CALF COMFORT PILOT STUDY AND COMPLIANCE AND EFFECTS OF COW COMFORT RECOMMENDATIONS IN SMALLHOLDER DAIRY FARMS IN KENYA

A Thesis

Submitted to the Graduate Faculty

in Partial Fulfilment of the Requirements

for the Degree of

Masters in Science

in the Department of Health Management

Faculty of Veterinary Medicine

University of Prince Edward Island

Emily Kathambi Kiugu

Charlottetown, P. E. I.

18/05/2018

THESIS/DISSERTATION NON-EXCLUSIVE LICENSE

Family Name: Kiugu	Given Name, Middle Name (if applicable): Emily Kathambi
Full Name of University: University of Prince Edward Island	
Faculty, Department, School: , Faculty of Veterinary Medicine	
Degree for which thesis/dissertation was presented: MSc	Date Degree Awarded:
Thesis/dissertation Title: CALF COMFORT PILOT STUDY, AND COMPLIANCE AND EFFECTS OF COW COMFORT RECOMMENDATIONS IN SMALLHOLDER DAIRY FARMS IN KENYA	
Date of Birth. It is **optional** to supply your date of birth. If you choose to do so please note that the information will be included in the bibliographic record for your thesis/dissertation. 13/01/1992	

In consideration of my University making my thesis/dissertation available to interested persons, I,

Emily Kathambi Kiugu

Hereby grant a non-exclusive, for the full term of copyright protection, license to my University,

The University of Prince Edward Island:

(a) to archive, preserve, produce, reproduce, publish, communicate, convert into any format, and to make available in print or online by telecommunication to the public for non-commercial purposes;

(b) to sub-license to Library and Archives Canada any of the acts mentioned in paragraph (a).

I undertake to submit my thesis/dissertation, through my University, to Library and Archives Canada. Any abstract submitted with the thesis/dissertation will be considered to form part of the thesis/dissertation.

I represent that my thesis/dissertation is my original work, does not infringe any rights of others, including privacy rights, and that I have the right to make the grant conferred by this non-exclusive license.

If third party copyrighted material was included in my thesis/dissertation for which, under the terms of the *Copyright Act*, written permission from the copyright owners is required I have obtained such permission from the copyright owners to do the acts mentioned in paragraph (a) above for the full term of copyright protection

I retain copyright ownership and moral rights in my thesis/dissertation, and may deal with the copyright in my thesis/dissertation, in any way consistent with rights granted by me to my University in this non-exclusive license.

I further promise to inform any person to whom I may hereafter assign or license my copyright in my thesis/dissertation of the rights granted by me to my University in this non-exclusive license.

Signature	**Date**

University of Prince Edward Island

Faculty of Veterinary Medicine

Charlottetown

CERTIFICATION OF THESIS WORK

We, the undersigned, certify that Emily Kathambi Kiugu, candidate for the degree of

Masters of Science has presented his/her thesis with the following title

CALF COMFORT PILOT STUDY AND COMPLIANCE AND EFFECTS OF COW COMFORT RECOMMENDATIONS IN SMALLHOLDER DAIRY FARMS IN KENYA

that the thesis is acceptable in form and content, and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate through an oral examination held on June 18th 2018.

Examiners

Dr. Bronwyn Crane ………………………………

Dr. Luke Heider ……………………………………

Dr. John VanLeeuwen ……………………………..

Dr. Shawn McKenna ………………………………

Dr. Collins Kamunde ……………………………...

Abstract

A cross-sectional study was carried out on 52 calves that were one year old and younger in 38 smallholder dairy farms (SDFs), to describe and determine factors associated with leg cleanliness scored from 1 (very clean) to 5(very dirty). Indoor housed calves had increased odds of having dirty legs (OR=8.6, p=0.031), compared to outdoor-housed calves. Concrete or wood floors (OR=7.9, p=0.047), poor body condition (OR=17.1, p=0.020) and use of bedding (OR=12.5, p=0.046) were risk factors associated with dirty legs.

A second cross-sectional study aimed to determine factors affecting lying time, stall cleanliness and cow cleanliness was carried out on 73 SDFs with 106 cows. Data loggers were used to record the lying time of cows while stall, udder and upper leg cleanliness were assessed on a score of 1 to 5. Face-to-face questionnaires were administered to the farmers in Kimeru. Multivariable linear and logistic regression models were fit manually through back ward elimination.

The mean daily lying time was 10.9 ± 2.2 hours and the mean stall cleanliness score was 2.4 ± 1.0. The mean average cleanliness score of the udder and upper legs were 1.9 ± 0.7 and 2.5 ± 1.1, respectively. Daily lying time increased with cow age (β=1.00, p=0.005) and decreased with poorly positioned neck rails (β=-1.64, p=0.039), dirty stalls (β=-0.97, p=0.008), delayed removal of manure (β=-1.48, p=0.002) and delayed addition of new bedding (β=-1.19, p=0.017). The association between frequency of addition of new bedding and lying time depended on frequency of manure removal (p=0.040). Risk factors for stall dirtiness were: delayed cleaning of the alley (OR=6.63, p=0.032), lack of bedding (OR= 4.92, p=0.008), and standing idle and/or backwards in the stall (OR=10.47, p=0.002). Dirty stalls were risk factors for udder dirtiness (OR=2.88, p=0.041) and upper hind leg dirtiness.

The degree of compliance in implementing farm-specific cow comfort changes recommended, and the effects of implementing the recommendations on lying time, stall cleanliness and cow cleanliness were evaluated using a randomized controlled trial carried out on 73 SDFs (106 cows). A total of 62 intervention farms received farm-specific recommendations on a maximum of 12 cow comfort parameters including: roof status, drainage of surface water, floor softness, floor flatness, stall width, stall length, leg space, lunge space, neck rail, brisket board, alley cleaning and sharps fixing, while 11 control farms received no recommendations. Proportion tests and Kruskal-Willis rank test were used to assess the differences cleanliness scores and lying time respectively, within and between groups, over the assessment time.

The farmers' overall compliance was 74% (46/62) and was higher when changes recommended were major (OR=6.3, p=0.004) or related to floor characteristics (p=0.047). Compliance was lower when farm-hands received recommendations compared to female farmers (OR=0.01, p=0.023) or when proposed changes were related to roof, alley and sharps fixes relative to stall design fixes (OR=0.1, p=0.004). Post-intervention, stall, udder and upper hind leg cleanliness scores improved significantly ($p<0.01$) in the intervention farms but not in control farms. The change in daily lying time was not significant within and between intervention and control groups.

Overall, some calf and cow comfort aspects were adequate and giving farm-specific cow comfort recommendations and having farmers participate in the implementation of the changes ensured good acceptance and improvement in cow comfort on SDFs.

Dedication

I dedicate this work to my mum Catherine Mataria for always being awesome.

Acknowledgements

I am grateful to the primary funding program for this research, the Canadian Queen Elizabeth II Diamond Jubilee Scholarships (QES) which are managed through a unique partnership of Universities Canada, the Rideau Hall Foundation (RHF), Community Foundations of Canada (CFC) and Canadian universities. This program is made possible with financial support from the Government of Canada, provincial governments and the private sector.

I am also grateful to my supervisory committee members for their guidance and mentoring: supervisor John VanLeeuwen (University of Prince Edward Island), and committee members Shawn McKenna, Collins Kamunde, Crawford Revie (University of Prince Edward Island) and George Gitau (University of Nairobi).

This research would also not have been possible without the support of the Prince Edward Island non-government organization Farmers Helping Farmers. Their existing relationships provided a strong foundation for the work and the entry point to the community. The support and co-operation of the Naari Dairy Cooperative Society was crucial to my research. I appreciate the help offered by Joan Muraya, Dennis Makau, Julia Kenny and Ren Chamberlain during data collection. I would like to thank Shauna Richards, Henrik Stryhn and Jenny Yu of Atlantic Veterinary College for their help with data analysis I am immensely grateful to you all.

I appreciate and thank my mother Catherine Mataria and my friends for their unconditional support while carrying out this research.

Table of Contents

List of Tables

List of figures

Chapter 1: Introduction

1.1 Overview

The welfare of animals kept in livestock production systems has raised concerns in countries around the world (Rollin, 2004). These concerns dwell on the functioning, feeling and natural living of the animals (von Keyserlingk, M A G et al., 2009). A number of animal welfare standards have been set for the growing dairy production industry around the world (Rushen, Butterworth and Swanson, 2011a). These animal welfare standards include requirements for stall dimensions and management practices that are based on research findings (Bickert, 2000; Tucker, Weary and Fraser, 2004). Tools used for assessment of welfare on dairy farms have been developed and used in various parts of the world to assure consumers and to identify critical aspects of cow comfort on farms that need to be addressed (Vasseur, Gibbons, Rushen, Pellerin, Pajor, Lefebvre and de Passille, 2015).

The housing design and management of dairy cattle is vital to lying behavior, feeding ease and social behavior, which subsequently impacts their productive performance (EFSA, 2006). Stall configuration and dimensions such as stall length and width (Tucker, Weary and Fraser, 2004), neck rail positioning (Tucker, Weary and Fraser, 2005) and brisket availability (Tucker, Zdanowicz and Weary, 2006), in addition to management practices such as bedding of lying surfaces (Fregonesi et al., 2007) influence lying patterns of cows, and these patterns can be used as indicators of cow comfort (Cook, Bennett and Nordlund, 2005a). Stall and cow cleanliness are also indicators of cow comfort and are influenced by stall design (Bernardi et al., 2009a), and management practices such as bedding availability (Norring, Manninen, Saloniemi et al., 2008) and frequency of manure removal (DeVries, Aarnoudse, Barkema, Leslie and von Keyserlingk, M A G, 2012).

Video surveillance (Cook, Nordlund and Oetzel, 2004; Gomez and Cook, 2010a), motion sensors (Lubaba et al., 2015) and data loggers are used to monitor cow behavior (Ito, Weary and von Keyserlingk, M A G, 2009; Bewley et al., 2010) and predict health risks, such as lameness (Mazrier et al., 2006; Ito et al., 2010).

In an effort to improve animal welfare on dairy farms, a number of approaches may be used, including education of farmers, creating legislation and enforcing it, and/or encouragement of farmers to implement changes (Whay and Main, 2015). Dissemination of knowledge and integration of farmers in the development and implementation of action plans has been shown to be important in successful interventions (Whay and Main, 2015).

This section provides an overview of topics covered in this first thesis chapter because they relate to the main aims of this thesis, which were: 1) to document the current status of cow and calf comfort on SDFs in Kenya; 2) to determine factors associated with cow comfort outcomes on SDFs in Kenya, such as lying time, stall cleanliness, and cow leg and udder cleanliness; and 3) to determine the compliance and benefits of a randomized controlled trial of recommendations to improve cow comfort on SDFs in Kenya. The remainder of this chapter will provide a brief literature review to build the context for this research and expand on the research questions in preparation for the remainder of the thesis.

1.2 Literature review

1.2.1 Time Budgets and Animal Welfare

Time budgets for lactating dairy cattle can provide some guidance on the average duration of normal activities in the various production systems. An example of a time budget for 205 cows from 16 American herds established by Gomez and Cook (2010) is shown in Table 1-1.

Table 1-1: Descriptive statistics for the component activities of the daily time budget for 205 cows in 16 free stall herds in the USA in 2009.

Activity	**Mean**	**SD**	**Minimum**	**Maximum**
Time milking (h/d)	2.7	1.1	0.5	6.0
Time feeding (h/d)	4.3	1.1	1.1	8.1
Time in alley including drinking (h/d)	2.5	1.5	0.4	7.5
Time standing in stall (h/d)	2.7	2.1	0.3	10.9
Time lying (h/d)	11.9	2.4	3.9	17.6
Lying bouts (n)	12.9	6.6	3.0	35.0
Lying bout duration (h)	1.2	0.4	0.4	2.9

Source: A. Gomez and N.B. Cook, 2010

In addition to Table 1-1, cows also spend about five to seven minutes per day drinking water (Cardot, Roux and Jurjanz, 2008). During a 24 hour period, the spending of time on one activity by cows has an effect on the time spent doing other component activities, either positively or negatively.

Many factors have an impact on a cow’s time budget. Considerations of ventilation, lighting, lying space, standing space, moving and dynamic space requirements should be made when designing and building free stalls to ensure optimal comfort for the cattle (Fregonesi and Leaver, 2001). For example, with high levels of aerosol contaminants causing respiratory disorders in cattle and workers, minimum levels of dust, ammonia, manure gases and disease organisms should be maintained in the stalls by providing adequate ventilation (Tibru and Chirila, 2008a). Also, cows require about 16-18 hours per day of light at an intensity of 10 to 30 lux to increase feed intake and milk yield by 6 to 16% (Fregonesi and Leaver, 2001).

Lying time part of the time budget, along with abnormal lying behaviour, and stall and cow cleanliness are important indicators of cow comfort related to stall design and management, and were features of focus for this thesis. The following sections review them in general, and later in this chapter, there is a section on what we know about them for smallholder dairy farms in tropical countries such as Kenya.

1.2.2 Important stall design features for cow comfort

Stall dimensions have a large impact on the time budget, and more specifically lying time and behaviour. Table 1-2 shows the definition of the nine major free-stall dimensions as described by Vasseur et al. (2015), as well as the target stall dimensions (cm) for cows of different body weight estimates as described by Nigel B. Cook. (2009).

Table 1-2: Free stall dimension definitions

Stall dimension (cm)	**Definition**	**Body weight estimate (kg)**		
		455	**545**	**636**
Stall width	Horizontal distance from centre-to-centre stall divider placement	112	117	122
Stall length	Horizontal distance from stall rear curb to the wall or beginning of front head-to-head stall	244	244	274
Bed length	Horizontal distance from rear curb to brisket board. If no brisket board: distance from rear curb to neck rail	163	168	173
Brisket board height	Vertical distance from top of the brisket board to stall surface (bedding surface)	8	8	10
Distance of neck rail from rear curb	Horizontal distance from rear edge of neck rail to front point of stall curb.	163	168	173
Neck rail height	Vertical distance from below neck rail to stall surface (bedding surface).	112	117	122
Lunge space	Forward and side space obstruction: 76 cm from top of the brisket board or 86 cm above stall surface	Same for all		
Side leg space	Vertical distance from lower edge of bottom divide rail to stall surface (bedding surface)	28	28	30
Curb height	Vertical distance from top of rear curb to alley floor	20	20	20

Source: (Cook. 2009; Vasseur et al., 2015)

The total stall length and width should be based on the weight of the cattle. Several researchers have recommended that the width of the stall should equal twice the hip width of the cow (McFarland and Gamroth, 1994; Bickert, 2000).

The neck rail and brisket board position the cow correctly in the stall when standing and lying down respectively, which helps keep the back part of the stall clean (Tibru and Chirila, 2008b; Bernardi et al., 2009b). Positioning of the neck rail with the aim of improving the comfort and health of the cows may have a negative effect on cleanliness of the stall and the cow (Bernardi et al., 2009b), while positioning the brisket board to improve stall cleanliness may have a negative effect on stall comfort and use (Tucker, Zdanowicz and Weary, 2006).

Provision of adequate side and/or forward lunge space without a solid front interfering with forward lunging allows the cows to stand without restriction (Fregonesi and Leaver, 2001). Using movement of the nose, it was estimated that cows use about 22 to 76cm of lunging space (Ceballos, 2003). Rear curbs 20 to 30cm high prevent overflow of manure from the alley to the stall.

A lateral slope of 3% across the width influences the cows to lie down in the same direction. A longitudinal slope of 2-6% prompts the cows to lie down towards the rear of the stall (Tibru and Chirila, 2008a).

In confined housing, the risk of injuries in cows is increased when smooth floors are used with cow walking distances that range from 180 to 2500m per day in the stalls (van Arendonk, 1989). Skid –resistant and grooved floors reduce injuries in cows due to slipping (Bergsten, 2001).

These important stall design features are important for proper use of stalls, which should lead to acceptable indicators of cow comfort and welfare, such as lying time and cow cleanliness, as reviewed in the next section.

1.2.3 Indicators of cow comfort and welfare related to stall design and management

1.2.3.1 Lying down time and factors

Dairy cattle require adequate rest and they spend approximately 12 hours per day lying down (Jensen et al., 2004; Jensen, Pedersen and Munksgaard, 2005). If prevented from lying down, cows show signs of stress such as; increased cortisol levels and decreased concentration of growth hormone in plasma has been observed in cows that have been prevented from lying down (Tucker, Weary and Fraser, 2005). After being prevented from lying down and feeding for some time, cows chose to lie down over feeding (Cooper, Arney and Phillips, 2007). Decreased dry matter intake by cows caused by uncomfortable stalls leads to severe negative repercussions on cows that include: excessive weight loss, impaired milk production and reproductive performance, and laminitis if excessive standing occurs on concrete surfaces (Tibru and Chirila, 2008b). Therefore, it is clear that lying behaviour is important for both health and welfare of cattle, and can be used to indicate how good and comfortable the stall is for that cow (Tucker, Weary and Fraser, 2003).

There are numerous factors affecting lying behaviour. Some of these factors are related to physiological (e.g. milk production) and pathological (e.g. lameness) characteristics of the cow. Design of the stalls used for lying down have a substantial role in lying time and behaviour. Management of the stalls and their bedding is also very important for optimizing lying time. These factors are discussed in turn.

In terms of physiological characteristics of cows, the amount of milk produced by dairy cattle influences their resting behaviour with high yielding cows spending less time lying down (Bewley et al., 2010; Norring, Valros and Munksgaard, 2012; Miller-Cushon and DeVries, 2017) and more time feeding (Bewley et al., 2010), standing and ruminating (Norring, Valros and Munksgaard, 2012). In addition, the amount of milk in the udder in high yielding cows affects their lying behaviour, likely due to the discomfort of lying down on a full udder, and an increase in the frequency of milking a high yielding cow increased the lying time of the cow (Overton et al., 2002). During the time between milkings, lying time decreased as time since last milking increased (Osterman and Redbo, 2001). At peak lactation, the total time spent lying down by high yielding cows is shorter compared to the total lying time in late lactation (Fregonesi and Leaver, 2001; Bewley et al., 2010). Also, the lying times of cows in late lactation were split into fewer lying bouts of longer duration in comparison to early lactation cows' lying time (Watters et al., 2013). Sleep indicators of lying down with the neck relaxed, as established in calves, are used as signs of sleep in adult cows in addition to not ruminating (Hänninen et al., 2008). The time between initially lying down to lying down in-actively without ruminating was lower in high producing cows in comparison to low producing cows (Norring, Valros and Munksgaard, 2012). The parity of cows is also associated with the lying behaviour of cows in that lying time increases and number of lying bouts decrease with an increase in parity (Sepelveda-Varas, Weary and Keyserlingk, 2014).All of these studies suggest an inverse relationship between the amounts of milk in the udder and lying time. One study has shown no effect of milking frequency on the time spent lying down by lactating cows in peak- versus mid- lactation (Tucker et al., 2007), however, this study included small numbers of cows under experimental conditions, and therefore it is unclear whether similar results would be found under commercial conditions with a large sample of cows and herds.

