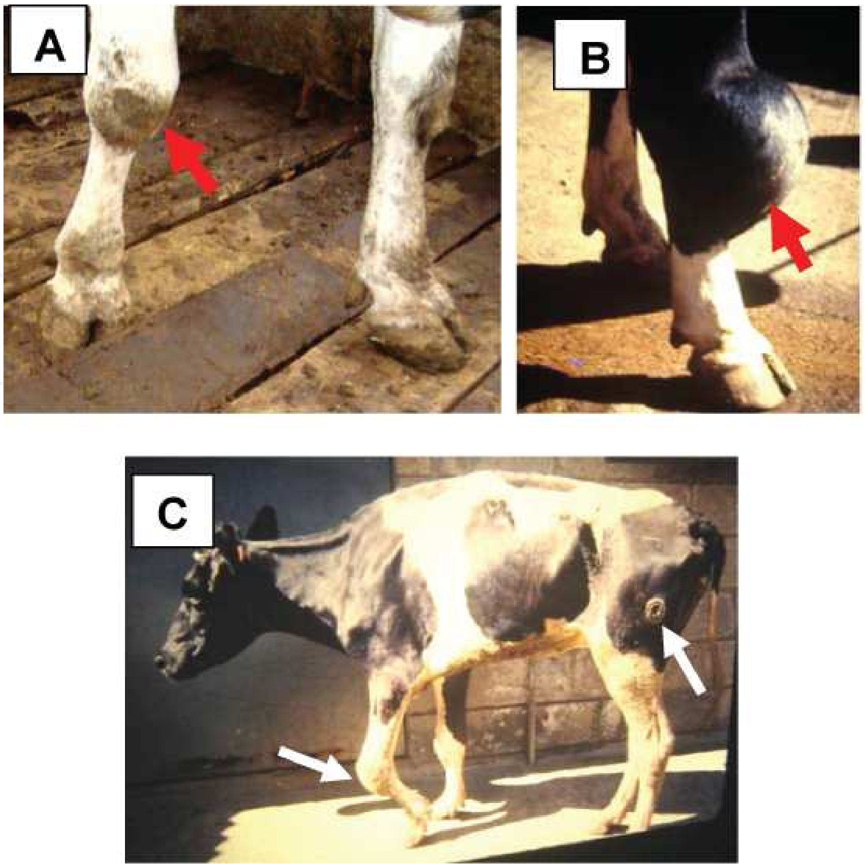

Figure 4. Signs of injuries on the cranial surface of the carpus. Picture A shows early swelling developing on the carpus (arrow); Picture B shows massively swollen carpal hygroma (arrow) as a result of prolonged repeated contusion of soft tissues cranial to the carpal joint subsequently forming a subcutaneous pre-carpal bursa. This swelling was full of viscous straw-coloured sterile fluid. Sometimes the carpal hygroma lesion could become infected and progress to joint ankylosis as in Picture C (arrow), which impairs the animal ability to move and feed, hence originating loss of body condition, which is also a sign of poor welfare. Frequent lying down from standing discomfort in a lame cow may result to development of decubital wounds as seen on the caudo-lateral aspect of the thigh in Picture C (arrow) and these aggravate poor animal welfare.

Cows in 64% (n=51) of the zero-grazing units had brisket injuries, which were evidenced by extensive patches of hair loss and/or scars on the brisket (Figure 5). Brisket injuries were found in 43.8% (n=134) of the 306 cows examined in this study. Injuries at the brisket area were caused by abrasive action of bare concrete in the cubicles and by high and sharp upper edge of the feed bunk on which the brisket rubbed continuously during feeding (Figure 6). A good feed bunk that takes into consideration animal welfare should be made of concrete, because it can be smoothened during construction to eliminate sharp edges that would injure cattle as they feed [28,31,89]. The feed bunk front side should not be too high but low enough for cattle to reach feeds without the brisket rubbing against the upper edge of the bunk. The few concrete feed bunks that were worn-out, and a high number of others made of iron sheets and timber, had sharpened edges that predisposed the cows to injuries of the mouth, head and neck regions. Nails and iron sheet pieces are likely to break from the iron sheet-lined feed bunks with time, and if ingested by the cows can lead to hardware disease apart from causing direct wounds on the body surface in the head, neck and brisket regions. Therefore, the state of feed bunks as found in this study, exposed cows to poor welfare.

Figure 5. Brisket injury consisting of swelling, scar tissue and hair loss (arrow) in one of the examined cows.

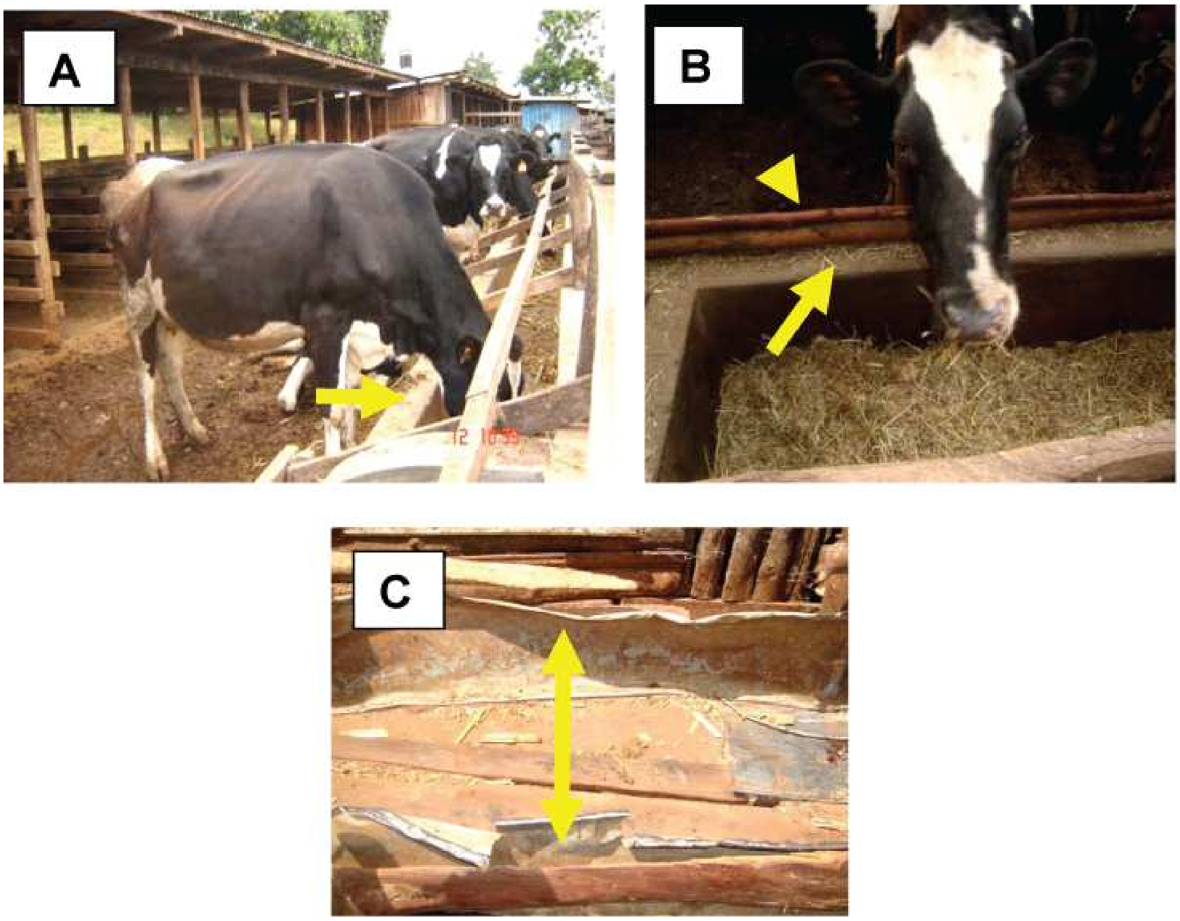

Figure 6. Various feed bunks with different designs and state of the upper front edge. Picture A shows concrete feed bunk with smooth upper front edge, which is at an acceptable low level off the brisket (arrow). Picture B shows low smooth-edged concrete feed bunk (arrow), but addition of wooden bars above the upper front edge (arrow head) on which the brisket could rub and be injured with time. Picture C shows the edges and main part of feed bunk lined with sharp broken iron sheet pieces (arrow), which could injure not only the brisket but also the tongue as it scoops the feed.

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Signs of injuries at the hock joint area were observed in 95% (n=76) of all the 80 zero-grazing units. These included healing wounds and scars, soft tissue swellings and hair loss (Figure 7). The lesions were found in 87% (n= 260) of the 306 cows examined. The high prevalence of injuries at the hock area was a good indicator of the uncomfortable state of the concrete floor and the bare concrete cubicles, which in turn were a definite reflection of the existing poor welfare of cattle in these zero-grazing units. Another region of the body with signs of injuries related to concrete floor and bare concrete cubicles was the ischial area. Injuries in this area were found in 76% (n=61) of the zero-grazing units and affected 41% (n=124) of the 306 cows examined. Cows tend to lie leaning more toward one side than the other, with the lateral aspect of the hock pressed against the floor (Figure 8). This explains the high prevalence of these injuries.