Housing system, lying area available, stall design, and type of lying surface affect cow lying and standing behaviour (Tucker, Weary and Fraser, 2003; Wagner-Storch, Palmer and Kammel, 2003; Tucker and Weary, 2004; Farevik et al., 2008; Fregonesi, von Keyserlingk, M A G and Weary, 2009). Housing cows in stalls is restrictive in one way or another compared to an open lying area with unlimited space available. Cows prefer to lie down and stand up in open areas in comparison to free-stalls (Fregonesi, von Keyserlingk, M A G and Weary, 2009). However, since a majority of dairy cows lie down in stalls of some kind, it is important to examine stall design and management factors of lying time.

Some studies have shown that cows spend more time lying down in stalls that have neck rails positioned higher above the surface and further from the rear curb (Tucker, Weary and Fraser, 2005; Fregonesi, von Keyserlingk, M A G and Weary, 2009). However, in another study assessing the difference in lying time and lying bouts when cows were kept in stalls with restrictive and less restrictive neck rails, it was observed that cows spent about 12 hours per day lying down regardless of neck rail position (Bernardi et al., 2009b). However, in that study, the number of lying bouts was higher in stalls with less restrictive neck rails (10.4 bouts per day) than in stalls with restrictive neck rails (9.6 bouts per day), indicating a desire to not stand up as often with restrictive neck rails.

Given access to stalls with and without a brisket board, more cows prefer stalls without a brisket board, and spend more time lying down in these stalls in comparison to stalls with a brisket board (Tucker, Zdanowicz and Weary, 2006). However, stall cleanliness is worse when there is no brisket board, as discussed later.

The type of base used in the stall influences the resting behaviour of cows. Cows in mattress-bedded stalls have a higher number of lying bouts of shorter duration compared to cows in sand bedded stalls (Gomez and Cook, 2010a), demonstrating better comfort on sand. However, longer lying bouts and shorter standing bouts have been reported in cows kept in stalls with concrete flooring compared to cows in mattress based stalls (Haley, de Passille and Rushen, 2001), suggesting that cows do not like to stand on concrete.

Availability, type, quality, quantity and dryness of bedding material impact cow lying behavior. Cows prefer lying down on well-bedded surfaces (Tucker, Weary and Fraser, 2003; Tucker and Weary, 2004) because they are soft and comfortable (Fulwider and Palmer, 2004). In 2004, Tucker and Weary established that cows preferred lying down on surfaces that had more bedding relative to little bedding. Every 1cm reduction in sand bedding decreased the lying time of cows by 10 minutes per day (Drissler et al., 2005). The quality of bedding in stalls decreases as it becomes wet from natural elements like rain, faeces or urine (Fregonesi et al., 2007). The lying times of cows decrease by 5 hours a day and they spend more time standing outside the stall when only wet bedding is available (Fregonesi et al., 2007; Reich et al., 2010). The lying time of cows increases when well maintained (Drissler et al., 2005) and dry (Fregonesi, von Keyserlingk, M A G and Weary, 2009) bedding is used on the lying surfaces.

There is a complex association between lameness and resting behaviour of cattle due to interactions and variations with other factors such as type of lameness, type of bedding, stall floor design, and other management practices. Ito at al. (2010) indicated an increase in lying down time in lame cows in deep bedded stalls in comparison to non-lame cows but found no difference in lying time between lame and non-lame cows kept in stalls bedded with mattresses. In a different study, lame cows in mattress-bedded stalls spent less time lying down compared to non-lame cows, while the lying time of lame and non-lame cows in sand bedded stalls was not different (Gomez and Cook, 2010a), with this study including a variety of lameness causes. In the same study, Gomez and Cook, (2010) showed that the time spent lying down by lame cows in mattress-bedded stalls was reduced exponentially with prolonged time in the milking parlour and increased time standing in the stall. In a different study, lame cows with sole ulcers kept in sand-bedded stalls spent more time lying down with longer lying bouts relative to non-lame cows due to the support and cushion provided by sand (Chapinal et al., 2009). However, Gomez and Cook, (2010) observed fewer lying bouts in lame cows and non-lame cows, with no difference observed in the lying bout duration of lame and non-lame cows (Gomez and Cook, 2010a). From these results, it would seem that cows with moderate to severe lameness, such as a sole ulcer, prefer lying down more when there is good comfort provided, such as sand or deep bedding, whereas lame cows did not lie down longer on mattresses, even when kept standing in milking parlours. Other diseases besides lameness, such as mastitis, reduce the lying time of lactating cows and this concept could be used to monitor and identify unhealthy cows (Cyples et al., 2012).

Overstocking cows by providing less than one free stall per cow reduces the lying time while increasing the time spent by cows standing outside the stalls. Fregonesi et al (2007) reported that the average lying time of cows decreased from 12.9 hours to 11.2 hours per day when stocking increased from 100% to 150%, while the time interval of the cows to lie down after milking decreased by 13 minutes in 150% stocking in comparison to 100% stocking.

Effects of seasonality on lying behaviour of cattle have been studied and findings indicated decreased lying down time with elevated temperatures because heat dissipates more efficiently when all surfaces of a cow contact the air (Cook et al., 2007). Standing behaviour is also influenced by the seasonality, where a large proportion of cows were standing with front feet in the stall (called perching) at higher ambient temperature

(Lombard et al., 2010). Abnormal lying/standing behaviours are discussed in more detail in the next section.

1.2.3.2 Abnormal lying behaviours and factors

Perching is an abnormal behaviour of cattle where the cows stand in the stall with the two front feet inside the lying area and the two rear feet outside the stall in the alley. The behaviour has been associated with poor stall designs, such as narrow stalls (Tucker and Weary, 2004) and neck rails located too close to the rear curb (Tucker, Weary and Fraser, 2003). If a stall had a restrictive neck rail, cows did not spend time standing with four feet in the stall, while they spent about 30 minutes per day standing fully in the stall if the neck rail was less restrictive (Bernardi et al., 2009b). Fewer cows stand with front feet only in the stall when longer stalls are available and the stocking density is lower (Lombard et al., 2010). Perching was shown to increase the risk of cows to more hind leg lameness, due to more weight being supported by the hind legs and the hind feet are more likely to be standing in manure in the alley (Colam-Ainsworth et al., 1989; Galindo, Broom and Jackson, 2000a). However, these findings were contradicted by Cook et al. (2005) who reported a lack of association between perching and lameness. The difference in these studies could have been due to other confounding factors such as stall floor type, floor design and floor dryness.

Another form of abnormal lying behaviour is idle standing in the stall. There are a number of factors that are associated with standing idly in stalls. Compared to healthy cows, lame cows spend more time standing in the stall and less time feeding (Gomez and Cook, 2010a). Time spent standing on the alley is significantly less for lame cows than non-lame cows due to fear of aggressive encounters with dominant cattle (Galindo, Broom and Jackson, 2000b). Overstocking of cows limits availability of stalls, which reduces the time spent by cows standing in the stall (Gomez and Cook, 2010a). As parity of the cows increases the time spent standing in the stall increases, which could be due to younger cows spending more time feeding, higher prevalence of lameness in older cows, or a combination of both (Gomez and Cook, 2010a).

The type of flooring and bedding available for the cows also affects the time spent standing in the stall. Cows in stalls with concrete flooring spend more time standing in the stall and not feeding (Haley, de Passille and Rushen, 2001). Cows kept in stalls with rubber mattresses spend more time standing in the stall compared to cows in sand-bedded stalls, which could be due to the preference of sand to mats in the stalls when lying down (Tucker, Weary and Fraser, 2003) or due to difficulty in lying down and standing up on rubber mat stalls because mats can be slippery when wet, forcing them to remain standing (Cook and Nordlund, 2009). Variation in milk production among cattle affects the time they spend lying down and standing but does not appear to affect the total time spent ruminating (Norring, Valros and Munksgaard, 2012).

Another abnormal behaviour is that cows may prefer to lie down in the alley instead of the assigned stalls. This abnormal behaviour may be due to inadequate stall space, faulty stall design (e.g. restrictive neck rails, or difficulty lying down and standing up due to in adequate forward or lunge space), and increased risk of injuries in the stall from sharp objects such as nails. Lying in the alley leads to soiling of the cows and increased risk of clinical or subclinical mastitis (Breen, Green and Bradley, 2009).

Other abnormal behaviours in cows include: reverse lying down with hindquarters forward in the stall, dog-like sitting on hindquarters, and horse-like rising starting with fore limbs. The last two behaviours indicate discomfort for the cow and are mostly due to improper design of the stall that impedes lying down and standing up movements and transitions for instance short stall lengths that restrict head-lunging (Dippel et al., 2009a).

1.2.3.3 Stall and cow cleanliness factors

Cow hygiene, also called cleanliness, can be assessed by determining the leg and udder hygiene scores of the cows on a scale of 1-4, where high scores imply poor cow hygiene and cleanliness (DeVries, Aarnoudse, Barkema, Leslie and Keyserlingk, 2012). Poor hygiene is caused by cow manure, urine and moisture that collect at the lying area of a stall and the alley floors where cows frequent (DeVries, Aarnoudse, Barkema, Leslie and Keyserlingk, 2012). Hygiene scores of 2 and 3 have been reported as the most common for both legs and udders of cows (DeVries et al., 2011; DeVries, Aarnoudse, Barkema, Leslie and Keyserlingk, 2012). Mean hygiene scores of 2.5, 2.5 and 2.8 for the upper thighs, legs and udders of the cows, respectively, were reported on farms with automatic milking systems in the Netherlands (Dohmen, Neijenhuis and Hogeveen, 2010).

Numerous cow-level, stall-level and farm-level factors influence the hygiene of cow stalls, which in turn affect the level of soiling and contamination and comfort of the cows (DeVries, Aarnoudse, Barkema, Leslie and Keyserlingk, 2012).

A negative relationship between milk yield and hygiene scores has been established, with several studies reporting poorer hygiene of the udder and lower legs in high producing cows due to increased dry matter intake which leads to increased manure output (Ellis et al., 2007; DeVries et al., 2011; DeVries, Aarnoudse, Barkema, Leslie and Keyserlingk, 2012). The parity of cows influences their cleanliness as well, with higher scores (dirty) observed as parity of the cows increased, likely because older cows are eating more and giving more milk than younger cows (Reneau et al., 2005a; DeVries, Aarnoudse, Barkema, Leslie and Keyserlingk, 2012).

Stall design impacts stall hygiene. For example, Bernardi et al. (2009) showed that stalls with less restrictive neck rails had higher contamination scores compared to stalls with neck rails that were restrictive. In addition, housing cows in large stalls and allowing them to stand or lie down too far forward in the stall increases the risk of defecation and urination in the stall, and the likelihood of it getting soiled (Tucker, Weary and Fraser, 2005; Fregonesi et al., 2009; Bernardi et al., 2009b).

Related to stall design, cow hygiene scores are also influenced by their lying behaviour, with poorer scores observed with increased lying time, especially in soiled stalls (DeVries, Aarnoudse, Barkema, Leslie and Keyserlingk, 2012). Conversely, the risk of high hygiene scores of the hind limbs increased with increasing time spent standing in Danish loose-housed dairy cows, however, this study was cross-sectional in nature, and therefore it is possible that cows were standing more because their lying areas were dirtier (Nielsen, Thomsen and Sorensen, 2011).

The hygiene of the cows varies with bedding type, with rubber-filled mattresses and water beds showing better association with better cleanliness scores (Fulwider et al., 2007; Norring, Manninen, Passille et al., 2008). On evaluation of bedding type for use in compost bedded packs, dry sawdust, corn cobs, pine woodchip fines and soy bean straw were found to be positively associated with cleanliness if proper bedding management is applied (Shane et al., 2010), such as, frequent removal of wet bedding and addition of new bedding (straw, shavings) at least once a day, particularly in waterbed dairies in the

USA (Fulwider et al., 2007; Norring, Manninen, Passille et al., 2008). We can infer that these findings would apply in other housing systems used for dairy production.

Increased frequency of removing manure from the alley floors is associated with improved stall and cow hygiene (Magnusson, Herlin and Ventorp, 2008; DeVries, Aarnoudse, Barkema, Leslie and Keyserlingk, 2012). The recommended frequency for optimal cleanliness is 12 times a day for alley floors for free stalls in Ontario, Canada (DeVries, Aarnoudse, Barkema, Leslie and Keyserlingk, 2012).

Tail docking of cows does not provide any benefit to cow hygiene by preventing soiling (Schreiner and Ruegg, 2002; Lombard et al., 2010). If a cow is lying down in an area where the tail can get dirty, then likely other parts of the cow will be dirty as well.

While suboptimal levels in cow comfort indicators are inherently important by themselves, their importance extends into impacts on health and performance measures, which are reviewed in the next section.

1.2.4 Effects of poor cow comfort on health and performance

The impact of cow comfort on dairy productivity has been an area of focus for many researchers across the world. An increase in milk yield has been observed in several instances where aspects of cow comfort were improved (Tarantola et al., 1998; Verbrugge, T A W M, 2015). Decreased incidence of subclinical mastitis has also been documented with cow comfort improvements, particularly through enhanced udder cleanliness (Barkema and Schukken, 1999; Koster et al., 2006; DeVries, Aarnoudse, Barkema, Leslie and von Keyserlingk, M A G, 2012). Lameness has also been abated by improvements in cow comfort (Cook, Nordlund and Oetzel, 2004).

1.2.4.1 Cow comfort effects on milk production and component benefits

Cows in a Piedmont farm, where the design of stalls was changed for improved comfort, registered an increase in milk production (Tarantola et al., 1998). Elsewhere, 16% of the variation in milk production in cows was attributed to cow comfort variables in a study in Uruguay (Verbrugge, T A W M, 2015).

As reviewed earlier, cow comfort has an impact on cow lying time. A decrease in time spent lying down leads to a reduction of milk produced by the cows (Uzal and Ugurlu, 2010a). For each hour increase in lying down time, there was a 1.0 to 1.7 kg/cow/day increase in milk production recorded (Grant, 2012). Cow comfort influences the quality of milk in that an increase in percentage fats and proteins was observed with improved cow comfort and increased lying time (Tarantola et al., 1998; Verbrugge, T A W M, 2015).

1.2.4.2 Cow comfort and other effects on clinical and sub-clinical mastitis in dairy cattle

Many quarter-level, cow-level, herd-level and environmental factors affect the risk and occurrence of clinical mastitis in cows. Quarter-level factors associated with occurrence of clinical mastitis in lactating cows include: position of the teat (Zadoks et al., 2001), previous infection of the quarter (Zadoks et al., 2001), and moderate or severe teat-end hyperkeratosis (Breen, Green and Bradley, 2009). In addition, leaking teats before and after milking are risk factors for occurrence of clinical mastitis in cows (Elbers et al., 1998).

Some breeds of cattle such as the red and white (Mease-Rhne-Yssel) in the Netherlands (Elbers et al., 1998), Jerseys in Ethiopia (Asmare and Kassa, 2017) and Ayrshires in Kenya (Mureithi and Njuguna, 2016), have been reported to be more predisposed to clinical mastitis. The risk of clinical mastitis increases with increasing parity (Zadoks et al., 2001; Breen, Green and Bradley, 2009) and decreasing month of lactation (Breen, Green and Bradley, 2009). Cows with dystocia and retained foetal membranes have higher chances of getting clinical mastitis (Peeler, Otte and Esslemont, 1994). The body condition score of cows has not been shown to be associated with the risk of clinical mastitis occurrence (Breen, Green and Bradley, 2009).

Several cow-level factors have been shown to be associated with elevated somatic cell counts in dairy cows, indicating subclinical mastitis. Devries et al. (2012) reported an increase in somatic cell counts in low yielding cows in comparison to high and mid-yielding cows, due to the dilution effect of the high yield (Green, Schukken and Green, 2006). The age and parity of lactating cows influence the risk of subclinical mastitis, with older and multiparous cows showing a higher chance of having elevated somatic cell counts (DeVries, Aarnoudse, Barkema, Leslie and Keyserlingk, 2012; Asmare and Kassa, 2017).

Management practices especially before, during and after milking, influence the herd prevalence of mastitis. Adequate udder cleaning and adequate pre- and post-dipping with teat dip have been shown to decrease the herd prevalence of mastitis (Ramirez et al., 2014). The type of milking practiced at the farm is associated with the risk of mastitis in farms, where automated milking systems have been linked to decreased teat health and elevated somatic cell counts in some farms (Hillerton et al., 2004).

Occurrence of clinical and subclinical mastitis in lactating cows is associated with poor stall and cow hygiene (Schreiner and Ruegg, 2002; Reneau et al., 2005a; Dohmen, Neijenhuis and Hogeveen, 2010). Research has shown that poor stall hygiene is associated with higher individual and bulk tank milk somatic cell counts (Barkema and Schukken, 1999; Koster et al., 2006; DeVries, Aarnoudse, Barkema, Leslie and von Keyserlingk, M A G, 2012) but poor hygiene of the alley did not affect the somatic cell counts of the same cows (Koster et al., 2006; DeVries, Aarnoudse, Barkema, Leslie and Keyserlingk, 2012). Increased frequency of removing manure from the stall and alley decreases the somatic cell counts in large dairy herds (DeVries, Aarnoudse, Barkema, Leslie and Keyserlingk, 2012). Consequently, poor cow hygiene which is associated with poor stall hygiene, is associated with elevated somatic cell counts and increased risk of subclinical udder infection (Schreiner and Ruegg, 2002; Reneau et al., 2005a; Dohmen, Neijenhuis and Hogeveen, 2010). Poor cow cleanliness, specifically poor udder hygiene scores is associated with increased risk and occurrence of mastitis (Ward et al., 2002).