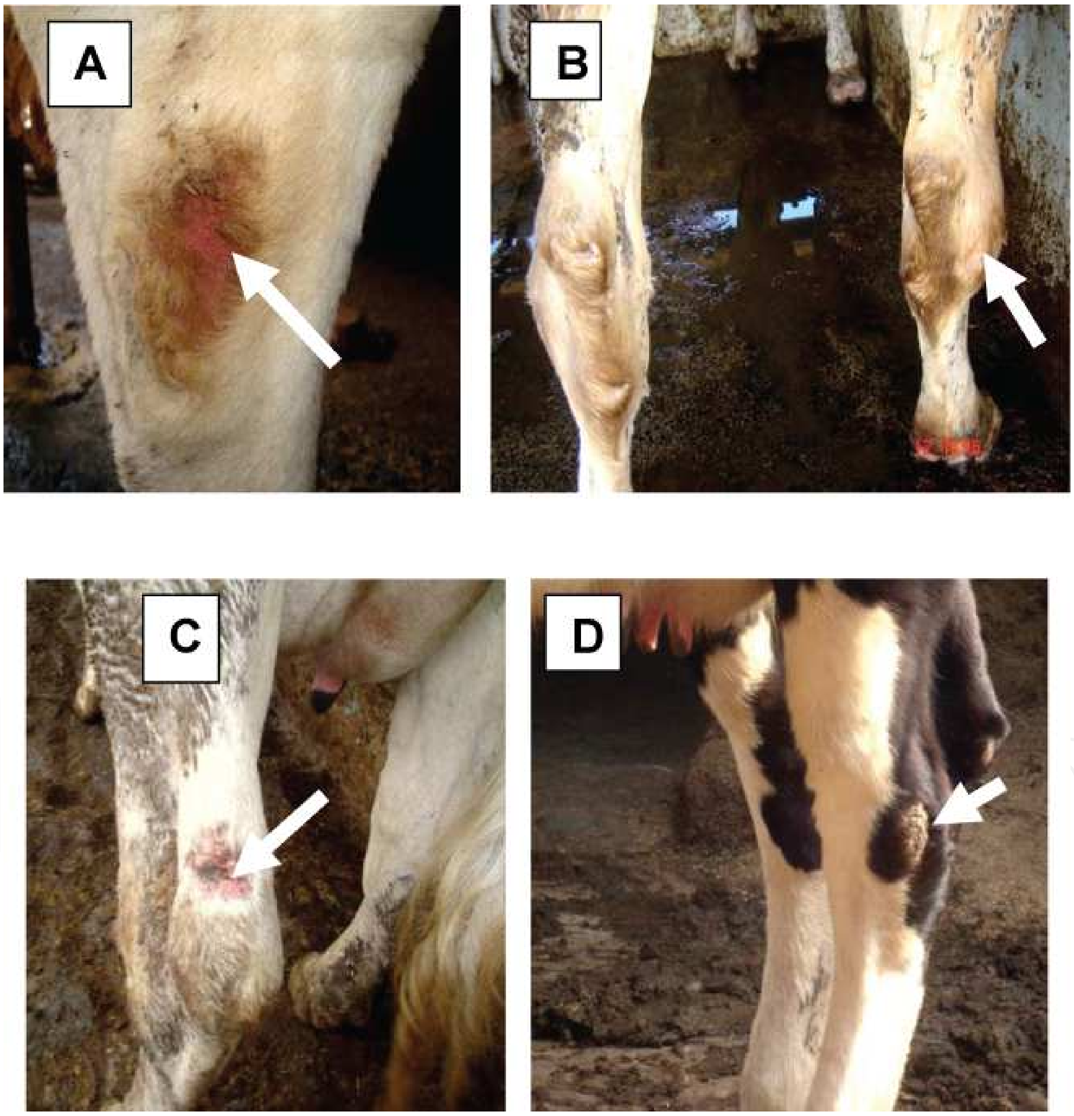

Figure 7. Injuries on the hock. Picture A shows hyperaemic skin with hair loss (arrow), Picture B shows hygroma swelling at the initial developing stage (arrow), Picture C shows healing wound caudal on the hock area (arrow). Picture D shows nodular scarring tumour-like swelling on the lateral aspect of the hock (arrow).

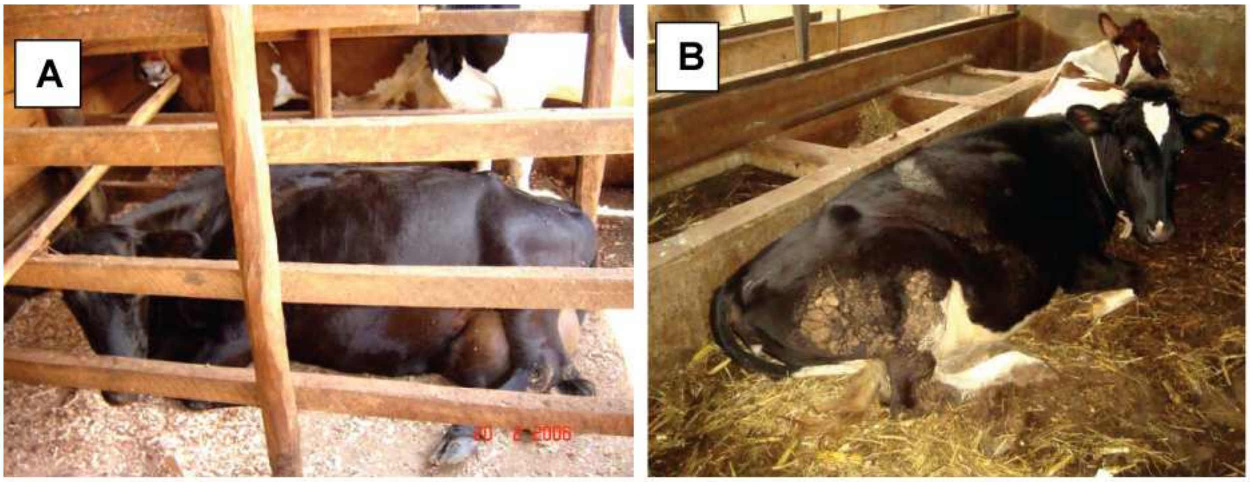

Figure 8. Pictures showing that the lying position of a cow presses on lateral aspect of one hock joint area such that if there is no adequate bedding material or padding, the hock area is easily injured by repeated pressure on hard floor particularly bare concrete floor. Picture A shows a cow lying on lateral aspect of the right hock, and Picture B the cow is lying on lateral aspect of the left hock.

Other signs of injuries found on the cows in some of the units evaluated were located on the rib cage area (Figure 9) and the tuber coxae (Figure 10). On the rib cage area they were found in 95% (n=76) of the units and they affected 75% (n=228) of the 306 cows examined; lesions on tuber coxae were found in 91% (n=72) of the units and they affected 67% (n= 204) of the 306 cows examined. In both areas the signs of injuries were mainly healing wounds or scars. Tuber coxae and rib cage injuries were associated with small cubicle space and protruding traumatic parts of the cattle housing structures, such as side dividing timber or wooden pieces, nails and iron sheets on the side walls. Some of the studied units had broken wooden sidewalls and collapsing roofing material that easily injure the animals (Figure 11). Small-sized cubicles, measuring 1.80 meters by 0.95 meters or less, were found in 74.6% (n=50) of the units evaluated in this study. Overstocking was found in more than half of the zero-grazing units. It caused squeezing and competition for space and feed among the animals, which facilitates injury from the protruding traumatic objects and collapsed roofing material in the cattle housing units. Overstocking meant that there were more cows than the number of cubicles available to rest (Figure 12) and in some cases the feeding space was inadequate for all the cows present. All these factors contributed to poor welfare of the cattle.

Figure 9. Scars sustained at the rib cage area (arrows) in one of the cows examined in the 80 zero-grazing units.

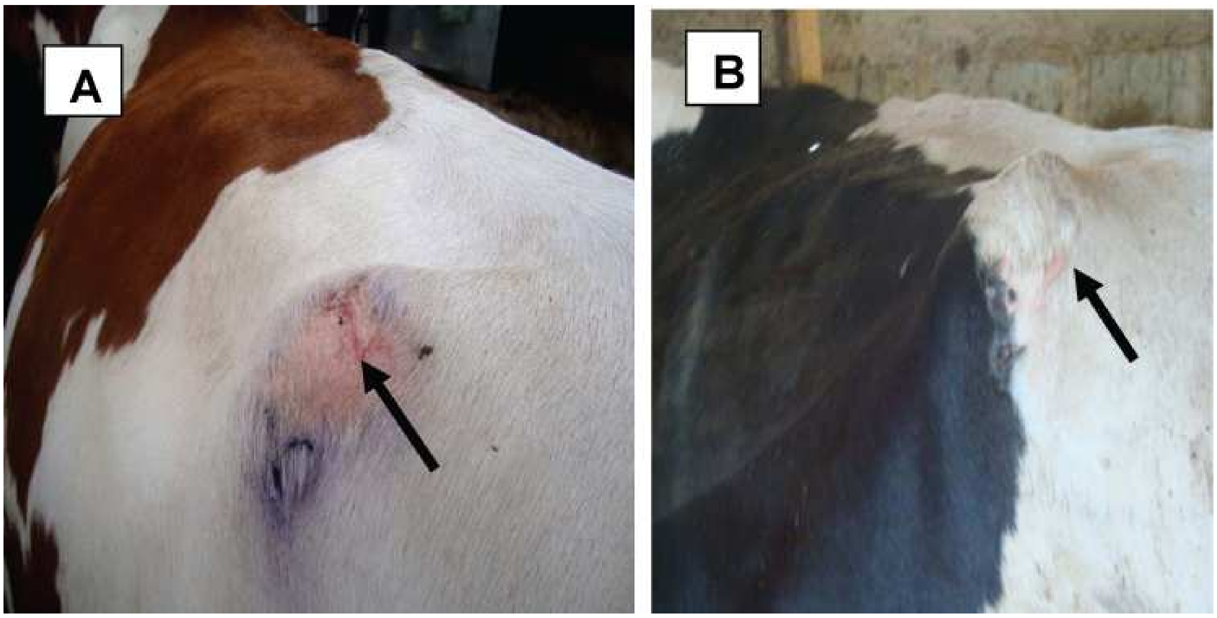

Figure 10. Signs of wounds on the tuber coxae. Picture A: hair loss and skin abrasion (arrow). Picture B: beginning of hair loss due to abrasion by housing structures (arrow)

Figure 11. Collapsed iron sheet roof and sides in one of the zero-grazing units evaluated. Both the roof and side timber are broken and collapsing. Yet cows are still housed inside (arrow).

Figure 12. One of the overstocked zero-grazing units with narrowed walk alley and the cows hardly having any room to turn or move. Animal interactions here and scrambling for space can cause them to press each other against the sharp wooden structures leading to injuries on the rib cage, tuber coxae and other protuberances.

Additional areas with lesions, but showing lower prevalence of injuries include the teats, udder, thighs and other areas of the limbs (Figure 13). These were mainly abrasions with hyperaemia of skin and hair loss. Injuries in these regions were mainly associated with roughness and bareness of the concrete floor and the cubicles. Occasionally, the skin in the thigh areas can also be injured by protruding sharp edges or objects in the housing unit. There were also pin-point nodular lesions on the teats of some of the cows, which resembled pox-like lesions. Although these lesions could have been caused by microorganisms such as viruses, poor environmental conditions would facilitate the entrance of such agents and persistence of infection.

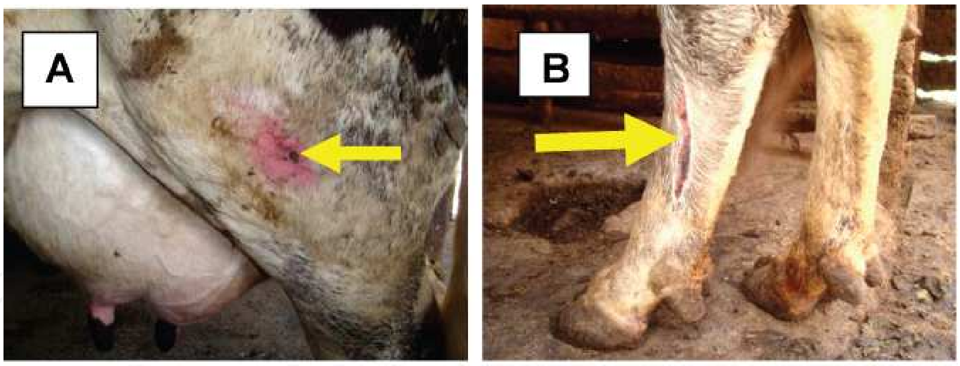

Figure 13. Pictures showing lateral limb injuries. Picture A shows a scarring bruised skin on the lateral side of the thigh (arrow); Picture B shows a healing longitudinal skin cut on the lateral aspect of the lower part of the limb (arrow).

The skin injuries observed in the current study were a reflection of the housing type and size, as well as the structures used to construct cattle houses. Similar injuries have been described in other studies [44]. Skin injuries in any part of the body of an animal are indicators of the welfare status of the animal particularly in relation to its environment. These lesions are associated with pain and suffering [43]. An environment that allows free movement of the animal without risk of disease or injury is paramount [28,31]. The key predisposing factors to external body injuries are the restrictiveness of housing types and structures that affect the cows' behavioral patterns [94]. The external injuries observed in the cows in this study were mainly located on body protuberances such as the hock and the tuber coxae. Others were in the areas of the body subjected to pressure during recumbency and feeding times such as the brisket, ischial region, udder, rib cage, and neck. These findings are in agreement with previous reports [94,95]. In this study, although injuries at different parts of the body were attributed to different risk factors, they still related to the nature of the housing environment.