There are complex relationships between stall cleanliness, cow lying time and mastitis because impacts of lying time on mastitis depend on the time cows are lying down in relation to milking times and whether stalls are dirty. Cows that lie down for the first time more than 90 minutes after machine milking have a lower risk of elevated somatic cell counts relative to cows that lie down less than 90 minutes after milking (Watters et al., 2013). In farms with automated milking, cows that take longer than 2.5 hours to lie down after milking (post-milking standing duration) increase their odds of acquiring a new intra-mammary infection compared to cows that take less than 2.5 hours to lie down after milking (DeVries et al., 2011), likely due to increased teat bacterial penetrability caused by pressure created by accumulation of milk within the teat cistern and gland sinuses (Schultze and Bright, 1983).

1.2.4.3 Cow comfort effects on lameness in dairy cows

Lameness in dairy cattle has been reported in all parts of the world with evidence indicating up to 50% prevalence in some farms (Whay et al., 2003). Lame cattle experience elevated scores of pain which is a big welfare concern (Logue and Offer, 2001), and show reduced milk production leading to economic losses to the farmers (Green et al., 2002). Abnormal postures observed in tentatively lame cows (and their sensitivity and specificity as indicators and tests for lameness) are: arched back (Se=0.63, Sp=0.64), cow-hocks (Se=0.54, Sp=0.57) and favouring some limbs while standing and /or walking (Se=0.05, Sp=0.98) (Hoffman et al., 2014). The risk of lameness increases with increase in the occurrence and frequency of abnormal lying behaviours (Dippel et al., 2009a).

There are a number of cow-level risk factors to lameness in cows. Body condition score of cows influence the risk of lameness; thin Holstein cows with a body condition score ranging between 1.25 to 2.50 have an increased chance of being lame when compared to Holstein cows with a condition score greater than 2.50 (Dippel et al., 2009a). However, because this study was cross-sectional in nature, reverse causality whereby lameness leads to thin cows could be responsible for this relationship. A study carried out in Great Britain showed that the risk and occurrence of lameness or leg injury in cattle was not affected by increasing levels of milk production (Haskell et al., 2006).

In terms of farm-level lameness factors, keeping cows in zero-grazing units throughout the year has been shown to have negative effects on their feet and leg health, where more cases of lameness and knee swellings were reported in zero-grazing free-stall farms compared to free grazing farms (Haskell et al., 2006). In addition, gait scores for assessing lameness remained stable or worsened in cows housed indoors compared to cows on pasture whose scores improved with time (Hernandez-Mendo et al., 2007). Lower scores of lameness and claw disorders were seen in bedding pack farms relative to free-stall and cubicle housing farms (Logue and Offer, 2001; Somers, J G C J et al., 2003; Haskell et al., 2006).

The risk of lameness occurring in cows is increased by inadequate stall design (Dippel et al., 2009b). Housing heavy cows in small stalls increases their risk of lameness and claw lesions (Haskell et al., 2006). Moreover, the type of stall flooring has been shown to affect the incidence of leg and claw lesions in cows whereby lying on concrete or wood alone increases the incidence risk of the lesions relative to using rubber mats on the floor (Vokey et al., 2001; Vanegas et al., 2006). However, the use of mats or mattresses in free-stalls did not decrease lameness in the cows observed (Chaplin et al., 2000).

Cook et al. (2005) reported a higher pen prevalence of clinical lameness in cows kept in stalls with mats than those in sand-bedded stalls, while use of straw, sand or sawdust in stalls decreased the damage seen on joints of cattle (Wechsler et al., 2000; Weary and Taszkun, 2000; Vokey et al., 2001). Another survey indicated that at least 80% of cows in stalls bedded with mattresses had hock lesions, while cows kept in sand bedded stalls had few or no hock lesions (Fulwider et al., 2007). The quantity of bedding also influenced the risk and occurrence of lameness; a lower prevalence of lameness was seen in cattle housed in deep-bedded sand stalls compared to cattle on mattresses with little or no bedding (Cook, Nordlund and Oetzel, 2004).

A higher risk of lameness in cows is also seen in stalls with inadequate stall management practices (Dippel et al., 2009b). Removal and collection of manure in stalls affects the comfort and health of the cows. Frequent manure removal improves the floor condition, while infrequent cleaning leads to wet surfaces that soften the hooves, and can lead to hoof lesions and lameness (Tibru and Chirila, 2008a).

While most lameness problems in cows are related to foot disease, injuries or lesions above the foot can also lead to lameness. The main cause of injury to the knees and hocks of cattle is abrasion on concrete surfaces, and leg collisions on stall partitions when lying down or standing up. Several studies have highlighted the importance of bedding stalls to prevent the risk of injury and lameness to knees and hocks in cows (Wechsler et al., 2000; Weary and Taszkun, 2000; Vokey et al., 2001). Large numbers of knee-swelling cases have also been reported in cattle kept in stalls with small lunging spaces (Cermak, 1981; Haskell et al., 2006).

1.2.5 Methods of monitoring cow comfort behaviors of cows

While lying time, abnormal behaviours, and lameness can be assessed visually, technology may also be used to measure them, as described in the next section. Researchers have used video surveillance to help monitor the behaviour of cows in experimental pens (Tucker, Weary and Fraser, 2003) and commercial barns (Cook, Nordlund and Oetzel, 2004; Gomez and Cook, 2010a). Although time consuming and technically challenging in large pens, video capture is considered the gold standard for behavioural tracking and provides information on the cows' time budget and any associations between these times.

Data loggers that automatically record lying time and bouts have also been used in commercial facilities to accurately depict cow behaviour without the need for watching cows in person or electronically (Ito, Weary and von Keyserlingk, M A G, 2009; Bewley et al., 2010). Data collected from these loggers has been used to predict lying time and health risks such as lameness (Mazrier et al., 2006; Ito et al., 2010), but they could not be used to estimate the other components of the cows' time budget (Gomez and Cook, 2010a). It has been proposed that data loggers could be fitted with GPS or radar- based position analysis to determine the location of the cows in the farm thereby estimating their time budget components (Schlecht et al., 2004; Gygax, Neisen and Bollhalder, 2007). Motion sensors that use electronic accelerometers were found to be superior in the classification of cow behaviour into lying, standing or walking when compared to video analysis (Robert et al., 2009).

Utilizing monitored cow comfort behaviours, several indices of cow comfort have been determined and used in the dairy industry to depict lying behaviour of cows (Cook, Bennett and Nordlund, 2005a). The cow comfort index (CCI) first described by Nelson (1986) is defined as the proportion of cows that were lying down touching a stall, and is used as an indicator for good stall use and lying time in a herd. A measurement similar to the CCI taken 1 hour after morning milking was proposed while aiming for a target greater than 0.85 (Overton et al., 2002) . In 2002, the stall standing index (SSI), which described the proportion of cows touching the stall that were standing with 4 feet in the stall, or perching on the platform was established and measurements collected 1 to 2 hours before morning or afternoon milking (Cook, 2002). The stall use index (SUI), defined as the proportion of cows in the pen not feeding and lying down in the stalls, was measured 1 hour after milking, aiming for a lower target of at least 75% (Overton et al., 2002).

Cook et al. (2005) measured the stall perching index (SPI), defined as the proportion of cows that were standing touching a stall with only the front feet in the stall and the rear feet in the alley. On monitoring the four indices above (CCI, SSI, SUI, and SPI), Cook et al. (2005) reported that they were not sensitive indicators of lying down time of cows and recommended use of the stall perching index (SPI) with measurements greater than 0.20 being associated with mean stall standing times greater than 2 hours per day.

Taken together, assessing cow comfort indicators with or without technological assistance takes time and effort to be done systematically and accurately for the purposes of research, but also for the purposes of benchmarking the current status of a cow or herd, and monitoring changes in that status over time. The next section reviews an example of a systemic approach to cow comfort assessment.

1.2.6 Methods of assessment of cow comfort in dairy farms

Vasseur et al. (2015) indicated that the following critical areas should be addressed when assessing dairy cow comfort; housing (stall design, space allowance, stall management, pen management, milking parlours and alleys), feed (body condition score and nutrition), and health and welfare (lameness, claw health, hoof trimming). To carry out a successful assessment of cow comfort in a farm or a given area, specific targets and indicators of comfort must be clearly outlined, in addition to the identification of the critical areas to address. The targets and indicators vary depending on the farm. Three types of measures are taken: animal-based, that is done on the individual cows; environment-based, that are done on the barn, stalls, and surrounding environment; and management-based, that are acquired by interviewing the farmers or farm workers (Vasseur, Gibbons, Rushen, Pellerin, Pajor, Lefebvre and de Passill, 2015). An example of an assessment tool used on farms in Quebec, Ontario and Alberta, Canada, is described in the Table 1-3.

Table 1-3: Critical areas, targets and indicators of cow comfort

Critical area	**Target**	**Indicator of cow comfort**	**Type of measurement**
Lying time	Cows lie down for 12 h/day	Herd average lying time from accelerometers	Animal-based
Hock, knee and neck injuries	Stalls that minimize hock, knee and neck injuries	% cows without hock, knee and neck injuries	Animal-based
Stall configuration	Meet recommendation for heaviest cow for each of the 9 dimensions	Average measures of stall width, stall length, bed length, brisket board height, lunge space, neck rail height, and distance from neck rail to rear curb, curb height. Body dimensions for heaviest cows: rump height and hook bone width	Environment-based
Space allowance at the stalls	Stocking density ≤ 1.2 cow per stall to reduce competition	Number of cows in pen divided by number of usable stalls	Environment-based
Space allowance at feeders	Linear feed bunk space must be at least 60cm/cow to reduce competition	Length of all feeders in pen divided by number of cows	Environment-based
	Presence of a barrier between cows at feed bunk to limit competition	Presence of headlocks or partitions between cows	Environment-based
	Standing alley where feeding should be at least 4.3m to allow sufficient space	Width of the alley where cows stand to feed	Environment-based
	Height of feed barrier must be high enough to allow the cows to feed comfortably	Height of feed barrier compared with 85% of rump height of 10% tallest cows	Environment-based
Stall base/bedding type and quality	Provide deep well bedded dry stalls	Type of bedding Estimation of bedding quantity Estimation of bedding dryness level	Environment-based

Stall/ bedding management	Cows must have low levels of contamination (cow cleanliness evaluation) Cows must be kept in an environment with low level of contamination (Stall cleanliness evaluation) Stalls must be cleaned at every milking Stalls must be routinely bedded	% cows clean or with light contamination on upper leg flank, udder and lower leg Estimation of stall cleanliness Frequency of raking and cow patty removal Frequency of new bedding added	Animal-based Environment-based Management-based Management-based
Pen management (Standing areas)	Minimize time spent by cows standing on concrete Provide slip-resistant flooring in standing areas Ensure the floor on the standing areas is cleaned Flush/scrape standing areas 2-3 times per day	Type of flooring in standing areas % of cows slipping or falling while walking around Estimation of floor cleanliness Frequency of flushing and/or scraping manure	Environment-based Animal-based Environment-based Management-based
Body condition scoring	No cows should be at a BCS of ≤ 2	% of cows with BCS ≤ 2	Animal-based
Nutrition and feeding	Keep a consistent feeding schedule Ensure continuous access to feed	Consistent feeding schedule Estimation of continuous feed access	Management-based Environment-based
Lameness	Fewer than 10% obvious or severe lame cows Routinely observe cows for lameness Proper procedure to treat lame cows Keep complete records of lameness	% of obviously/severely lame cows Lameness monitoring routine schedule Lameness treatment procedure Lameness record keeping	Animal-based Management-based Management-based Management-based
Claw health/hoof trimming	Trim claws about 2 months before calving to minimize lameness Keep complete records of hoof trimming	Hoof-trimming routine schedule Hoof-trimming record keeping	Management-based Management-based

Source: (Vasseur, Gibbons, Rushen, Pellerin, Pajor, Lefebvre and de Passill, 2015)

While there has been much research on animal welfare and how it relates to cow comfort, there is limited research on how it relates to calf comfort. The next section reviews calf comfort.

1.2.7 Calf comfort: similarities and differences to cow comfort

To maintain bodily integrity while growing, calves need access to air with sufficient oxygen, adequate rest in the right postures to prevent sleep deprivation, movement and exercise space for bone and muscle development, adequate and well balanced diet (colostrum, milk, calf starter), enough water and social contact (EFSA, 2006).

As with cows, the housing design and management of dairy calves is vital to feeding ease, lying and social behavior of the calves, which subsequently impacts their growth and development (EFSA, 2006). The recommended space allowance for calves is 3.0m^2 per calf, while the minimum area required is 1.5m^2 per calf (NADIS, 2017). Calves kept in pens that are about 1 by 1.5 meters have shown a higher percentage of the day in lying behavior and lymphocyte proliferation compared to calves kept in smaller pens (EFSA 2006). Factors, such as pen area per calf, type of floor, type of bedding and weather conditions, interact on calf behaviour in outdoor kept calves (EFSA 2006).

Housing of dairy calves can be done individually, in pairs or in groups. Individual housing of calves in dairy production has raised animal welfare concerns (Raussi et al., 2003; Vieira et al., 2010). In Quebec and USA, 87.9% and 67.9% of farms, respectively, housed their calves individually pre- and post-weaning, respectively (Vasseur et al., 2010; USDA, 2008). The European Union regulations indicate that group-housing is mandatory for calves older than 8 weeks (Council of the European Union, 1997). Benefits attributed to pair and group housing include: reduced labour requirements per calf (Costa et al., 2015), improved social behavior of calves (Faerevik et al., 2006; Duve & Jensen, 2012), decreased fear for a new diet during weaning (Costa et al., 2014), higher intakes of starter feed (De Paula Vieira et al., 2010) and increased weight gains (De Paula Vieira., 2010; Chua et al., 2002; Xicatto et al., 2002; Tapki et al., 2007). The preference of individual housing is due to studies showing increased weight gains in singly raised calves (Maatje et al., 1993), decreased calf morbidity (Tomkins, 1991) and less behavioural issues such as cross-sucking (Van Putten, 1982). Weight gains in sick calves are lower than in healthy calves, explaining the reason for individual housing having higher weight gains, depending on the frequency of disease.

Dairy calves spend about 18h/day lying down (Wilson et al., 1999; Panivitat et al., 2004; Chua et al., 2002; Camiloti et al., 2012). The type of lying surface in pens influences the lying time and posture of calves (Le Neindre, 1993). When comparing preference of calves to lie down on bare concrete or sawdust bedded surfaces, they showed aversion to the former (Camiloti et al., 2012). Hanninen et al. (2005) reported that calves did not show any significant difference in lying behavior when kept in pens with concrete surface versus rubber mats.

Accessibility of dry, soft and deep bedding is essential for growth of calves (Camiloti et al., 2012; Lago et al., 2006). Deep and dry bedding not only improves calf cleanliness, but it decreases heat loss in the calves through radiation and conduction, respectively, thus preventing hypothermia, which can happen more easily in calves with a higher surface area-to-mass ratio compared to cows (Camiloti et al., 2012).

The frequent addition of greater amounts of bedding in pens also increases the lying posture related to sleeping, and therefore increases comfort in calves (Ninomiya and Sato, 2009). The lying behavior has also been used as an indicator of how well calves adjust to new housing (Von Keyserlingk., 2011).

Regardless of whether it is calf comfort or cow comfort that requires improvements on a farm, achieving those improvements requires strategic approaches. The next section briefly reviews approaches to knowledge transfer, with the aim of implementing improvements for cow and calf comfort.

1.2.8 Animal welfare knowledge transfer approaches

In an effort to improve animal welfare on dairy farms, at least 3 different approaches including: education of farmers, creating legislation and enforcing it, and/or encouragement of farmers to implement changes may be used (Whay and Main, 2015). Transfer of knowledge to farmers using a top-down approach has been described (Whay and Main, 2015) and used in introducing a lameness control plan in UK dairy farms but the implementation rates reported were poor (Bell et al., 2009). However, in 2012, a 12% decrease in lameness prevalence was reported in UK dairy herds when farmers were given information and supported in formulating farm-specific lameness plans rather than implementing pre-defined general control measures (Main et al., 2012). Similarly, the incidence of mastitis decreased by one-third in Swiss dairy farms when the farmers were integrated in the development of measures for mastitis prevention and treatment (Ivenleyer, 2008). Dissemination of knowledge and integration of farmers in the development and implementation of the action plans has been shown to be important for successful interventions (Whay and Main, 2015).

Animal welfare research, and programs to improve cow comfort, have been done for cows kept in free-stalls and tie-stalls on large dairy herds in Canada and Australia

(Tremetsberger, Leeb and Winckler, 2015; Bouffard et al., 2017). However, there has been very limited research examining cow comfort and calf comfort on SDFs in developing countries, as explained in the next section.

1.3 Cow and calf comfort in the Kenyan/African context, and research rationale

In the Kenyan context, dairy farming is a major contributor to the gross domestic product (Behnke et al., 2013) with livestock providing about 45% of the output of the agricultural and forestry sector (Behnke et al., 2013). Dairy cattle kept in high potential areas produce milk that contributes about 70% of the total gross value of livestock contribution to the Kenyan agricultural sector (Behnke et al., 2013). The largest proportion of dairy farms is made up of SDFs (Global Forum On Agricultural Research, 2016). SDF farmers have limited income, and rely on revenue from milk as the primary or secondary source of income, and hence their livelihood.

Small holder dairy farmers incur economic losses as a consequence of poor cow and calf welfare. In this regard, improved welfare and comfort of cows and calves is vital for the young stock growth, and subsequent productivity and performance as a dairy cow, leading to income generation and improved livelihoods of farmers. One observational study of injuries and poor cattle welfare among SDF farmers in Kenya, found that more than half of the cows had hock and carpal injuries, and bare concrete with limited or no bedding was common (Aleri, Nguhiu-Mwangi and Mogoa, 2011; Richards, 2017). Thus, there is ample opportunity for improvement of cow comfort and welfare.

Dairy calves are raised to replacement heifers on most SDFs. There is need to facilitate not only optimal growth rate and performance but also comfort, rest and welfare of calves. Good animal welfare reduces the stress level in calves, enhances immune function and subsequently increases weight gain (De Paula Vieira, von Keyserlingk and Weary, 2010). There have been reports of calf growth, morbidity and mortality on SDFs in Kenya (G. S. Peter et al., 2015; S. G. Peter et al., 2016). To our knowledge, there has never been an assessment of calf comfort in Kenya or other developing countries.