Statistical analysis of simple associations between injuries and disease was carried out and several factors were associated. Injuries in the various body regions reported in the foregone pages were found to be associated with various factors within the zero-grazing units. The factors with strong association are presented in table 2.

Injured body region	Risk factor	Chi-square value (χ^2)	P value
Dorsal surface of the neck	Presence of neck bar	20.25	<0.0001
	Height of neck bar	22.93	<0.0001
Brisket area	Presence of neck bar	8.14	0.0043
	Height of neck bar	7.37	0.025
Teat /udder/thighs	Bare concrete floor	12.57	0.014
	Quality of bedding	5.15	0.023
Hock joint area	Narrow walk alley	10.68	<0.0011
Ischial region	Concrete floor	8.86	0.012

Table 2. Risk factors associated with the occurrence of body injuries in the 306 cows examined in the 80 smallholder zero-grazing units evaluated for the welfare of dairy cattle in the peri-urban areas of Nairobi, Kenya.

The presence of neck-bar over the feed bunk had a strong association with injuries on the dorsal surface of the neck (χ^2=20.25; p<0.0001) and the surface of the brisket (χ^2= 8.14; p=0.0043). The position of the height of the neck-bar from the top edge of the feed bunk was also found to influence presence or absence of injuries at the dorsal surface of the neck (χ^2=22.93; p<0.0001) and the surface of the brisket (χ^2=7.37; p=0.025. Injuries in the hock joint area were significantly influenced by narrow walk alleys (χ^2=10.68; p<0.001), whilst injuries at the ischial area were significantly associated with poor quality (excessively rough and pot-holed) concrete floors (χ^2=8.86; p=0.012). Teat, udder and thigh injuries were found to have a significant association with bare concrete-floored cubicles (χ^2 =12.57; p=0.014) and also with presence or absence of bedding and the quality of bedding (χ^2=5.15; p=0.023). Lameness was found to be associated with excess slurry in the walk alley (χ^2=29.58; p=0.042).

The housing systems in the smallholder zero-grazing units in this study greatly restricted the cows from freely expressing their normal behavior and enjoying free movement. The restricting sizes of these animal units are normally due to the small pieces of land owned and the financial constraints of these smallholder farmers, which makes it difficult for them to build cattle housing units with the recommended dimensions [29]. This means that it may be difficult to guarantee the freedom of expression of normal behavior and movement for the cows in such smallholder zero-grazing units. The restriction of movement is likely to predispose the cows to lameness [96]. The particularly small size of cubicles found in these units were contrary to what is recommended [97] and was incriminated as one of the factors that predisposed the cows to frequent injuries on the rib-cage, tuber coxae and ischial area, thus supporting previous findings [98]. All these housing factors predisposing the cows to body injuries and lameness are associated with causing pain and suffering, hence poor welfare.

3.3. Body condition score as indicators of welfare

Body condition score (BCS) was also found to be a good indicator of the dairy cow welfare for these zero-grazing units. It reflects mainly on the feeding regime, nutritional value of the diet and the feed quantities supplied to the cows. The average body condition score of the cows evaluated in these 80 units was 2.20. Out of the 306 cows examined, the distribution of the body condition score was found to be as is presented in table 3.

BCS	Number of cows	Percentage of cows (%)
1 – 1.5	19	6
2 – 2.5	177	58
3 – 3.5	100	33
4 – 4.5	10	3
5	0	0
Total	306	100

Table 3. Distribution of the body condition scores among the 306 cows examined in the 80 smallholder zero-grazing units evaluated for welfare of dairy cattle in the peri-urabn areas of Nairobi, Kenya.

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From the results, about 91% (n=277) of the 306 cows examined had fair body condition (BCS between 2 and 3.5), which indicated that the feeding practiced in these zero-grazing units was moderate. Only a few cows had poor body condition below 1.5 (6%; n=19). Similarly, good body condition above 3.5 was found in only 3% (n=10) of the cows examined, which shows that nutritional quality and feed quantity or feeding regime in these zero-grazing units falls below the optimal expectations of good feeding practices for dairy cows. The body condition score (BCS) was influenced by the presence, amount and frequency of concentrate feeding, mineral supplementation and protein supplementation, as shown in Table 4. Body condition score 1 had significant association with occasional (irregular) feeding of concentrates (χ^2=14.77; p=0.022), absence of concentrate feeding (χ^2=7.90; p=0.048), occasional mineral supplementation (χ^2=49.87; p<0.0001) as well as absence of mineral supplements (χ^2=8.23; p=0.042). Body condition score 2 was found to have a significant association with variation (number of times) in the frequency of concentrate feeding (χ^2= 22.69; p=0.012), regular (daily) concentrate feeding (χ^2=13.29; p=0.021) and regular mineral supplementation (χ^2=12.02; p=0.035). Body condition score 3 was found to have a significant association with high levels of concentrate feeding (χ^2=35.65; p=0.017), regular (daily) concentrate feeding (χ^2=13.29; p=0.021), variations in amounts of mineral supplementation (χ^2=29.08; p=0.016) and regular mineral supplementation (χ^2=15.03; p<0.01). Body condition score 4 was found to have a significant association with regular protein supplementation (χ^2=14.46; p=0.023).