Poor comfort of dairy cows leads to decreased lying time (Fregonesi et al., 2009), reduced milk production (Uzal and Ugurlu, 2010b), increased risk of lameness (Dippel et al., 2009a) and increased risk of mastitis (Mureithi and Njuguna, 2016). Improved welfare and comfort of cows is vital to the productivity (Verbrugge, T A W M, 2015) and performance of dairy cattle (Watters et al., 2013) and subsequently the income and livelihood of farmers. However, quantification of the benefits of good cow comfort on cow performance are limited in developing countries such as Kenya.

Animal welfare requirements, such as stall dimensions, are based on research findings in developed countries (Bickert, 2000; Tucker, Weary and Fraser, 2004). Failure to follow these recommendations can affect lying time and cow cleanliness, based on research on commercial dairy farms in developed countries (Bouffard et al., 2017). In semi-commercial, SDFs in Kenya, cows are kept in zero-grazing units, and little has been reported on improvement of health and welfare of the cows by dissemination of knowledge using the top-down approach or the farmer integration approach.

A recent study in Central Kenya reported that improving cow comfort on SDFs by making cow comfort changes for the farms had a positive effect on cow productivity and performance (Aleri, Nguhiu-Mwangi and Mogoa, 2011; Richards, 2017). The design of that study ensured that the degree of implementation of the required changes would not vary between farmers because the researcher identified and implemented the changes for each farm in the intervention group. With these findings in mind, we speculated that identifying farm-specific cow comfort parameters that could be changed to improve cow comfort and recommending these changes to the farmers, a variation in compliance to implement those changes would be observed between farmers. The effects of improving the cow comfort parameters on cow comfort and productivity on farms given cow comfort recommendations would be influenced by the farmers' compliance. Furthermore, to achieve optimal animal and farmer benefits, recommendations for changes to improve calf and cow comfort should be carried out using readily available resources at minimum costs for the smallholder dairy farmer, due to their limited income and resources. Recommendations that are cost-prohibitive are unlikely to be implemented, regardless of the setting.

Clearly, there has been very limited research examining cow and calf comfort on SDFs in developing countries, and there is need for more research in these areas to assist the millions of smallholder dairy farmers to improve their management with evidence based recommendations. In particular, it is important to better understand the existing housing design and management of cows and calves on SDFs in Kenya. It is also important to see how well farmers would actually make recommended changes to their cow housing and management, and measure the impacts of those changes, as described in the next section.

1.4 Thesis research objectives and structure

The research described in this thesis was aimed at improving our understanding of the existing cow and calf comfort status related to housing design and management on SDFs in Kenya, and determining the compliance of dairy farmers to implementing cow comfort changes recommended (in terms of stall design and management), and the impacts of the changes made by the farmers on lying time, stall hygiene and cow cleanliness in SDFs in Kenya.

The specific objectives were:

1. To describe calf comfort and determine the individual and pen-level factors that affect calf comfort (in particular, calf leg hygiene) of smallholder dairy farms in Meru, Kenya, using a cross-sectional study.
2. To determine the factors associated with lying time, and stall and cow dirtiness in smallholder dairy farms in Meru, Kenya, using a cross-sectional study.
3. To:
    a. Conduct an assessment of farmers' compliance to implement specific cow stall design and management changes recommended to improve cow comfort for their farm, using a randomized controlled trial; and
    b. Determine the effects of the recommended changes on lying time, stall and cow dirtiness using a randomized control trial

Because farmer-integrated knowledge transfer has had better results and acceptance of improvements to farming practices (Whay and Main, 2015), we hypothesized that at least half of the farmers would implement recommended changes and subsequently cow comfort and productivity would improve post-intervention on compliant farms.

The thesis contains the following chapters.

- Chapter 1: An introduction, literature review and the aims of this study
- Chapter 2: A cross-sectional study was conducted of calf comfort and factors associated with upper hind leg cleanliness of 52 calves from 38 smallholder dairy farms in Kenya.
- Chapter 3: Using 106 cows on 73 smallholder dairy farms in Kenya, the lying time, and stall and cow cleanliness, was described and factors that were associated with these outcomes were evaluated.
- Chapter 4: A randomized controlled trial was conducted with 90 cows from 62 farms in the intervention group, and 16 cows from 11 farms in the control group. We chose an unbalanced herd level allocation because we hypothesized that a third of farms in the intervention group would not comply with the recommendations. Up to 12 cow comfort farm-specific parameters were recommended for change in the intervention farms. Compliance of the farmers was assessed after a given time, and the effects of implementation of the recommended changes were evaluated on cow lying time, and stall and cow cleanliness.

- Chapter 5: The methods and findings from the three substantive chapters are summarized and discussed and the conclusions from all the chapters are linked in a general discussion followed by overall recommendations.

1.5 Study partners and background

This multi-disciplinary, multicultural and multi-partner project was funded primarily by the Canadian Queen Elizabeth II Diamond Jubilee Scholarships (QES). It was developed at the University of Prince Edward Island (UPEI) in collaboration with a Canadian nonprofit organization, Farmers Helping Farmers (FHF) that works in Kenya, and five Kenyan partners which included two universities, a dairy co-operative, and two women's groups, as described below (Shileche A, 2018).

Over the course of four years (2015-2018), the project sought to improve and sustain smallholder family nutrition, horticultural and dairy farming in Eastern Kenya through practical evidence-based best practices and to demonstrate the impact of training and provisions of critical infrastructure through research conducted in the rural community. The project coordinated efforts of Canadian undergraduate and Kenyan graduate students across three disciplines (veterinary medicine, human nutrition and education) to implement integrated field-based training techniques and research projects (Shileche A, 2018).

After completing one academic year at UPEI, Kenyan students spent eighteen months (doctoral) and 3 months (masters) in Naari teaching farmers how and why to cook healthy meals and how to feed, breed and make cows comfortable. Canadian undergraduate students were in Kenya for 90-day internships and worked with Kenyan students to educate farmers and collect data. Students assessed the impact of training and FHF interventions on cow nutrition, reproduction and comfort; human food security and diet diversity; and nutrition knowledge, attitudes and practices. In addition, two students assessed the use of traditional face-to-face training compared to integrate face-to-face and cell phone training methods. Training and research activities were implemented through workshops, farm demonstrations and cell phone technology (Shileche A, 2018).

UPEI faculty members, from the Department of Health Management at the Atlantic Veterinary College, and the Department of Applied Human Sciences in the Faculty of Science, drew from their academic experiences and research collaborations with faculty members at two Kenyan universities to develop a cross-cultural learning abroad project that integrated veterinary medicine, human nutrition, and education studies. UPEI and Kenyan university faculty members and FHF were involved in the selection of undergraduate and graduate students for the project. UPEI faculty members were responsible for primary supervision of the graduate student scholarly work (Shileche A, 2018).

Farmers Helping Farmers is a Canadian based non-profit organization with a long-standing presence working with Kenyan farmer groups. In 2014, FHF started collaborating with Naari Dairy Farmers Cooperative Society and two Women's Groups to improve their members' family income through agricultural education and resources. As well, FHF provided women's group members with equipment such as water tanks, drip irrigation and vegetable grow bags and horticultural training to improve sustainability and yields from kitchen [vegetable] gardens. Also, it partnered with a number of schools in the Naari region to build vegetable gardens to contribute to healthy lunch meals for the students. FHF and UPEI's Atlantic Veterinary College have developed a dairy health management handbook that provides important information to smallholder dairy farmers in Naari. Similarly, FHF has a horticulture handbook that provides additional guidance for sustainable vegetable growing. In this project, FHF

Kenyan staff worked directly with farm women to install critical horticulture infrastructure and to conduct dairy and horticulture training. The staff assisted undergraduate and graduate students in facilitating training to farmers and collection of research data. As well, staff organized meetings, directed students to training locations or participant homes, and sometimes translated the teaching or research conversations from English into the native language and back to English. (Shileche A, 2018).

Kenyatta University and the University of Nairobi are public institutions of higher learning in Nairobi, Kenya. Programs at these institutions served as the grounds for recruiting Kenyan graduate students, while faculty members in veterinary medicine and human nutrition disciplines are collaborators and academic supervisors (Shileche A, 2018).

Naari Dairy Farmers Cooperative Society (NDFCS) is a cooperative in the northern part of Meru County, Kenya. It provides livelihood opportunities to about 500 small-scale dairy farmers through the sale of their milk. The cooperative ensures that milk is collected on a daily basis from farmers, transported to the dairy facility, cooled and sold for retail sales or processing. It also provides access to credit and financing to members who sell their milk to the dairy. In 2014, NDFCS and Farmers Helping Farmers collaborated on training some members of the cooperative society on milk quality and agronomy. These farmers were very receptive to this new information and expressed their willingness to learn more about the health and management of cattle and human nutrition, leading to the successful proposal that funded this QES project (Shileche A, 2018).

Two local Women's Groups were participants in the FHF and QES interventions and have about 30 members each. Kenyan women use such groups to access resources to improve their livelihoods, for example, women save money and take out loans when group savings have accumulated. Moreover, these groups provide a chance for women to socially interact and support each other emotionally. Farmers Helping Farmers has previously been involved with one of the Women's Groups through a kitchen gardening project. Members of the two women's groups were eager participants in project training and research activities with the FHF staff, Canadian undergraduate student interns and the Kenyan graduate student researchers (Shileche A, 2018).

According to a report by Kenya National Bureau of Statistics (KNBS) and Society for International Development (2013), Meru County is characterized as having a youthful population with75% of the population below 35 years of age. A significant proportion of the residents have low literacy levels, with only 18% of residents having completed post-primary level education. Nearly half of the residents (42%) earn a living through smallholder agriculture. Farmers keep cows for milk production and grow crops such as maize, beans, sorghum, vegetables and fruits, tea, and coffee. Kenyan smallholder farmers working on and off the farm earn an average combined household income of 22,000 KSh per month ($275 CAD) (Rapsomanikis, 2015) (Shileche A, 2018).

The current study was conducted in the Kiirua/Naari area of Meru County in Eastern Kenya. Kiirua/Naari is one of the forty-five electoral wards in Meru, has a population of 27,299 people, and covers 118.6 square kilometers at an elevation of about 2,000 meters above sea level (KNBS, 2009). The majority of residents practice agriculture, especially dairy farming (Shileche A, 2018).

1.6 References

Proposal for a Council Directive amending Directive 91/629/EEC laying down minimum standards for the protection of calves (presented by the Commission), COM (96) 21 final, 24 January 1996

Abade, C.C., Fregonesi, J.A., von Keyserlingk, M A G and Weary, D.M., 2015. Dairy cow preference and usage of an alternative freestall design, Journal of Dairy Science, 98, 960-965

Akdag, F., Arslan, S., Caynak, A. and Teke, B., 2011. The relationships of phenotype, genotype and some environmental factors with birth weight in Jersey calves, African Journal of Biotechnology, 10, 7308-7313

Aleri, J.W., Nguhiu-Mwangi, J. and Mogoa, E.M., 2011. Housing-design as a predisposing factor for injuries and poor welfare in cattle within smallholder units in periurban areas of Nairobi, Kenya, Livestock Research for Rural Development, 23, 53

Algers, B.B., Broom, D.M., Canali Caniatti, E., Hartung, J., FJ, M.S.C. and Veissier, I., 2006. Scientific Report on the risks of poor welfare in intensive calf farming systems Annex to EFSA Journal

Asmare, A.A. and Kassa, F., 2017. Incidence of dairy cow mastitis and associated risk factors in Sodo town and its surroundings, Wolaita Zone, Ethiopia, Slovak Journal of Animal Science, 50, 77-89

Barkema, H. and Schukken, Y., 1999. Management style and its association with bulk milk somatic cell count and incidence rate of clinical mastitis, Journal of Dairy Science, 82, 1655-1663

Barrientos, A.K., Chapinal, N., Weary, D.M., Galo, E. and von Keyserlingk, M A G, 2013. Herd-level risk factors for hock injuries in freestall-housed dairy cows in the northeastern United States and California, Journal of Dairy Science, 96, 3758-3765

Behnke, R., Centre, O., Wolford, G. and Muthami, D., 2013. A Living from Livestock IGAD Livestock Policy Initiative The Contribution of Livestock to the Kenyan Economy

Bell, N.J., Bell, M.J., Knowles, T.G., Whay, H.R., Main, D.J. and Webster, A.J.F., 2009. The development, implementation and testing of a lameness control programme based on HACCP principles and designed for heifers on dairy farms, The Veterinary Journal, 180, 178-188

Bergsten, C., 2001. Effects of conformation and management system on hoof and leg diseases and lameness in dairy cows, Veterinary Clinics of North America, Food Animal Practice, 17, 1-23

Bernardi, F., Fregonesi, J., Winckler, C., Veira, D.M., von Keyserlingk, M A G and Weary, D.M., 2009a. The stall-design paradox: Neck rails increase lameness but improve udder and stall hygiene, Journal of Dairy Science, 92, 3074-3080

Bernardi, F., Fregonesi, J., Winckler, C., Veira, D.M., von Keyserlingk, M A G and Weary, D.M., 2009b. The stall-design paradox: Neck rails increase lameness but improve udder and stall hygiene, Journal of Dairy Science, 92, 3074-3080

Bewley, J.M., Boyce, R.E., Hockin, J., Munksgaard, L., Eicher, S.D., Einstein, M.E. and Schutz, M.M., 2010. Influence of milk yield, stage of lactation, and body condition on dairy cattle lying behaviour measured using an automated activity monitoring sensor, Journal of Dairy Research, 77, 1-6

Bickert, W.G., 2000. Freestall Design, Natural resource, agriculture and engineering service - publications NRAES, 205-213

Bouffard, V., de Passille, A.M., Rushen, J., Vasseur, E., Nash, C.G.R., Haley, D.B. and Pellerin, D., 2017. Research: Effect of following recommendations for tiestall configuration on neck and leg lesions, lameness, cleanliness, and lying time in dairy cows, Journal of Dairy Science, 100, 2935-2943

Bradley, A.J. and Green, M.J., 2001. Aetiology of clinical mastitis in six Somerset dairy herds, Veterinary Record, 148, 683-686

Breen, J.E., Green, M.J. and Bradley, A.J., 2009. Quarter and cow risk factors associated with the occurrence of clinical mastitis in dairy cows in the United Kingdom, Journal of Dairy Science, 92, 2551-2561

Camiloti, T.V., Fregonesi, J.A., von Keyserlingk, M A G and Weary, D.M., 2012. Short communication: Effects of bedding quality on the lying behavior of dairy calves, Journal of Dairy Science, 95, 3380-3383

Cardot, V., Roux, Y. and Jurjanz, S., 2008. Drinking behavior of lactating dairy cows and prediction of their water intake, Journal of Dairy Science, 91, 2257-2264

Ceballos, A., 2003. How cows lie down : a 3-D kinematic evaluation of the lying down behaviour of holstein dairy cows

Cermak, J., 1981. Zoocentric approach to definition of cubicle length and width for Friesian dairy cows, Modelling, design and evaluation of agricultural buildings.Papers presented at CIGR Seminar, Aberdeen, UK, 31 August-4 September 1981., 97-105

Chapinal, N., de Passill�, A.M., Weary, D.M., von Keyserlingk, M A G and Rushen, J., 2009. Research-Article: Using gait score, walking speed, and lying behavior to detect hoof lesions in dairy cows, Journal of Dairy Science, 92, 4365-4374

Chaplin, S.J., Tierney, G., Stockwell, C., Logue, D.N. and Kelly, M., 2000. An evaluation of mattresses and mats in two dairy units, Applied Animal Behaviour Science, 66, 263-272

Chua, B., Coenen, E., van Delen, J. and Weary, D.M., 2002. Effects of Pair Versus Individual Housing on the Behavior and Performance of Dairy Calves, Journal of Dairy Science, 85, 360-364

Colam-Ainsworth, P., Lunn, G.A., Thomas, R.C. and Eddy, R.G., 1989. Behaviour of cows in cubicles and its possible relationship with laminitis in replacement dairy heifers

Cook, N.B., Mentink, R.L., Bennett, T.B. and Burgi, K., 2007. The Effect of Heat Stress and Lameness on Time Budgets of Lactating Dairy Cows, Journal of Dairy Science, 90, 1674-1682

Cook, N.B., Bennett, T.B. and Nordlund, K.V., 2005a. Monitoring indices of cow comfort in free-stall-housed dairy herds, Journal of Dairy Science, 88, 3876-3885

Cook, N.B., Bennett, T.B. and Nordlund, K.V., 2005b. Monitoring Indices of Cow Comfort in Free-Stall-Housed Dairy Herds*, Journal of Dairy Science, 88, 3876-3885

Cook, N.B., Nordlund, K.V. and Oetzel, G.R., 2004. Article: Environmental Influences on Claw Horn Lesions Associated with Laminitis and Subacute Ruminal Acidosis in Dairy Cows, Journal of Dairy Science, 87, E46

Cook, N.B., 2002. The Influence of Barn Design on Dairy Cow Hygiene, Lameness and Udder Health, Proceeding of the annual convention - american association of bovine practitioners, 97-103

Cook, N.B. and Nordlund, K.V., 2009. Review: The influence of the environment on dairy cow behavior, claw health and herd lameness dynamics, The Veterinary Journal, 179, 360-369

Cooper, M.D., Arney, D.R. and Phillips, C.J.C., 2007. Two- or four-hour lying deprivation on the behavior of lactating dairy cows, Journal of Dairy Science, 90, 1149-1158

Costa, J.H.C., Meagher, R.K., von Keyserlingk, M A G and Weary, D.M., 2015. Early pair housing increases solid feed intake and weight gains in dairy calves, Journal of Dairy Science, 98, 6381

Costa, J.H.C., Daros, R.R., von Keyserlingk, M A G and Weary, D.M., 2014. Complex social housing reduces food neophobia in dairy calves, Journal of Dairy Science, 97, 7804-7810

Cyples, J.A., Fitzpatrick, C.E., Leslie, K.E., DeVries, T.J., Haley, D.B. and Chapinal, N., 2012. The effects of experimentally induced Escherichia coli clinical mastitis on lying behavior of dairy cows, Journal of Dairy Science, 95, 2571-2575

De Paula Vieira, A., von Keyserlingk, M.A.G. and Weary, D.M., 2010. Effects of pair versus single housing on performance and behavior of dairy calves before and after weaning from milk, Journal of Dairy Science, 93, 3079-3085