BCS	Associated factor	Chi-square value (χ^2)	P value
1	Occasional concentrate feeding	14.77	0.022
	Absence of concentrate feeding	7.90	0.048
	Occasional mineral supplementation	49.87	<0.0001
	Absence of mineral supplementation	8.23	0.0415
2	Variation in frequency of concentrate feeding	22.69	0.012
	Regular concentrate feeding	13.29	0.021
	Regular mineral supplementation	12.02	0.035
3	High levels of concentrate feeding	35.65	0.017
	Variations in amounts of mineral supplementation	29.08	0.016
	Regular mineral supplementation	15.03	<0.01
	Regular concentrate feeding	13.19	0.022
4	Regular protein supplementation	14.46	0.0023

Table 4. Factors associated with the body condition score (BCS) for the cows examined in 80 smallholder zero-grazing units evaluated for the welfare of dairy cattle in the peri-urban areas of Nairobi, Kenya.

Generally, the feeding of forages to cows in these zero-grazing units was more consistent than the feeding of concentrates. Forages included mainly grasses such as napier grass (Pennisetum purpurem), Kikuyu grass (pennisetum clandestum), Rhodes grass [Chloris gayana], maize stover, and in few occasions banana plant stems. Forages were fed to all the cows in all the 80 zero-grazing units. Moreover, main variations in dairy cow feeding practices in these zero-grazing units were found on concentrate feeding. Concentrates were fed to cows only in 85% (n= 68) of the zero-grazing units evaluated in this study. In the remaining 15% (n=12) of the units, cows were not fed on concentrates at all. Of the zero-grazing units that provided concentrates, 98.5% (n=67) used commercially available concentrates, while 1.5% (n=1) used farm-made concentrate mixtures. The farm-made concentrate mixtures consisted of pollard, maize germ, wheat bran, yeast, cotton seed cake and minerals. The formulation ratios of the ingredients in the farm-made mixtures were not revealed to the investigator. In the farms that provided concentrates, 83.8% (n=57) fed it only to lactating cows while 16.2% (n=11) fed it to all cows. Concentrates were provided 2-3 times per day, intentionally coinciding with milking times. In the farms that provided concentrates, 32.4% (n=22) fed each cow on an average of 2-4 kilograms of concentrates per day, 29.4% (n=20) on an average of 5-7 kilograms per day, 23.5% (n=16) on an average of 8-10 kilograms per day and in 14.7% (n=10) on more than 10 kilograms per day (Table 5).

Daily concentrate amount (Kilograms / cow)	Number of Zero-grazing units	Percentage of Zero-grazing units
2 – 4	22	32.4
5 – 7	20	29.4
8 – 10	16	23.5
> 10	10	14.7
Total	68	100

Table 5. Amount of concentrates fed to cows per day in 68 of the 80 smallholder zero-grazing units evaluated for welfare of dairy cattle in the peri-urban areas of Nairobi, Kenya.

According to data in table 5, concentrate feeding in most zero-grazing units was minimal in quantity, and particularly when considering that in many of these units it was partial since the cows were fed only when lactating.

Cows in 88.75% (n=71) of the zero-grazing units were given mineral supplements. In the remaining 11.25% (n=9) of the units, no minerals were provided for the cows. In the zero-grazing units that provided minerals, 77.5% (n=55) of them provided minerals ad libitum, 19.7% (n=14) at 200g to 500g per cow per day, and 2.8% (n=2) of them only occasionally during the lactation period. The mineral supplements were commercially bought and they included: "Unga high phosphorus"-SuperPHOS® (Danthil Enterprises) and "Maclick Super®" (Coopers Limited). The latter was available either in powder form or as a mineral lick block. The constituents of the mineral supplements included higher concentrations of the major elements such as calcium, phosphorus, sodium, chloride and magnesium and lower concentrates of trace elements such as iron, copper, manganese, zinc, sulphur, cobalt, iodine, selenium and molybdenum. Regular mineral supplementation has been shown to be protective on occurrence of some claw conditions such as sole bruising and white line separation [17].

Additional protein supplements such as cotton seed cake, sorghum, fish-meal and high protein forage (Alfafa/Lucerne-*Medicago sativa*) were provided in 36% (n=29) of the zero-grazing units. These protein supplements were added to concentrates, but the high protein forages such as Lucerne were mixed with fodder feeds. Protein supplements were added and fed to cattle only during early lactation. Protein supplementation had no influence on occurrence of claw lesions, but on body condition score, which is discussed in the paragraphs below.

Concentrates are rich in proteins and carbohydrates and have some levels of minerals and vitamins, hence their usefulness in supplementing forages that generally have less of these nutrients. Apart from being essential for growth and for improved milk production [6,99], concentrates also make the diet of dairy cows more complete, thus contributing to their good welfare [99]. However, if fed in large quantities, carbohydrate feeds could lead to ruminal tympany, sub-acute ruminal acidosis and subsequent laminitis [100], which consequently results in lameness that negatively impacts on the welfare of the cow [31,44]. The inconsistencies of concentrate feeding observed in this study including total failure to feed the cows on any concentrate, irregular feeding frequencies and feeding irregular amounts, demonstrated the farmers' ignorance concerning the need and the importance of concentrate feeding. Discriminatory feeding of concentrates only to lactating cows but denying it to the young, non-pregnant, as well as dry cows further supports evidences to this ignorance.

The farmers' perception of the need for concentrate feeding was only associated with the benefits of increased milk production. All these inconsistencies and irregularities of concentrate feeding deny the cow access to a balanced feed type that promotes health, growth and energy [99,101]. Such varied irregularity in concentrate feeding of dairy cattle from one zero-grazing unit to the next has not been reported elsewhere, and is in sharp contrast to the more standardized dairy cattle feeding regimes in intensively managed dairy production systems in the developed countries [102]. The association observed in this study between body condition status and the level of concentrate feeding demonstrates the benefit of concentrate inclusion in the diet. It further points out to the fact that lack of, and irregular concentrate feeding has a direct negative effect on the welfare of the cows. The stronger influence of occasional (irregular) concentrate feeding than its total absence on body condition score, can be attributed to the fact that when the cow's body is denied concentrates completely, it probably adjusts through compensatory mechanisms. Conversely, occasional inconsistent feeding does not allow the cow physiological adjustment to one consistent system, but rather destabilizes it, hence negatively affecting the general welfare of the animal.