DeVries, T.J., Aarnoudse, M.G., Barkema, H.W., Leslie, K.E. and Keyserlingk, M.A.G., 2012. Associations of dairy cow behavior, barn hygiene, cow hygiene, and risk of elevated somatic cell count, Journal of Dairy Science, 95, 5730-5739

DeVries, T.J., Aarnoudse, M.G., Barkema, H.W., Leslie, K.E. and von Keyserlingk, M A G, 2012. Associations of dairy cow behavior, barn hygiene, cow hygiene, and risk of elevated somatic cell count, Journal of Dairy Science, 95, 5730-5739

DeVries, T.J., Deming, J.A., Rodenburg, J., Seguin, G., Leslie, K.E. and Barkema, H.W., 2011. Association of standing and lying behavior patterns and incidence of intramammary infection in dairy cows milked with an automatic milking system, Journal of Dairy Science, 94, 3845-3855

Dippel, S., Dolezal, M., Brenninkmeyer, C., Brinkmann, J., March, S., Knierim, U. and Winckler, C., 2009a. Risk factors for lameness in freestall-housed dairy cows across two breeds, farming systems, and countries, Journal of Dairy Science, 92, 5476-5486

Dippel, S., Dolezal, M., Brenninkmeyer, C., Brinkmann, J., March, S., Knierim, U. and Winckler, C., 2009b. Risk factors for lameness in freestall-housed dairy cows across two breeds, farming systems, and countries, Journal of Dairy Science, 92, 5476-5486

Dohmen, W., Neijenhuis, F. and Hogeveen, H., 2010. Relationship between udder health and hygiene on farms with an automatic milking system, Journal of Dairy Science, 93, 4019-4033

Dohoo, I.R., Martin, S.W. and Stryhn, H., 2012. Methods in Epidemiologic Research, (Charlottetown, P.E.I. : VER, Inc., c2012)

Drissler, M., Gaworski, M., Tucker, C.B. and Weary, D.M., 2005. Freestall maintenance: effects on lying behavior of dairy cattle, Journal of Dairy Science, 88, 2381-2387

Duve, L.R. and Jensen, M.B., 2012. Social behavior of young dairy calves housed with limited or full social contact with a peer1, Journal of Dairy Science, 95, 5936-5945

Elbers, A.R., Miltenburg, J.D., De Lange, D., Crauwels, A.P., Barkema, H.W. and Schukken, Y.H., 1998. Risk factors for clinical mastitis in a random sample of dairy herds from the southern part of The Netherlands, Journal of Dairy Science, 81, 420-426

Ellis, K.A., Innocent, G.T., Mihm, M., Cripps, P., McLean, W.G., Howard, C.V. and Grove-White, D., 2007. Dairy cow cleanliness and milk quality on organic and conventional farms in the UK, Journal of Dairy Research, 74, 302-310

El-Tarabany, M. and Ali, M.A., 2015. Incidence, production and economic losses of clinical mastitis in Egyptian Holstein cows, Iranian Journal of Applied Animal Science, 5, 813-818

Farevik, G., Tjentland, K., Lavik, S., Andersen, I.L. and Boe, K.E., 2008. Resting pattern and social behaviour of dairy calves housed in pens with different sized lying areas, Applied Animal Behaviour Science, 114, 54-64

Færevik, G., Jensen, M.B. and Bøe, K.E., 2006. Dairy calves social preferences and the significance of a companion animal during separation from the group, Applied Animal Behaviour Science, 99, 205-221

Fregonesi, J.A., von Keyserlingk, M A G, Tucker, C.B., Veira, D.M. and Weary, D.M., 2009. Research-article: Neck-rail position in the free stall affects standing behavior and udder and stall cleanliness, Journal of Dairy Science, 92, 1979-1985

Fregonesi, J.A., von Keyserlingk, M A G and Weary, D.M., 2009. Cow preference and usage of free stalls compared with an open pack area, Journal of Dairy Science, 92, 5497-5502

Fregonesi, J.A., Veira, D.M., von Keyserlingk, M A G and Weary, D.M., 2007. Effects of Bedding Quality on Lying Behavior of Dairy Cows, Journal of Dairy Science, 90, 5468-5472

Fregonesi, J.A. and Leaver, J.D., 2001. Behaviour, performance and health indicators of welfare for dairy cows housed in strawyard or cubicle systems, Livestock Production Science, 68, 205-216

Fulwider, W.K., Grandin, T., Garrick, D.J., Engle, T.E., Lamm, W.D., Dalsted, N.L. and Rollin, B.E., 2007. Article: Influence of Free-Stall Base on Tarsal Joint Lesions and Hygiene in Dairy Cows, Journal of Dairy Science, 90, 3559-3566

Fulwider, W.K. and Palmer, R.W., 2004. Article: Use of Impact Testing to Predict Softness, Cow Preference, and Hardening Over Time of Stall Bases, Journal of Dairy Science, 87, 3080-3088

Galindo, F., Broom, D.M. and Jackson, P.G.G., 2000a. A note on possible link between behaviour and the occurrence of lameness in dairy cows, Applied Animal Behaviour Science, 67, 335-341

Galindo, F., Broom, D.M. and Jackson, P.G.G., 2000b. A note on possible link between behaviour and the occurrence of lameness in dairy cows, Applied Animal Behaviour Science, 67, 335-341

Gitau, G.K., McDermott, J.J., Adams, J.E., Lissemore, K.D. and Waltner-Toews, D., 1994. Factors influencing calf growth and daily weight gain on smallholder dairy farms in Kiambu District, Kenya, Preventive veterinary medicine, 21, 179-190

Global Forum On Agricultural Research, 2016. Improving the economic lives of smallholder farmers

Gomez, A. and Cook, N.B., 2010a. Time budgets of lactating dairy cattle in commercial freestall herds, Journal of Dairy Science, 93, 5772-5781

Gomez, A. and Cook, N.B., 2010b. Time budgets of lactating dairy cattle in commercial freestall herds, Journal of Dairy Science, 93, 5772-5781

Grant, R., 2012. Economic benefits of improved cow comfort, Novus Int.St.Charles, MO

Green, L.E., Schukken, Y.H. and Green, M.J., 2006. On distinguishing cause and consequence: Do high somatic cell counts lead to lower milk yield or does high milk yield lead to lower somatic cell count?, Preventive veterinary medicine, 76, 74-89

Green, L.E., Hedges, V.J., Schukken, Y.H., Blowey, R.W. and Packington, A.J., 2002. The impact of clinical lameness on the milk yield of dairy cows, Society for Veterinary Epidemiology and Preventive Medicine.Twentieth anniversary proceedings of a meeting held at University of Cambridge, UK, 3rd-5th April, 2002

Gygax, L., Neisen, G. and Bollhalder, H., 2007. Accuracy and validation of a radar-based automatic local position measurement system for tracking dairy cows in free-stall barns, Computers and Electronics in Agriculture, 56, 23-33

Haley, D.B., de Passille, A.M. and Rushen, J., 2001. Assessing cow comfort: effects of two floor types and two tie stall designs on the behaviour of lactating dairy cows, Applied Animal Behaviour Science, 71, 105-117

Hanninen, L., De Passille, A.M. and Rushen, J., 2005. The effect of flooring type and social grouping on the rest and growth of dairy calves, Applied Animal Behaviour Science, 193

Hänninen, L., Mäkelä, J.P., Rushen, J., de Passillé, A.M. and Saloniemi, H., 2008. Assessing sleep state in calves through electrophysiological and behavioural recordings: A preliminary study, Applied Animal Behaviour Science, 111, 235-250

Haskell, M.J., Rennie, L.J., Bowell, V.A., Bell, M.J. and Lawrence, A.B., 2006. Housing system, milk production, and zero-grazing effects on lameness and leg injury in dairy cows, Journal of Dairy Science, 89, 4259-4266

Hernandez-Mendo, O., von Keyserlingk, M A G, Veira, D.M. and Weary, D.M., 2007. Article: Effects of Pasture on Lameness in Dairy Cows, Journal of Dairy Science, 90, 1209-1214

Hillerton, J.E., Dearing, J., Dale, J., Poelarends, J.J., Neijenhuis, F., Sampimon, O.C., Miltenburg, J D H M and Fossing, C., 2004. Impact of automatic milking on animal health, Automatic milking: a better understanding.Conference Proceedings, Lelystad, Netherlands, March 2004

Hoffman, A.C., Moore, D.A., Vanegas, J. and Wenz, J.R., 2014. Association of abnormal hind-limb postures and back arch with gait abnormality in dairy cattle, Journal of Dairy Science, 97, 2178-2185

Hossain, S., Reza, M.A., Hasan, M.N., Sorwar, M.G. and Billah, M., 2016. Impact of clinical mastitis in dairy farming at Keshabpur upazilla in Jessore in Bangladesh, Bangladesh Journal of Veterinary Medicine, 14, 59-64

Houben, E.H.P., Brand, A., Dijkhuizen, A.A. and R.B.M. Huirne, 1994. Economics of mastitis and mastitis control in dairy cattle

Ito, K., Chapinal, N., Weary, D.M. and Von Keyserlingk, M A G, 2014. Associations between herd-level factors and lying behavior of freestall-housed dairy cows, Journal of Dairy Science, 2081

Ito, K., von Keyserlingk, M A G, LeBlanc, S.J. and Weary, D.M., 2010. Lying behavior as an indicator of lameness in dairy cows, Journal of Dairy Science, 93, 3553-3560

Ito, K., Weary, D.M. and von Keyserlingk, M A G, 2009. Lying behavior: Assessing within- and between-herd variation in free-stall-housed dairy cows, Journal of Dairy Science, 92, 4412-4420

Ivenleyer, S., 2008. Effects of a two-year dairy herd health management programme on udder health, use of antibiotics and longevity, Schweizer Archiv fur Tierheilkunde, 150, 499-505

Jensen, M.B., Pedersen, L.J. and Munksgaard, L., 2005. The effect of reward duration on demand functions for rest in dairy heifers and lying requirements as measured by demand functions, Applied Animal Behaviour Science, 90, 207-217

Jensen, M.B., Munksgaard, L., Pedersen, L.J., Ladewig, J. and Matthews, L., 2004. Prior deprivation and reward duration affect the demand function for rest in dairy heifers, Applied Animal Behaviour Science, 88, 1-11

Koster, G., Tenhagen, B.-., Scheibe, N. and Heuwieser, W., 2006. Factors Associated with High Milk Test Day Somatic Cell Counts in Large Dairy Herds in Brandenburg. II. Milking Practices, Journal of Veterinary Medicine Series A, 53, 209-214

Kunz, P. and Leimbacher, A., 1983. How to rear healthy calves over the first few months. / Damit die Kalber gesund uber die ersten Monate kommen, Landtechnische Zeitschrift, 34, 370-375

Lago, A., McGuirk, S.M., Bennett, T.B., Cook, N.B. and Nordlund, K.V., 2006. Calf respiratory disease and pen microenvironments in naturally ventilated calf barns in winter, Journal of Dairy Science, 89, 4014-4025

Le Neindre, P., 1993. Evaluating housing systems for veal calves, Journal of animal science, 1345

Logue, D.N. and Offer, J.E., 2001. The effect of forage type on foot health in dairy heifers, Veterinary Journal (London, England: 1997), 162, 7-8

Lombard, J.E., Tucker, C.B., von Keyserlingk, M A G, Kopral, C.A. and Weary, D.M., 2010. Associations between cow hygiene, hock injuries, and free stall usage on US dairy farms, Journal of Dairy Science, 93, 4668-4676

Lubaba, C.H., Hidano, A., Welburn, S.C., Revie, C.W. and Eisler, M.C., 2015. Movement Behaviour of Traditionally Managed Cattle in the Eastern Province of Zambia Captured Using Two-Dimensional Motion Sensors, PLoS ONE

Maatje, K. and Verhoeff, J., 1991. Automated feeding of milk replacer and health control of group-housed veal calves, New trends in veal calf production.Proceedings of the international symposium on veal calf production, Wageningen, Netherlands, 14-16 March 1990., 71-75

Magnusson, M., Herlin, A.H. and Ventorp, M., 2008. Effect of alley floor cleanliness on free-stall and udder hygiene, Journal of Dairy Science, 91, 3927-3930

Main, D.C.J., Leach, K.A., Barker, Z.E., Sedgwick, A.K., Maggs, C.M., Bell, N.J. and Whay, H.R., 2012. Evaluating an intervention to reduce lameness in dairy cattle, Journal of Dairy Science, 95, 2946-2954

Mason, W., 2017. Association between age and time from calving and reported lameness in a dairy herd in the Waikato region of New Zealand, New Zealand veterinary journal, 65, 163-167

Mazrier, H., Tal, S., Aizinbud, E. and Bargai, U., 2006. A field investigation of the use of the pedometer for the early detection of lameness in cattle

McFarland, D.F. and Gamroth, M.J., 1994. Free-stall designs with cow comfort in mind, Dairy systems for the 21st century. Proceedings of the third international dairy housing conference held in Orlando, Florida, USA, 2-5 February 1994., 145-158

McFarland, D.F., 1991. Experiences with free stall design in Pennsylvania, Paper - American Society of Agricultural Engineers, 17

Mellor, D.J., 2017. Operational Details of the Five Domains Model and Its Key Applications to the Assessment and Management of Animal Welfare, Animals (2076-2615), 7, 1-20

Miller-Cushon, E. and DeVries, T.J., 2017. Short communication: Associations between feed push-up frequency, feeding and lying behavior, and milk yield and composition of dairy cows, Journal of Dairy Science, 100, 2213-2218

Mugambi, D.K., Mwangi, M., Wambugu, S.K. and Gitunu, A.M.M., 2015. Assessment of performance of smallholder dairy farms in Kenya: an econometric approach, Journal of Applied Biosciences, 85, 7891-7899

Mureithi, D.K. and Njuguna, M.N., 2016. Prevalence of subclinical mastitis and associated risk factors in dairy farms in urban and peri-urban areas of Thika Sub County, Kenya, Livestock Research for Rural Development, 28, Article 13

Muthee, J.K., Gakuya, D.W. and Nduhiu, J., 2005. Preliminary investigation of the status of bovine mastitis in a medium scale dairy farm in Kabete area, Kenya, The Kenya Veterinarian, 29, 57-59

National Animal Health, Monitoring System, 2009. Dairy 2007. Part IV, Reference of Dairy Cattle Health and Management Practices in the United States, 2007, (United States, North America)

Negash, M., 2005. Birth weight and gestation length in Holstein-Friesians, Bulletin of Animal Health and Production in Africa, 53, 135-137

Nielsen, B.H., Thomsen, P.T. and S�rensen, J.T., 2011. Identifying risk factors for poor hind limb cleanliness in Danish loose-housed dairy cows, Animal, 5, 1613-1619

Ninomiya, S. and Sato, S., 2009. Effects of �Five freedoms� environmental enrichment on the welfare of calves reared indoors, Animal Science Journal, 80, 347

Norring, M., Valros, A. and Munksgaard, L., 2012. Milk yield affects time budget of dairy cows in tie-stalls, Journal of Dairy Science, 95, 102-108

Norring, M., Manninen, E., Passill�, A.M.d., Rushen, J., Munksgaard, L. and Saloniemi, H., 2008. Effects of sand and straw bedding on the lying behavior, cleanliness, and hoof and hock injuries of dairy cows, Journal of Dairy Science, 91, 570-576

Norring, M., Manninen, E., Saloniemi, H., de Passille, A.M., Rushen, J. and Munksgaard, L., 2008. Effects of sand and straw bedding on the lying behavior, cleanliness, and hoof and hock injuries of dairy cows, Journal of Dairy Science, 91, 570-576

Nyongesa, D., Mwirigi, M.K., Yongo, D. and Makokha, S., 2016. Gender-Concerns: Do They Matter in Smallholder Dairy Groups in Kenya?, International Journal of Agricultural Resources, Governance and Ecology, 12, 1-17

Oddoye, E.O.K., Okantah, S.A., Obese, F.Y. and Gyawu, P., 1999. Growth performance, body condition score and milk yield of Sanga cattle in smallholder peri-urban dairy herds in the Accra Plains of Ghana, Bulletin of Animal Health and Production in Africa, 47, 143-148

Osterman, S. and Redbo, I., 2001. Effects of milking frequency on lying down and getting up behaviour in dairy cows, Applied Animal Behaviour Science, 70, 167-176

Overton, M.W., Sischo, W.M., Temple, G.D. and Moore, D.A., 2002. Using time-lapse video photography to assess dairy cattle lying behavior in a free-stall barn, Journal of Dairy Science, 85, 2407-2413

Panivivat, R., Kegley, E.B., Pennington, J.A., Kellogg, D.W. and Krumpelman, S.L., 2004. Article: Growth Performance and Health of Dairy Calves Bedded with Different Types of Materials, Journal of Dairy Science, 87, 3736-3745

Peeler, E.J., Otte, M.J. and Esslemont, R.J., 1994. Inter-relationships of periparturient diseases in dairy cows, Veterinary Record, 134, 129-132

Peter, G.S., Gitau, G.K., Mulei, C.M., Vanleeuwen, J., Richards, S., Wichtel, J., Uehlinger, F. and Mainga, O., 2015. Prevalence of Cryptosporidia, Eimeria, Giardia, and Strongyloides in pre-weaned calves on smallholder dairy farms in Mukurwe-ini District, Kenya, Veterinary World, 8, 1118-1125

Peter, S.G., Gitau, G.K., Richards, S., Vanleeuwen, J.A., Uehlinger, F., Mulei, C.M. and Kibet, R.R., 2016. Risk factors associated with Cryptosporidia, Eimeria, and diarrhea in smallholder dairy farms in Mukurwe-ini Sub-County, Nyeri County, Kenya, Veterinary World, Vol 9, Iss 8, Pp 811-819 (2016), 811

Ramirez, N.F., Keefe, G., Dohoo, I., Sanchez, J., Arroyave, O., Ceron, J., Jaramillo, M. and Palacio, L.G., 2014. Herd- and cow-level risk factors associated with subclinical mastitis in dairy farms from the High Plains of the northern Antioquia, Colombia, Journal of Dairy Science, 4141

Raussi, S., Lensink, B.J., Boissy, A., Pyykkenen, M. and Veissier, I., 2003. The effect of contact with conspecifics and humans on calves' behaviour and stress responses, Animal Welfare, 12, 191-203

Reich, L.J., Weary, D.M., Veira, D.M. and von Keyserlingk, M A G, 2010. Effects of sawdust bedding dry matter on lying behavior of dairy cows: A dose-dependent response, Journal of Dairy Science, 93, 1561-1565

Reneau, J.K., Seykora, A.J., Heins, B.J., Endres, M.I., Farnsworth, R.J. and Bey, R.F., 2005a. Association between hygiene scores and somatic cell scores in dairy cattle, Journal of the American Veterinary Medical Association, 227, 1297-1301

Reneau, J.K., Seykora, A.J., Heins, B.J., Endres, M.I., Farnsworth, R.J. and Bey, R.F., 2005b. Association between hygiene scores and somatic cell scores in dairy cattle, Journal of the American Veterinary Medical Association, 227, 1297-1301

Richards, S. M., 2017. Productivity and welfare of cows on smallholder dairy farms in Kenya, PhD Dissertation, University of Prince Edward Island, Charlottetown

Robert, B., White, B.J., Renter, D.G. and Larson, R.L., 2009. Evaluation of three-dimensional accelerometers to monitor and classify behavior patterns in cattle, Computers and Electronics in Agriculture, 67, 80-84

Roche, J.R., Friggens, N.C., Kay, J.K., Fisher, M.W., Stafford, K.J. and Berry, D.P., 2009. Invited review: Body condition score and its association with dairy cow productivity, health, and welfare, Journal of Dairy Science, 92, 5769-5801

Rollin, B.E., 2004. Animal agriculture and emerging social ethics for animals, Large animal.Proceedings of the North American Veterinary Conference, Volume 18, Orlando, Florida, USA, 17-21 January 2004

Rudel, T.K., 2009. Tree farms: driving forces and regional patterns in the global expansion of forest plantations, Land Use Policy, 26, 545-550

Rushen, J., Butterworth, A. and Swanson, J.C., 2011a. Animal behavior and well-being symposium: farm animal welfare assurance: science and application, Journal of animal science, 1219

Rushen, J., Butterworth, A. and Swanson, J.C., 2011b. Animal behavior and well-being symposium: farm animal welfare assurance: science and application, Journal of animal science, 1219

S. Sreedhar, 2015. Growth Performance of Indigenous and Cross Bred Calves in Coastal Region of Andhra Pradesh, 3

Saharia, J., Saikia, S. and Dutta, G.N., 1997. Effect of housing on the incidence of sub-clinical mastitis in dairy cows, Indian Veterinary Journal, 74, 436-438

Schlecht, E., Halsebusch, C., Mahler, F. and Becker, K., 2004. The use of differentially corrected global positioning system to monitor activities of cattle at pasture, Applied Animal Behaviour Science, 85, 185-202

Schreiner, D.A. and Ruegg, P.L., 2002. Effects of tail docking on milk quality and cow cleanliness, Journal of Dairy Science, 85, 2503-2511

Schultze, W.D. and Bright, S.C., 1983. Changes in penetrability of bovine papillary duct to endotoxin after milking, American Journal of Veterinary Research, 44, 2373-2375

Sepelveda-Varas, P., Weary, D.M. and Keyserlingk, M.A.G., 2014. Lying behavior and postpartum health status in grazing dairy cows, Journal of Dairy Science, 97, 6334-6343

Shane, E.M., Endres, M.I., Johnson, D.G. and Reneau, J.K., 2010. Bedding options for an alternative housing system for dairy cows: a descriptive study, Applied Engineering in Agriculture, 26, 659-666

Shitandi, A., Anakalo, G., Galgalo, T. and Mwangi, M., 2004. Prevalence of bovine mastitis amongst smallholder dairy herds in Kenya, Israel Journal of Veterinary Medicine, 59, 20-23

Somers, J G C J, Frankena, K., Noordhuizen-Stassen, E. and Metz, J.H.M., 2003. Prevalence of claw disorders in Dutch dairy cows exposed to several floor systems, Journal of Dairy Science, 86, 2082-2093

Sprecher, D.J., Hostetler, D.E. and Kaneene, J.B., 1997. A Lameness Scoring System That Uses Posture and Gait to Predict Dairy Cattle Reproductive Performance, Theriogenology, 1179

Steensels, M., Bahr, C., Berckmans, D., Halachmi, I., Antler, A. and Maltz, E., 2012. Lying patterns of high producing healthy dairy cows after calving in commercial herds as affected by age, environmental conditions and production, Applied Animal Behaviour Science, 136, 88-95

Tapk, I., 2007. Effects of individual or combined housing systems on behavioural and growth responses of dairy calves, Acta Agricultura Scandinavica.Section A, Animal Science, 57, 55-60

Tarantola, M., Bergero, D., Schiavone, A. and Ladetto, G., 1998. Housing and productivity of dairy cows: study on a Piedmont farm. / Stabulazione e produttivit�della vacca lattifera: studio su una azienda Piemontese, Large Animals Review, 4, 13-17

Tibru, I. and Chirila, D., 2008a. Building for cow comfort, Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca.Veterinary Medicine, 65, 225-233

Tibru, I. and Chirila, D., 2008b. Building for cow comfort, Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca.Veterinary Medicine, 65, 225-233

Tomkins, T., 1991. Loose-housing experience in North America, New trends in veal calf production.Proceedings of the international symposium on veal calf production, Wageningen, Netherlands, 14-16 March 1990., 67-70

Tremetsberger, L., Leeb, C. and Winckler, C., 2015. Animal health and welfare planning improves udder health and cleanliness but not leg health in Austrian dairy herds, Journal of Dairy Science, 98, 6801-6811

Tucker, C.B., Dalley, D.E., Burke, J.L.K. and Clark, D.A., 2007. Milking cows once daily influences behavior and udder firmness at peak and mid lactation, Journal of Dairy Science, 90, 1692-1703

Tucker, C.B., Zdanowicz, G. and Weary, D.M., 2006. Brisket boards reduce freestall use, Journal of Dairy Science, 89, 2603-2607

Tucker, C.B., Weary, D.M. and Fraser, D., 2005. Influence of neck-rail placement on free-stall preference, use, and cleanliness, Journal of Dairy Science, 88, 2730-2737

Tucker, C.B. and Weary, D.M., 2004. Article: Bedding on Geotextile Mattresses: How Much is Needed to Improve Cow Comfort?, Journal of Dairy Science, 87, 2889-2895

Tucker, C.B., Weary, D.M. and Fraser, D., 2004. Free-Stall Dimensions: Effects on Preference and Stall Usage, Journal of Dairy Science, 87, 1208-1216

Tucker, C.B., Weary, D.M. and Fraser, D., 2003. Article: Effects of Three Types of Free-Stall Surfaces on Preferences and Stall Usage by Dairy Cows, Journal of Dairy Science, 86, 521-529

Uzal, S. and Ugurlu, N., 2010a. The time budget of dairy cows as affected by season and housing system, Journal of International Environmental Application & Science, 5, 638-647

Uzal, S. and Ugurlu, N., 2010b. The time budget of dairy cows as affected by season and housing system, Journal of International Environmental Application & Science, 5, 638-647

van Arendonk, J., 1989. Phenotypic and Genetic Association between Fertility and Production in Dairy-Cows, Livestock Production Science, 21, 1-12

Van Putten, G., 1982. Welfare in veal calf units

Vanegas, J., Overton, M., Berry, S.L. and Sischo, W.M., 2006. Effect of rubber flooring on claw health in lactating dairy cows housed in free-stall barns, Journal of Dairy Science, 89, 4251-4258

Vasseur, E., Gibbons, J., Rushen, J., Pellerin, D., Pajor, E., Lefebvre, D. and de Passill, A.M., 2015. An assessment tool to help producers improve cow comfort on their farms, Journal of Dairy Science, 98, 698-708

Vasseur, E., Gibbons, J., Rushen, J., Pellerin, D., Pajor, E., Lefebvre, D. and de Passill�, A.M., 2015. An assessment tool to help producers improve cow comfort on their farms, Journal of Dairy Science, 98, 698-708

Vasseur, E., Gibbons, J., Rushen, J., Pellerin, D., Pajor, E., Lefebvre, D. and de Passillé, A.M., 2015. An assessment tool to help producers improve cow comfort on their farms, Journal of Dairy Science, 98, 698-708

Vasseur, E., Borderas, F., Cue, R.I., Lefebvre, D., Pellerin, D., Rushen, J., Wade, K.M. and de Passillé, A.M., 2010. A survey of dairy calf management practices in Canada that affect animal welfare, Journal of Dairy Science, 93, 1307-1316

Veissier, I., Capdeville, J. and Delval, E., 2004. Cubicle housing systems for cattle: comfort of dairy cows depends on cubicle adjustment, Journal of animal science, 82, 3321-3337

Verbrugge, T A W M, 2015. Cow comfort in relation to milk yield on pasture based dairy herds in Uruguay

Vokey, F.J., Guard, C.L., Erb, H.N. and Galton, D.M., 2001. Article: Effects of Alley and Stall Surfaces on Indices of Claw and Leg Health in Dairy Cattle Housed in a Free-Stall Barn, Journal of Dairy Science, 84, 2686-2699

von Keyserlingk, M A G, Cunha, G.E., Fregonesi, J.A. and Weary, D.M., 2011. Introducing heifers to freestall housing, Journal of Dairy Science, 94, 1900-1907

von Keyserlingk, M A G, Rushen, J., de Passille, A.M. and Weary, D.M., 2009. Invited review: The welfare of dairy cattle—Key concepts and the role of science, Journal of Dairy Science, 92, 4101-4111

Wagner-Storch, A., Palmer, R.W. and Kammel, D.W., 2003. Article: Factors Affecting Stall Use for Different Freestall Bases, Journal of Dairy Science, 86, 2253-2266

Wakchaure, R.S. and Meena, R., 2010. Factors Affecting, Birth Weight, Age and Weight at First Calving in Sahiwal Cattle, Indian Journal of Animal Research, 173

Ward, W.R., Hughes, J.W., Faull, W.B., Cripps, P.J., Sutherland, J.P. and Sutherst, J.E., 2002. Observational study of temperature, moisture, pH and bacteria in straw bedding, and faecal consistency, cleanliness and mastitis in cows in four dairy herds, Veterinary Record, 151, 199-206

Watters, M.E.A., Meijer, K.M.A., Barkema, H.W., Leslie, K.E., Keyserlingk, M.A.G. and DeVries, T.J., 2013. Associations of herd- and cow-level factors, cow lying behavior, and risk of elevated somatic cell count in free-stall housed lactating dairy cows, Preventive veterinary medicine, 111, 245-255

Weary, D.M. and Taszkun, I., 2000. Hock Lesions and Free-Stall Design, Journal of Dairy Science, 83, 697-702

Wechsler, B., Schaub, J., Friedli, K. and Hauser, R., 2000. Behaviour and leg injuries in dairy cows kept in cubicle systems with straw bedding or soft lying mats, Applied Animal Behaviour Science, 69, 189-197

Whay, H.R. and Main, D.C.J., 2015. Improving animal care and welfare: practical approaches for achieving change, Improving animal welfare: a practical approach

Whay, H.R., Main, D.C.J., Green, L.E. and Webster, A.J.F., 2003. Animal-based measures for the assessment of welfare state of dairy cattle, pigs and laying hens: consensus of expert opinion, Animal Welfare, 12, 205-217

Wildman, E.E., Jones, G.M., Wagner, P.E., Boman, R.L., Troutt, H.F., J. and Lesch, T.N., 1982. A dairy cow body condition scoring system and its relationship to selected production characteristics, Journal of Dairy Science, 65, 495-501

Wilson, L.L., Terosky, T.L., Stull, C.L. and Stricklin, W.R., 1999. Effects of individual housing design and size on behavior and stress indicators of special-fed Holstein veal calves, Journal of animal science, 77, 1341-1347

Xiccato, G., Trocino, A., Queaque, P.I., Sartori, A. and Carazzolo, A., 2002. Rearing veal calves with respect to animal welfare: effects of group housing and solid feed supplementation on growth performance and meat quality, Livestock Production Science, 75, 269-280

Zadoks, R.N., Allore, H.G., Barkema, H.W., Sampimon, O.C., Wellenberg, G.J., Gr�hn, Y.T. and Schukkent, Y.H., 2001. Cow- and quarter-level risk factors for streptococcus uberis and staphylococcus aureus mastitis

Zurbrigg, K., Kelton, D., Anderson, N. and Millman, S., 2005. Stall dimensions and the prevalence of lameness, injury, and cleanliness on 317 tie-stall dairy farms in Ontario, Canadian Veterinary Journal, 46, 902-909

Chapter 2: Cross-sectional study of welfare of calves kept in dairy farms in the Meru region of Kenya, 2017.

2.1 Abstract

This study was aimed at describing calf comfort and determining the individual and pen level factors that affect comfort (in particular, calf leg hygiene) of smallholder dairy farms in Meru County, Kenya.

A cross-sectional study was carried out on 52 calves that were one year old and younger in 38 dairy farms (mean ± SD: herd size = 1.71 ± 0.7 milking cows; milk production = 6.7 ± 3.1 liters/day) in Meru, Kenya in 2017, to describe their comfort and determine the factors associated with leg hygiene as a summary parameter for calf comfort. Calf biodata, health status and leg hygiene were assessed, along with pen characteristics such as area, hygiene, and knee impact and knee wetness scores, while a questionnaire was administered to the farmers to gather information regarding calf housing management practices in the farm.

The calves had a mean body weight of 85.2±32.8 kg and average daily weight gain (ADG) of 0.50 ± 0.45 kg. A total of 71% of calves had a good body condition score greater than or equal to 2.5, and each calf had a space allowance of 2.52 ± 1.56m^2. Approximately 75% of the calves (39/52) were kept in pens and the rest were reared outdoors. For the 39 calves kept in pens, 23% and 33% of them had a failed knee impact and knee wetness test, respectively, with 62% of pens having bedding and 26% of pen floors being wood or concrete. In univariable analyses of the 52 calves, indoor housed calves had an increased odds of having dirty calf legs by 8.6 times (p=0.031), compared to outdoor-housed calves. In the final multivariable logistic regression model of 39 calves in pens, concrete or wood floors (OR=7.9, p=0.047), poor body condition (OR=17.1, p=0.020) and use of bedding (OR=12.5, p=0.046) were risk factors associated with dirtiness of calf legs, compared to dirt floors, good body condition, and no bedding, respectively.

Overall, some calf comfort aspects were adequate for the majority of calves examined, but 69% of the pens were categorized as dirty, leading to dirty calves, especially in pens with wooden or concrete floors and poor bedding management. Small holder dairy farmers in Kenya should be trained on calf housing management to improve calf comfort and productivity.

Keywords: calf comfort, hygiene, dairy calves, Kenya

2.2 Introduction

Animal welfare has become a global concern in regard to livestock, companion and wild animals (Rollin, 2004).To maintain body integrity while growing, calves need: access to air with sufficient oxygen, adequate rest in the right postures to prevent sleep deprivation, movement and exercise space for bone and muscle development, an adequate and well-balanced diet (colostrum, milk, calf starter), enough water and social contact (Algers et al., 2006). Housing management of dairy calves is vital to lying behavior, feeding status and social behaviour of the calves, subsequently impacting their growth and development (Algers et al., 2006). The recommended space allowance for young calves is 0.95m by 1.35m (Kunz and Leimbacher, 1983). Calves kept in pens that are about 1 by 1.5 m have shown a higher percentage of lying behavior and lymphocyte proliferation compared to calves kept in smaller pens (Algers et al., 2006). Factors such as pen area per calf, type of floor, type of bedding and weather conditions interact with each other (Algers et al., 2006).

Housing of dairy calves can be done individually, in pairs or groups. Individual housing of calves in dairy production has raised animal welfare concerns (Raussi et al., 2003; De Paula Vieira, von Keyserlingk and Weary, 2010). In Canada and USA, 87.9% and 67.9% of farms housed their calves individually pre and post-weaning, respectively (National Animal Health, Monitoring System, 2009; Vasseur et al., 2010). The European Union regulations indicate that group housing is mandatory for calves older than 8 weeks (Anonymous 1996). Benefits attributed to paired and group-housing include: reduced labour requirements per calf (Costa et al., 2015); improved social behavior of calves (Færevik, Jensen and Bøe, 2006; Duve and Jensen, 2012); decreased fear for a new diet during weaning (Costa et al., 2014); higher intakes of starter feed (De Paula Vieira, von Keyserlingk and Weary, 2010); and increased weight gains (Chua et al., 2002; Xiccato et al., 2002; Tapk, 2007; De Paula Vieira, von Keyserlingk and Weary, 2010). The preference of individual housing is due to studies showing increased weight gains in singly raised calves (Maatje and Verhoeff, 1991), decreased calf morbidity (Tomkins, 1991) and less behavioral issues such as cross-sucking (Van Putten, 1982).

Dairy calves spend about 18hr/day lying down (Wilson et al., 1999; Chua et al., 2002; Panivivat et al., 2004; Camiloti et al., 2012). The lying behavior has also been used as an indicator of how well calves adjust to new housing (von Keyserlingk, M A G et al., 2011). The type of lying surface in pens influences the lying time and posture of calves (Le Neindre, 1993). Calves showed an aversion to lying down on bare concrete versus a sawdust-bedded surface (Camiloti et al., 2012). Calves did not show any significant difference in lying behavior when kept in pens with concrete surface or rubber mats (Hanninen, De Passille and Rushen, 2005). Accessibility of dry, soft and deep bedding is essential for growth of calves (Lago et al., 2006; Camiloti et al., 2012). Deep and dry bedding decreases heat loss in calves through radiation and conduction, respectively, thus preventing hypothermia (Camiloti et al., 2012). The frequent addition of ample amounts of bedding in pens increases the use of lying posture related to sleeping and comfort in calves (Ninomiya and Sato, 2009).

In Kenya, dairy farming is a major contributor to the gross domestic product (Behnke et al., 2013). Dairy calves are raised to replacement heifers on most smallholder farms. There is need to facilitate not only optimal growth rate and performance but also comfort, rest and welfare of calves. Good animal welfare reduces the stress level in calves, enhances immune function and subsequently increases weight gain (De Paula Vieira, von Keyserlingk and Weary, 2010). There have been reports of calf growth, morbidity and mortality on smallholder dairy farms in Kenya (G. S. Peter et al., 2015; S. G. Peter et al., 2016). To our knowledge, there has never been an assessment of calf comfort or its factors on smallholder dairy farms in Kenya or other developing countries.

This study was aimed at describing calf comfort and determining the individual and pen level factors that affected calf comfort (in particular, calf leg hygiene) of smallholder dairy farms in Meru County, Kenya.