The study also indicated that good body condition of the cows was enhanced when additional protein supplements were mixed with the concentrate feeds. These observations could be attributed to the fact that concentrates supply the primary nutrient requirements to the cow as well as sufficient reserves needed for secondary processes such as normal lactation [99,101], and increased milk production [18]. Therefore, concentrates are pertinent constituents of the dairy cow diet if the stress of both body maintenance and milk production has to be avoided.

Regular mineral supplementation supplied in a majority of the zero-grazing units in this study is a reflection of good animal welfare practice, since minerals enhance animal growth, reproduction and health [99,101]. In this study, the importance of mineral supplementation was evidenced by the association between regular supplementation and fair body condition, while occasional or absence of mineral supplementation was associated with poor body condition. Irregular mineral supplementation like was found with irregular concentrate feeding destabilizes the body more than complete absence of minerals, hence affecting body condition score that impacts negatively on the welfare of the cows. Findings from previous studies indicate that absence or insufficient mineral supplementation impacts negatively on growth rate and reproduction, leading to anoestrus [101,103], and hence inevitably affecting animal welfare.

3.4. Other parameters indicating poor welfare

Gross soiling with slurry on various areas of the bodies of the cows was observed in all the zero-grazing units evaluated in this study. In all the cows examined, all their limbs were soiled. The flanks and udder were soiled in 97% (n=297) and 90% (n=28) of the cows, respectively (Figure14). Soiling was an indicator of the management of the slurry in the zero-grazing unit, which means if the body is grossly dirty with raw or dried slurry, then possibly slurry is left to accumulate for long on the floor before being scrapped or washed off. Removal of slurry and cleaning of the cow housing floors was done at least once per day in 55% (n=44) of the units. For the remaining 45% (n=36) of the units, it was done only occasionally, either once a week or once every two weeks (Figure 15). The frequency of cleaning the slurry from the floor was significantly associated with soiling of flanks (χ^2=80; p<0.0001), limbs (χ^2=16.06; p<0.0011) and udder (χ^2=13.58; p=0.0035) (Table 6).

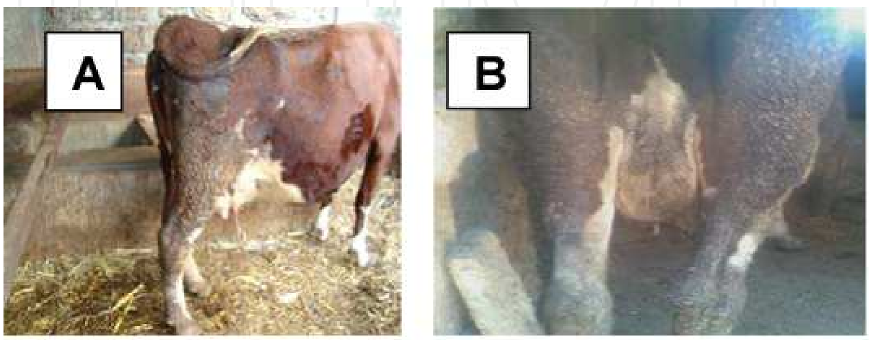

Figure 14. Gross soiling of the whole limb area in Picture A, and the udder plus whole hind quarters in Picture B, with slurry accumulated in the unit facilities.

http://dx.doi.org/10.5772/53678

Figure 15. Slurry accumulated in animal facilities. Picture A shows slurry in an earthen floor. Picture B shows slurry in concrete floor. Picture C shows slurry and narrow walk alley. Picture D-Despite slurry accumulation on parks, the cows in this unit were clean because the cubicles had good clean bedding of sawdust, which meant the cows never lay on the slurry.

Soiled body region	Associated factor	Chi-square value (χ^2)	P value
Flanks	Excess slurry in cow house	80	<0.0001
Limbs	Excess slurry in cow house	13.58	0.0035
Udder	Excess slurry in cow house	16.06	<0.0011

Table 6. Factors associated with soiling in various body parts of cows examined among the 80 smallholder zero-grazing units evaluated for welfare of dairy cattle in the peri-urban areas of Nairobi, Kenya.

Although more than half of the smallholder units in the current study had slurry removed frequently, the excessive slurry found in the rest of the units is likely to affect health of the claws and the udders of the cows. The holding of slurry in cow housing units for long without cleaning it out, exposes the claws to continuous wet environment which softens the horny parts of the claws, predisposing them to development of lesions as previously reported [17,44]. Accumulated slurry also exposes udders to unhygienic conditions that predispose them to mastitis, particularly when the cows lie on it most of the time as observed previously [17,44]. The subsequent development of claw lameness and mastitis will cause pain and inevitably lead to poor welfare. Furthermore, this study was able to show that accumulation of slurry caused excessive soiling of the skin in some parts of the body mainly because most of the time the cows were found lying on it. This is supported by the strong statistical association between the presence of slurry and soiling of the hind quarters as well as the udder region. This may probably be exacerbated by poor housing designs, which were reported previously as the main predisposing factor for soiling of these body regions [104] due to likelihood of these designs forcing the cows to lie on the walk alleys where slurry accumulates. Moreover, prolonged soiling of the skin is not only likely to cause loss of hair especially when the matting is being removed after slurry dries on the skin, but it also interferes with normal health of the epidermis of the involved areas [54]. It is therefore important that slurry is removed from cattle houses at least once per day in order to promote good animal welfare [28].