2.3 Materials and Methods

2.3.1 Ethical approval

The study was approved by the Research Ethics Board and the Animal Care Committee of the University of Prince Edward Island, the Naari Dairy Co-operative Society and Farmers Helping Farmers, a partnering non-governmental organization with over 35 years of experience working with Kenyan farmers and farm groups. Consent was obtained from all the participants in the study

2.3.2 Study design and sampling method

This research was a cross-sectional study carried out in 38 dairy farms in the Naari region of Meru County in Kenya between May and August 2017. The full list of active farmers in the Naari Dairy Co-operative Society (NDCS) was used as the initial sampling frame that was narrowed down to 200 farms using simple random sampling for a companion study. The following inclusion criteria were used to further identify 100 farms from the 200 farms for on-going monitoring for the companion project: zero-grazing units for the lactating cows and up to three cows per farm. Farms without calves and farms with calves older than one year were excluded from the study, leaving 52 calves and 38 farms for the study.

2.3.3 Data collection

The 52 calves were assessed for their: biodata, welfare, health status and management.

For biodata, the weight was estimated in kilograms using a dairy cow heart girth weight tape. The height was measured using a height stick with a level that was placed at the withers. All calves were hybrids, thus the breeds were described as cross-bred if the calves were visibly and predominantly Friesian, Guernsey, Ayrshire or Jersey, and indigenous if they were visibly and predominantly Zebu, Boran or other local breeds. The body condition score was described using the 5-score chart that ranged from 1(very thin) to 5 (excessively fat), with quarter-point increments (Wildman et al., 1982).

For calf welfare data, the leg hygiene of the calves was assessed using a 5-score system (Reneau et al., 2005a) that included: 1 (very clean), 2 (clean), 3 (fair), 4 (dirty) and 5 (very dirty). Lameness observed in the calves was classified using a 3-point scoring system modified from a 5-point system (Sprecher, Hostetler and Kaneene, 1997) as: absent (normal gait), mild (uneven gait) or severe (short striding gait with at least one limb or reluctance to put weight on at least one limb). Neck, carpal and hock injuries were classified using a 3-score system: 1 (no swelling and no hair loss), 2 (minor swelling and/or bald area visible) and 3 (medium/major swelling and/or bald area, broken skin or scab present) developed by Cornell University and used in various studies (Lombard et al., 2010; Barrientos et al., 2013).

For the calves kept in pens: data on pen dimensions, floor type, and roof adequacy, type of bedding, pen hygiene, knee wetness and knee impact tests scores were collected. The pen dimensions were measured in cm. The knee impact test (from a crouched position on your feet, tipping forward so your knees contact the floor surface) was used to determine how soft the stall surface was, and was categorized into three possible levels: normal, marginal and hard. If the floor was soft and did not cause any level of discomfort on the knees, the floor was categorised as normal which indicated a passing grade on the knee impact test. If the floor was somewhat uncomfortable on the knees, such as a cement floor with a modest amount of bedding or a dirt floor that was compacted, then it was classified as marginal. If the floor caused extreme discomfort on the knees on impact, the floor was classified as hard and this indicated failure of the knee impact test.

The degree of wetness on the floor surface was assessed using the knee wetness test, which was categorised as normal if the knee was completely dry after about 10-15 seconds of knee contact on the floor, marginal if the knee had some noticeable moisture, and wet if the knee was completely wet after the contact with the floor. The knee wetness and impact tests have been used elsewhere to assess floor conditions for cattle (McFarland, 1991). We included a marginal category to the knee tests to adapt the tests to the highly variable stall management conditions that exist in Kenya where dirt (not sand) and crop waste are commonly used for floor surfaces.

The pen hygiene score mirrored the leg hygiene score where the categories included: 1 (very clean), 2 (clean), 3 (fair), 4 (dirty) and 5 (very dirty). The adequacy of the roof (yes or no) was determined based on the roof; covering the entire pen and not allowing water to enter.

The health status of the calves was determined by conducting a physical examination of the calf that included but not limited to; heart rate and character, respiratory rate and character, color of mucous membranes, palpation of superficial lymph nodes, rumen movements (where applicable), skin condition, joints and feet examination, and examination of the umbilicus. Any abnormalities observed were recorded and treated on the farm.

A questionnaire was administered to the 38 farmers' face- to-face by the investigator using the native language of Kimeru to gather information on the housing management status of the pre-weaned and weaned calves.

2.3.4 Data management and analysis

Collected data were entered manually into Microsoft excel 2013 (Microsoft, Sacramento, California, USA), cleaned, coded and imported to Stata® 14.2 statistical software (StataCorp LLC, College station, Texas, USA) for analysis. Descriptive statistics, such as means, standard deviations and ranges, were determined for continuous variables, while proportions were calculated for binary and categorical variables.

Average daily weight gain (ADG) was estimated by dividing the difference between body weight during the study and an estimated birth weight by the age of the calves in days. The average birth weight was estimated as an average from birth weights reported in small holder farms in Africa (Oddoye et al., 1999; Negash, 2005; Akdag et al., 2011). Comparison of continuous variables across different groups was done using the t-test, while comparison of categorical variables across different groups was done using Chi-squared tests.

Univariable logistic regressions were used to determine unconditional associations of variables with calf cleanliness. This outcome of interest was generated by dichotomizing the leg hygiene score, with scores ≤ 2.5 categorized as clean while scores greater than 2.5 were categorized as dirty, with 2.5 being the mid-point of the scale range of 1 to 5. This outcome variable was chosen for regression analyses because calf cleanliness represents an overall comfort parameter, and it had sufficient variability in the data for regression analyses.

Variables with a $P<0.2$, on univariable analyses, were eligible to be fit in a multivariable logistic regression model to determine factors associated with calf dirtiness, while controlling for possible confounding effects. Since there were 52 calves in total but only 39 calves within pens, two multivariable models were fit, one for each of the calf-level variables and pen-level variables. Variables eligible for these separate models were also utilized to build a combined model of both calf-level and pen-level variables. These multivariable logistic regression models were fit through backward elimination, retaining variables with p-values less than 0.1due to the small sample size. The final combined logistic regression model was assessed for two-way interactions, independence, linearity, goodness of fit, influential observations and predictive ability.

2.4 Results

The calves' ages ranged from 1 week to 12 months with an average of 5.2±3.1 months, with more details provided in Table 2-1. Nearly half of the calves were heifers, while less than a quarter of calves were categorized as indigenous. The calves had a mean (and standard deviation) body condition score of 2.5±0.4, ranging from 1.5 to 3.5. Two calves showed signs of respiratory infection on physical examination that was characterized by coughing and abnormal lung sounds. The mean and standard deviation of body weight and height of the calves were 85±32.8 kg and 83.5±9.7cm, respectively while ADG was 0.50±0.45 kg.

Lameness, carpal lesions and hock lesions were absent in all the calves, while a neck lesion was seen in one female calf aged 10 months.

Seventy-five percent of the calves (39/52) were reared in pens on 28 separate farms (Table 2-1). The average pen area was $3.09 \pm 1.46 m^2$, with the number of calves per pen ranging from one to three, with a mean of 1.4±0.5 calves per pen. The available pen area per calf averaged $2.52 \pm 1.56 m^2$, with a range of 1.02 to 7.64 m^2. When the calves in the smallholder dairy farms were reared in housing systems that were substantially different from each other across farms in the study, all the calf pens assessed had an appropriate roof. For the 39 calves kept in pens, 23% and 33% of them had a failed knee impact and knee wetness test, respectively, with 62% of pens having bedding and 26% of pen floors being wood or concrete. The overall mean pen hygiene score was 2.9±0.9, while the mean leg hygiene score was 2.3±1.1. Sixty-five percent (34/52) of all the calves observed were categorized as clean, with a leg hygiene score less than or equal to 2.5. For the 39 pens, 23 (59%) were categorized as clean.

Table 2-1 provides a summary of data on categorical calf- and pen-level factors, along with the relative proportions of calves with dirty leg hygiene scores.

Table 2-2 outlines the mean, standard deviation and range of pen and leg hygiene scores across three groups of bedding availability for 39 calves housed in pens. Leg hygiene scores and pen hygiene scores appear to be similar for the calves in pens with no bedding or bedded with sawdust or wood shavings. However, for the calves in pens with crop waste or other types of bedding, the pen hygiene scores are the dirtiest, while the calf hygiene scores are the cleanest. Availability of bedding, regardless of type, was associated with pen hygiene (χ^2=7.90; P=0.019).

On univariable analyses, variables with a $p<0.2$ including: age, breed, BCS and the housing variable were fit into the preliminary multivariable logistic regression model of calf-related variables associated with calf cleanliness among the 52 calves. Type of floor, type of bedding and pen hygiene score were variables with a p<0.2 on univariable analyses, and were therefore fit into the preliminary multivariable logistic regression model of pen-level variables associated with calf cleanliness among the 39 calves in pens.

For the multivariable logistic regression of calf-related variables, body condition score had a slight correlation with age (r=0.20). The odds of calves being categorized as dirty were higher in older calves (2.5 - 5.5 months) in comparison to younger calves (OR=37.2, P=0.009). Cross-bred calves had higher odds of having a dirty score relative to indigenous calves (OR=22.9, P=0.022), while indoor-reared calves were dirtier than outdoor-reared calves (OR=8.6, P=0.031).

The multivariable logistic regression model of pen-related variables indicated that the odds of calves being dirty were 6.8 times higher in calves kept in groups compared to the odds of calves housed individually (P=0.097). Calves in pens categorized as dirty had 6.4 times higher odds of being categorized as dirty (P=0.088) compared with calves in pens categorized as clean. The odds of calves having a dirty score (>2.5) were higher in pens with bedding than calves in pens without bedding (P=0.025). In addition, use of sawdust or wood shavings as bedding increased the odds of calves being categorized as dirty by 13.2 times versus no bedding at all (P=0.017).

When combining the calf- and pen-related factors in the multivariable logistic regression model for calf leg hygiene in the 39 calves raised in pens, concrete or wood floors, poor body condition and use of bedding were risk factors associated with calves categorized as dirty (Table 2-3). There were no interactions between the main effects of the final model.

The goodness of fit test indicated that the final logistic regression model fit the data (χ^2 =3.34; P=0.503).

2.5 Discussion

This is the first assessment of calf comfort among smallholder dairy farms in tropical countries and provides useful information for guiding extension officers and animal health professionals on how to assess basic parameters of calf welfare, without getting into the 5 domains of welfare recently proposed (Mellor, 2017). This study demonstrated that the population of calves surveyed had reasonable space allowance, but one-quarter to one-third of the indoor-reared calves were housed in pens with suboptimal flooring and bedding management, leading to failed knee impact and knee wetness tests, dirtier pens and dirtier calves (Table 2-1). Calves with leg hygiene scores categorized as dirty were significantly associated with wood or concrete floors and bedding use that was not managed properly (Table 2-3).

There is limited information on calf- and pen-related factors associated with calf comfort in smallholder dairy farms in Kenya; leg hygiene scores of the calf can be used as indicators of calf comfort.

In the calf-related multivariable logistic regression model, indoor calves (75%) were dirtier than outdoor-reared calves, and this could be due to poor management practices, such as delays in bedding addition and/or manure removal. The 13 calves kept outside were either tethered with a long rope or grazing in a field, and therefore their frequent movement during the day, and more space for lying, standing and movement likely explains the low likelihood of having dirty leg hygiene scores (OR=0.12) in comparison with indoor calves. A survey of calf management practices in Quebec showed that inappropriate calf housing systems such as tie-stalls (13.9%) and attachment against a wall (5.7%) were risk factors for poor calf welfare (Vasseur et al., 2010). The outdoor-reared calves were not included in the multivariable regression analyses of combined calf- and pen-level factors.

The average lying space of $2.5m^2$ available for each calf in our study was higher than that recommended ($1.4\ m^2$) for calves with an average weight of up to 160 kg in Germany (Kunz and Leimbacher, 1983). Calves housed in groups (36%) were categorized as dirtier (Table-1) than individually housed calves (64%), which could be explained by limited space availability per calf (group calves had $1.5\pm0.5\ m^2$, while individual calves had $3.1\pm1.7\ m^2$), in addition to poor manure and bedding management practices.

A higher body condition score can be attributed to sufficient feed intake, good health status and subsequently larger body weight which was observed in calves with body condition scores greater than 2.5 in the study (P=0.019). Calves with higher body condition scores (>2.25) were also less likely to have dirty leg scores which could be due to better management practices by the farmers such as regular removal of manure. The odds of calves having low body condition score (≤2.25) were 4.7 times higher in calves that were categorized as dirty versus clean calves (P=0.018), which shows that poor management practices may lead to poor welfare and performance of the calves. A recent study stipulated that changes in an animal's BCS may possibly reflect on its welfare state but the relationship is complicated by other factors that affect welfare (Roche et al., 2009).

The estimated average daily gain (0.5 kg) was higher than the mean daily gain reported in a study carried out in the Nakuru region of Kenya (Gitau et al., 1994), this difference may be due to the larger sample size used in the study (n=601) and the design of the study (longitudinal) where the birth weight of calves was measured while in this study, the sample size was small (n=52) and the birth weight was an estimate from three different studies in Africa. Cross-bred calves had a higher mean body weight (P=0.029) and average daily gain (P=0.015), which could be attributed to their faster growth rate in comparison to the indigenous-bred calves (S. Sreedhar, 2015). Similar results were reported in a study done on Sahiwal Cattle in India (Wakchaure and Meena, 2010). The higher odds of having dirty legs seen in older calves (>2.5 months) could be due to the larger amounts of fecal excrement in pens of these calves compared to the young ones regardless of the lying space available per calf.

In the pen-related (and combined) multivariable logistic regression model, calves kept in pens with wooden or concrete floors had significantly higher odds of being dirty (Table-3) which could be due to poor drainage of urine or wet manure or delayed cleaning of the pen at regular intervals.

Availability of any bedding in the pens increased the odds of a dirty leg hygiene score of the calves which could be due to delayed removal of dirty wet bedding and insufficient or delayed addition of new bedding in the pens. The higher odds of calves being dirty in pens bedded with sawdust and wood shavings could be due to low availability and high cost of acquiring new sawdust and wood shavings in comparison with crop waste that is readily available at the farms. Other studies have shown that the type of bedding used in rearing calves can have an effect on calf cleanliness (Panivivat et al., 2004).

As expected, calf cleanliness was strongly related to the pen hygiene whereby a dirty score for the pen translated into a large portion of the pen being wet, which left little to no clean lying down space thus increasing the likelihood of the calves being dirty. We also speculate that poor moisture absorbency of crop waste may explain the higher mean of pen hygiene score in crop waste bedded pens compared with sawdust or wood shavings bedded pens (Table 2-2). Crop waste used as bedding may imply that new bedding is added as frequently as the cow is fed new pasture, which could explain the cleaner scores of calves in crop waste bedded stalls regardless of the pen hygiene scores being high (Table 2-2).

The small sample size for calf-related factors (52) and pen-related factors (39) limited the number of significant relationships and associations observed. The small number of farms (38) also may have limited the variation in calf cleanliness. Furthermore, the cross-sectional nature of this study provides us with data on housing, calf comfort and hygiene at one point of our visit, without information on previous housing, welfare and hygiene. Other calf welfare outcomes, such as the five domains of welfare, and detailed calf management practices (including feeding) would also be useful parameters to measure and document. A larger cohort study of more calves on more farms measuring the 5 domains of welfare would add perspective to the observations in our study.

2.6 Conclusion and Recommendations

Overall, some welfare aspects of the examined calves were adequate, with nearly adequate pen sizes, good roofs, many good knee impact and knee wetness tests, and 65% of calves having a relatively clean leg hygiene scores. However, there was definitely room for improvement, particularly in overall pen hygiene where 69% of the pens were categorized as dirty. Rearing calves in pens with sawdust and wood shavings was negatively associated with the calf leg hygiene, providing a reminder that adding dry bedding should be accompanied with removal of wet bedding. The cleanliness of the calves was also associated with the type of floor in the pens, being worse in concrete or wooden floors, likely because they cannot absorb moisture the way dirt can. If possible, calves should be reared on surfaces that allow moisture to drain away, such as sand or sandy dirt, which makes it easier to keep calves dry with less labour (daily manure removal and clean dry bedding addition). If calves are reared on wood or concrete floors, they require manure removal and dry bedding addition /management at least daily, if not twice daily. These recommendations would ensure that calves would be kept in pens with clean, soft and dry bedding to optimize their performance. Farmers should be trained on the importance of good housing management practices of the calves to enhance their growth and welfare. Further research should be carried out to determine the solid feed intake, growth rate and diseases of dairy calves in Kenya.

The body condition score could be a good indicator of good welfare of the calves since it was associated with leg hygiene, and is an indicator of nutritional management. Further research should be carried to determine relationships between calf welfare parameters, body condition score, feed intake, growth rate and diseases of dairy calves in Kenya.

2.7 Conflict of interest

The authors declare that they have no competing interests.

2.8 Acknowledgements

We are grateful to the primary funding program for this research, the Canadian Queen Elizabeth II Diamond Jubilee Scholarships (QES) which are managed through a unique partnership of Universities Canada, the Rideau Hall Foundation (RHF), Community Foundations of Canada (CFC) and Canadian universities. This program is made possible with financial support from the Government of Canada, provincial governments and the private sector. We acknowledge the University of Nairobi that provided resources aiding in selection, orientation, training and supervision of QES Scholars and interns who participated in the program. We also acknowledge the large contribution made by volunteers and staff of Farmers Helping Farmers, a non-governmental organization – their existing relationships and agricultural efforts and inputs provided a strong foundation for the work and the entry point to the Naari community. We acknowledge the leadership and members of the Naari Dairy Cooperative Society in Meru for their co-operation in the study. We appreciate the help offered by Shauna Richards with the analysis of the accelerometer data, and Ren Chamberlain and Julia Kenny for their help in data collection in the field.

2.9 References

Rollin B.E. (2004) Animal agriculture and emerging social ethics for animals. Large animal Proceedings of the North American Veterinary Conference, Vol 18, Orlando, Florida, USA, 17-21 January 2004.

Algers B.B, Broom D.M., Caniatti Canali E., Hartung J., Fj M.S.C. and Veissier I. (2006) Scientific report on the risks of poor welfare in intensive calf farming systems Annex to EFSA Journal.

Kunz, P. and Leimbacher, A. (1983) How to rear healthy calves over the first few months. / Damit die Kalber gesund uber die ersten Monate kommen, *Landtechnische Zeitschrift.*, 34: 370-375.