None of the 80 zero-grazing units evaluated had proper milking parlour; instead the cows were milked in unsuitable improvised cubicles with protruding traumatic pieces of wood or nails in 76% (n=61) of the units, or in their sleeping cubicles in the remaining 24% (n=19) units (Figure 16). Only 12% (n=10) of the zero-grazing units had maternity stalls into which pregnant cows were transferred in the last few days prior to parturition. In the remaining 88% (n=70) of the units, cows calved in their resting cubicles (Figure 17) and in the walk alleys. Lack of maternity areas constituted a poor welfare risk factor, which exposed the cow and her newborn calf to trauma by the rest of the cows in the unit. Moreover, the level of hygiene within the cattle unit is reduced due to spread of bloody fetal fluids and placental remnants [28].

Figure 16. A cow being milked inside an improvised enclosure with a stack of firewood on the left, which poses a risk of injury to the cow when the animal struggles. The firewood can also slide off toward the cow from the top.

Figure 17. A cow calving in a lying position inside the sleeping cubicle. The cow is stuck in this position with her hind limbs having slipped under the lower side-bar (arrow), which further predisposed them to risk of injury. The head was also at risk of injury from being squeezed toward the inside wall.

3.5. Farmers and stockmen perspective on animal welfare

Farmers and stockmen acknowledged the need for cattle to have ready access to feed and to water in 98.75% (n=79) and 88.75% (n=71) of the zero-grazing units, respectively. In 47.5% (n=38) of the units evaluated, farmers and stockmen supported the need for alleviating unnecessary pain and suffering of the cattle as well as providing prompt medical attention when needed. In 31.25% (n=25) of the units, they also shared the opinion that animals suffer when mistreated and that there was the need to protect them from conditions that expose them to distress. The need for provision of a shelter and good housing systems to avoid animal discomfort and physical stress was acknowledged by farmers in 28.75% (n=23) of the units evaluated. The need to provide sufficient housing space with adequate facilities so as to allow for expression of normal behavioral patterns of animals was acknowledged by the farmers and stockmen in 5% (n=4) of the zero-grazing units evaluated in this study (Table 7).

Welfare input	Positive response (%)	Negative response (%)
Feed at all times	98.75	1.25
Water at all times	88.75	11.25
Medical attention when required	47.50	52.50
Appropriate treatment / handling	31.25	68.75
Comfortable housing	28.75	71.25
Adequate space for movement	5.00	95.00

Table 7. Percentages of responses from farmers and stockmen on their perspective of animal welfare issues in the 80 smallholder zero-grazing dairy units evaluated for the welfare of dairy cattle in peri-urban areas of Nairobi, Kenya.

The farmers and stockmen were found to have poor human-animal interaction, as exemplified by shouting and whipping of the cows particularly during milking times. Such interactions caused fear that made the cattle aggressive, leading to agonistic behavior towards making them difficult to handle contrary to good animal welfare recommendations [28]. Nevertheless, the few farmers who supported the need for alleviation of animal pain and suffering as well as provision for animal comfort were found to be better informed on other factors that also contribute to the improvement of production. Generally, the farmers and stockmen interviewed in the current study seemed to have the attitude that animal suffering and its alleviation were not important and that animal comfort was absolutely unnecessary. In spite of these attitudes, the farmers' and stockmen's perspective of animal welfare matters tend to agree with the understanding that animal welfare is affected by a hierarchy of needs whose importance is classified in priority order as life sustaining, health sustaining and comfort sustaining needs [6,105].

3.6. Mixing cattle of different age groups and with other species

In 74% (n=59) of the zero-grazing units evaluated in this study, cattle were housed separately according to their age groups, while for 26% (n=21) of the units the different groups were non-existent, with animals indiscriminately mixed irrespective of their age and lactation stage. Only male calves were separated from the rest of the cattle in all farms. In only 18% (n=14) of the studied units other species of animals such as poultry, pigs, sheep and goats were reared separately, although their houses were attached to the cattle housing facilities. However, in some of the units, chicken house was on top of the cattle house (Table 8).

Mixing practice	Number of zero-grazing units	Percentage of zero-grazing units
Separate age groups	59	74
Mixing of age groups	21	26
Only cattle reared	66	82
Cattle and other species	14	18

Table 8. Animal mixing practices in the 80 smallholder zero-grazing units evaluated for welfare of dairy cattle in the peri-urban areas of Nairobi, Kenya.

Although only a small percentage (26%; n= 21) of the smallholder units in this study housed cattle of different age groups together, it still creates conditions that would enhance development of negative social interactions. Such interactions create fear and disrupt feeding for the subordinate cattle. Eventually, this will inevitably affect health and productivity of the animals negatively [3,101], and subsequently lead to increased stress and poor animal welfare. In the units that had poultry production in rooms on an upper floor above cow houses, particularly separated by timber from the cows below, the cow houses are likely to have accumulations of ammonia from the chicken waste (faeces). This will exacerbate effects of poor ventilation. In the rest of the cattle units that were the majority (74%; n=59), cattle were housed according to their appropriate age groups according to the universal recommendations [28,31].

4. Conclusions and recommendations

The studies presented herein conclude that poor cattle welfare exist in the Kenyan smallholder zero-grazing units, and were able to identify some of the factors responsible for it, through direct indicators in the animals such as lameness lesions, body surface injuries, body condition scores and soiling of the body with slurry. The main factors resulting in poor welfare of dairy cows in the zero-grazing units within the peripheral areas of Nairobi include substandard housing designs, cattle housing in poor state, suboptimal feeding and poor husbandry practices. In this work, physical and environmental parameters that can be used to assess the welfare level in these zero-grazing units were discussed. The farmer perceptions and ignorance on animal welfare issues additionally precipitates cattle poor welfare.

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