Raussi, S., Lensink, B.J., Boissy, A., Pyykkenen, M. and Veissier, I. (2003) The effect of contact with conspecifics and humans on calves' behaviour and stress responses, *Anim Welf.,* 12: 191-203.

De Paula Vieira, A., Von Keyserlingk, M.A.G. and Weary, D.M. (2010) Effects of pair versus single housing on performance and behavior of dairy calves before and after weaning from milk, *J. Dairy Sci.,* 93: 3079-3085

Vasseur, E., Borderas, F., Cue, R.I., Lefebvre, D., Pellerin, D., Rushen, J., Wade, K.M. and de Passillé, A.M. (2010) A survey of dairy calf management practices in Canada that affect animal welfare, *J. Dairy Sci.,* 93: 1307-1316.

National Animal Health, Monitoring System, Dairy (2007) Part IV, Reference of dairy cattle health and management practices in the United States, 2007, United States, North America: 2009.

Proposal for a Council Directive amending Directive 91/629/EEC laying down minimum standards for the protection of calves (presented by the Commission), COM (96) 21 final, 24 January 1996

Costa, J.H.C, Meagher, R.K., von Keyserlingk, M. A. G. and Weary, D.M. (2015) Early pair housing increases solid feed intake and weight gains in dairy calves, J. Dairy Sci., 98: 6381.

Færevik, G., Jensen, M.B. and Bøe, K.E. (2006) Dairy calves social preferences and the significance of a companion animal during separation from the group, *Appl.Anim.Behav.Sci.,* 99: 205-221.

Duve, L.R. and Jensen, M.B. (2012) Social behavior of young dairy calves housed with limited or full social contact with a peer, *J.Dairy Sci.,* 95: 5936-5945.

Costa, J.H.C., Daros, R.R., von Keyserlingk, M. A. G. and Weary, D.M. (2014) Complex social housing reduces food neophobia in dairy calves, *J. Dairy Sci.,* 97: 7804-7810.

Chua, B., Coenen, E., van Delen, J. and Weary, D.M. (2002) Effects of Pair Versus Individual Housing on the Behavior and Performance of Dairy Calves, *J. Dairy Sci.,* 85: 360-364

Xiccato, G., Trocino, A., Queaque, P.I., Sartori, A. and Carazzolo, A. (2002) Rearing veal calves with respect to animal welfare: effects of group housing and solid feed supplementation on growth performance and meat quality, *Livest.Prod.Sci.,* 75: 269-280, 2002.

Tapk, I. (2007) Effects of individual or combined housing systems on behavioural and growth responses of dairy calves, *Acta Agriculturé Scandinavica.Section A*, *Animal Sci. J.,* 57: 55-60, 2007.

Maatje, K. and Verhoeff, J. (1991) Automated feeding of milk replacer and health control of group-housed veal calves, New Trends in Veal Calf Production. Proceedings of the International Symposium on Veal Calf Production, Wageningen, Netherlands, 14-16 March 1990. pp. 71-75.

Tomkins, T. (1991) Loose-housing experience in North America, New Trends in Veal Calf Production, Proceedings of the International Symposium on Veal Calf Production, Wageningen, Netherlands, 14-16 March 1990. pp. 67-70.

Van Putten, G. (1982) Welfare in veal calf units, *Vet.Rec.,* 111(19): 437-440.

Wilson, L.L., Terosky, T.L, Stull, C.L. and Stricklin, W.R. (1999) Effects of individual housing design and size on behavior and stress indicators of special-fed Holstein veal calves, *J.Anim.Sci.,*77: 1341-1347.

Panivivat, R., Kegley, E.B., Pennington, J.A., Kellogg, D.W. and Krumpelman, S.L (2004) Article: Growth Performance and Health of Dairy Calves Bedded with Different Types of Materials, *J.Dairy Sci.,* 87: 3736-3745.

Camiloti, T.V., Fregonesi, J.A., von Keyserlingk, M. A. G. and Weary, D.M. (2012) Short communication: Effects of bedding quality on the lying behavior of dairy calves, *J.Dairy Sci.,* 95: 3380-3383.

von Keyserlingk, M. A. G., Cunha, G.E., Fregonesi, J.A. and Weary, D.M. (2011) Introducing heifers to freestall housing, *J.Dairy Sci.,* 94: 1900-1907.

Le Neindre, P. (1993) Evaluating housing systems for veal calves. *J.Anim.Sci.,* 71(5): 1345-1354.

Hanninen, L., De Passille, A.M. and Rushen, J. (2005) The effect of flooring type and social grouping on the rest and growth of dairy calves, *Appl.Anim.Behav.Sci.,* 91: 193-204.

Lago, A., McGuirk, S.M., Bennett, T.B., Cook, N.B. and Nordlund, K.V. (2006) Calf respiratory disease and pen microenvironments in naturally ventilated calf barns in winter, *J.Dairy Sci.,* 89: 4014-4025.

Ninomiya, S. and Sato, S. (2009) Effects of Five freedoms of environmental enrichment on the welfare of calves reared indoors, *Animal Sci. J.,* 80: 347.

Behnke, R., Centre, O., Wolford, G. and Muthami, D. (2013) A Living from Livestock IGAD Livestock Policy Initiative; the Contribution of Livestock to the Kenyan Economy

Peter, G.S., Gitau, G.K., Mulei, C.M., Vanleeuwen, J., Richards, S., Wichtel, J., Uehlinger, F. and Mainga, O. (2015) Prevalence of Cryptosporidia, Eimeria, Giardia, and Strongyloides in pre-weaned calves on smallholder dairy farms in Mukurwe-ini District, Kenya, *Vet World.,* 8: 1118-1125.

Peter, S.G., Gitau, G.K., Richards, S., Vanleeuwen, J.A., Uehlinger, F., Mulei, C.M. and Kibet, R.R. (2016) Risk factors associated with Cryptosporidia, Eimeria, and diarrhea in smallholder dairy farms in Mukurwe-ini Sub-County, Nyeri County, Kenya, *Vet World.,* 9(8): 811-819.

Wildman, E.E., Jones, G.M., Wagner, P.E., Boman, R.L., Troutt J.H.F. and Lesch, T.N. (1982) A dairy cow body condition scoring system and its relationship to selected production characteristics, *J. Dairy Sci.,* 65: 495-501.

Reneau, J.K., Seykora, A.J., Heins, B.J., Endres, M.I., Farnsworth, R.J. and Bey, R.F. Association between hygiene scores and somatic cell scores in dairy cattle, *J.Am.Vet.Med.Assoc.,* 227: 1297-1301.

Sprecher, D.J., Hostetler, D.E. and Kaneene, J.B. (1997) A Lameness Scoring System That Uses Posture and Gait to Predict Dairy Cattle Reproductive Performance, Theriogenology, (6): 1179.

Barrientos, A.K., Chapinal, N., Weary, D.M., Galo, E. and von Keyserlingk, M. A. G. (2013) Herd-level risk factors for hock injuries in freestall-housed dairy cows in the northeastern United States and California, *J. Dairy Sci.,* 96: 3758-3765.

Lombard, J.E., Tucker, C.B., von Keyserlingk, M. A. G., Kopral, C.A and Weary, D.M. (2010) Associations between cow hygiene, hock injuries, and free stall usage on US dairy farms, *J. Dairy Sci.,* 93: 4668-4676.

McFarland, D.F., 1991. Experiences with free stall design in Pennsylvania. Paper – *Biol Eng Trans*,17.

Akdag, F., Arslan, S., Caynak, A. and Teke, B. (2011) The relationships of phenotype, genotype and some environmental factors with birth weight in Jersey calves, *Afr. J. Biotechnol.*, 10: 7308-7313.

Oddoye, E.O.K., Okantah, S.A., Obese, F.Y. and Gyawu, P. (1999) Growth performance, body condition score and milk yield of Sanga cattle in smallholder peri-urban dairy herds in the Accra Plains of Ghana, *Bull Anim Health Prod Afr.*,47: 143-148.

Negash, M. (2005) Birth weight and gestation length in Holstein-Friesians, *Bull Anim Health Prod Afr.*, 53: 135-137

Mellor, D.J. (2017) Operational Details of the Five Domains Model and Its Key Applications to the Assessment and Management of Animal Welfare, *Animals (2076-2615)*, 7: 1-20

Roche, J.R., Friggens, N.C., Kay, J.K., Fisher, M.W., Stafford, K.J. and Berry, D.P. (2009) Invited review: Body condition score and its association with dairy cow productivity, health, and welfare, *J. Dairy Sci.*, 92: 5769-5801.

Gitau, G.K., McDermott, J.J., Adams, J.E., Lissemore, K.D. and Waltner-Toews, D (1994) Factors influencing calf growth and daily weight gain on smallholder dairy farms in Kiambu District, Kenya, *Prev.Vet.Med.*, 21: 179-190.

Sreedhar, S. (2015) Growth Performance of Indigenous and Cross Bred Calves in Coastal Region of Andhra Pradesh, *Livest. res. int.*, 3(4): 99-102.

Wakchaure R.S. and Meena, R. (2010) Factors Affecting, Birth Weight, Age and Weight at First Calving in Sahiwal Cattle, *Indian J.Anim.Res.*, 44(3): 173-177.

Table 2-1: Calf and pen-level characteristics of calves in 38 smallholder dairy farms in Meru County, Kenya, 2017, along with the relative proportions and p-values associated with dirty leg hygiene scores in calves.

Factor	**Groups**	**Frequency (Percent)**	**Percent dirty calves**	**P-value**	**Global P-value**
		Calf-level factors (n=52 calves on 38 farms)			
Age (months)	<2.5	12 (23)	8.3		
	≥2.5 & <5.5	14 (27)	50.0	0.041	0.071
	≥5.5	26 (50)	38.5	0.081	
Breed	Cross-bred	44 (85)	38.6		
	Indigenous	8 (15)	12.5	0.183	n/a
Sex	Female	27 (52)	40.7		
	Male	25 (48)	28.0	0.337	n/a
BCS	>2.25(good)	37 (71)	24.3		
	≤2.25 (poor)	15 (29)	60.0	0.018	n/a
Health status	Healthy	50 (96)	34.0		
	Non-healthy	2 (4)	50.0	0.646	n/a
Housing	Indoors in pens	39 (75)	41.0		
	Outdoors	13 (25)	15.4	0.108	n/a
		Pen-level factors (n=39 calves in 35 pens on 28 farms)			
Calf grouping	1 calf per pen	25 (64)	36.0		
	>1 calf per pen	14 (36)	50.0	0.396	n/a
Floor type	Dirt	29 (74)	31.0		
	Concrete & wood	10 (26)	70.0	0.039	n/a
Bedding type	None	15 (39)	33.3		
	Sawdust & wood shavings	11 (28)	72.7	0.055	0.034
	Crop waste	13 (33)	23.1	0.551	
Pen hygiene	Clean	9 (23)	33.3		
	Fair	18 (46)	27.8	0.766	0.091
	Dirty	12(31)	66.7	0.138	
Knee impact	Normal	2 (5)	50.0		
	Marginal	28 (72)	39.3	0.767	0.931
	Hard	9 (23)	44.4	0.887	
Knee wetness	Normal	9 (23)	44.4		
	Marginal	17 (44)	35.3	0.649	0.812
	Wet	13 (33)	46.2	0.937	

Table 2-2: Descriptive statistics of pen hygiene and leg hygiene scores across 3 types of bedding availability for 39 calves on 28 smallholder dairy farms in Meru County, Kenya, 2017.

Factor	**Pen hygiene scores***				**Leg hygiene scores***				
Bedding	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	N
None	2.53	0.72	1	4	2.27	1.12	1	4	15
Sawdust &wood shavings	2.95	1.17	1	4	3.05	1.42	1	5	11
Crop waste& others	3.15	0.80	1.5	5	2.00	0.79	1	3.5	13

*Pen and leg hygiene scores were assessed using a 5-score system that included; 1 (very clean), 2 (clean), 3 (fair), 4 (dirty) and 5 (very dirty).

Table 2-3: Final multivariable logistic regression model of calf- and pen-level factors associated with dirtiness of 39calves on 28 smallholder dairy farms in Kenya in 2017.

Factor	**Odds Ratio**	**95% CI**	**P-value**
Body condition score			
>2.25 (good)	Reference	Reference	
≤2.25 (poor)	17.06	[1.567, 185.781]	0.020
Floor type			
Dirt	Reference	Reference	
(wood &concrete)	7.91	[1.025, 61.131]	0.047
Bedding type			
None	Reference	Reference	
Sawdust, wood shavings or crop waste	12.55	[1.043, 150.865]	0.046

Chapter 3: Risk factors associated with cow lying time and, stall and cow cleanliness in smallholder dairy farms in Meru, Kenya.

3.1 Abstract

Lying time and cow cleanliness are indicators of cow comfort and animal welfare that can be influenced by stall parameters and management practices. This cross-sectional study aimed to determine the stall factors and management practices affecting lying time, stall cleanliness, cow cleanliness (udder and upper leg), and subclinical mastitis (SCM) in smallholder dairy cows in Meru County, Kenya. A total of 106 milking cows from 73 farms were assessed for daily lying time and cleanliness and presence of SCM using the California Mastitis Test (CMT). Data loggers attached on the inside of the left hind leg below the hock joint were used to record the lying time of cows for three days. Stall, udder and upper leg cleanliness were assessed using a 5-score system (1(very clean) to 5(very dirty). Management practices information was acquired using a questionnaire that was administered face-to-face to the farmers in their native Kimeru language. Univariable linear models and logistic models were used to identify potential risk factors ($p<0.25$) for lying time, SCM and cleanliness (stall, udder and upper legs), respectively. Using these eligible variables, multivariable linear and logistic regression models were fit manually through back ward elimination, and variables that were significant ($p<0.05$), confounders or had interaction effects were retained in the final models.

The mean daily milk yield per cow was 6.6 ± 3.3 liters and 44 cows (42%) had a CMT score of ≥ 1. The mean daily lying time was 10.9 ± 2.2 hours and the mean stall

cleanliness score was 2.4 ± 1.0. The mean average cleanliness score of the udder and upper legs were 1.9 ± 0.7 and 2.5 ± 1.1, respectively. A total of 35% of the stalls were categorised as dirty (>2.5), while 13% and 47% of the cows had udder and leg cleanliness scores >2.5, respectively.

From the final multivariable models, daily lying time increased with cow age (p=0.005). Two cow-level and two farm-level variables decreased lying time: (i) poorly positioned neck rails (p=0.039); (ii) stall cleanliness scores >2.5 (p=0.008; (iii) delayed removal of manure (p=0.002); and (iv) delayed addition of new bedding (p=0.017), respectively. There was an interaction between frequency of stall manure removal and frequency of adding new bedding (p=0.040). Farm-level risk factors for stall dirtiness included: delayed cleaning of the alley (OR=6.63, p=0.032), lack of bedding (OR= 4.92, p=0.008), and standing idle and/or backwards in the stall (OR=10.47, p=0.002). Stalls categorized as dirty (OR=2.88, P=0.041) and lack of bedding (OR=2.73, p=0.065) were cow-and farm-level risk factors for dirtiness of the udder, respectively, while the stall being dirty (OR=2.3, p=0.043) was the only risk factor (cow-level) for dirtiness of the upper legs.

It was recommended that farmers should pay attention to the specific factors identified regarding the stall design and housing management practices that impact on cleanliness of cows and their lying time.

3.2 Introduction

The welfare of animals kept in livestock production systems has raised concerns around the world (Rollin, 2004). Some of the main cow welfare concerns include: lying time; stall comfort and cleanliness: udder and leg cleanliness, and lameness (Vasseur et al., 2015).

Dairy cattle require adequate rest and spend approximately 12 hours per day lying down (Jensen et al., 2004; Jensen, Pedersen and Munksgaard, 2005). Numerous cow- and stall-based factors affect cow lying time. Dairy cow' lying times increase with an increase in parity (Gomez and Cook, 2010a; Sepelveda-Varas, Weary and Keyserlingk, 2014). High yielding cows typically spend less time lying down compared with low yielding cows (Bewley et al., 2010; Norring, Valros and Munksgaard, 2012; Miller-Cushon and DeVries, 2017).

Regarding stall-based factors, cows spend more time lying down in stalls that have neck rails positioned higher above the floor surface (Tucker, Weary and Fraser, 2005; Fregonesi, von Keyserlingk, M A G and Weary, 2009), while more cows prefer stalls without a brisket board (Tucker, Zdanowicz and Weary, 2006). Cows prefer lying down on well-bedded surfaces (Tucker, Weary and Fraser, 2003; Tucker and Weary, 2004) that are well-maintained (Drissler et al., 2005) and have dry bedding (Fregonesi, von Keyserlingk, M A G and Weary, 2009). Conversely, the lying time of cows decreases as quality (e.g. amount, depth, dryness) of bedding decreases (Fregonesi et al., 2007). Additionally, these factors also influence cow cleanliness (Fulwider et al., 2007; Norring et al., 2008). Management practices such as frequency of manure removal have been shown to affect udder and leg cleanliness (Magnusson, Herlin and Ventorp, 2008; DeVries, Aarnoudse, Barkema, Leslie and Keyserlingk, 2012).

Dirty udders can lead to mastitis, and the risk of clinical and subclinical mastitis increases with: increasing parity (Zadoks et al., 2001; Breen, Green and Bradley, 2009), and poor stall and cow cleanliness (Schreiner and Ruegg, 2002; Reneau et al., 2005a; Dohmen, Neijenhuis and Hogeveen, 2010). In small holder dairy farms (SDF), high clinical and subclinical mastitis prevalence has been associated with dirt floors (Hossain et al., 2016; Mureithi and Njuguna, 2016), small numbers of lactating cows, and milking practices (Asmare and Kassa, 2017). The consequences of mastitis include: death (acute mastitis); decreased milk yield and animal welfare; poor quality of milk, which could lead to possible milk quality penalties; and increased cost of veterinary services (Houben et al., 1994; Bradley and Green, 2001; El-Tarabany and Ali, 2015).

The following factors have been associated with cow lameness, low body condition scores (Dippel et al., 2009); housing heavy cows in small sized stalls (Haskell et al., 2006); perching of cows (Colam-Ainsworth et al., 1989; Galindo, Broom and Jackson, 2000); concrete or wooden floors (Vokey et al., 2001; Vanegas et al., 2006); use of little or no bedding (Cook, Nordlund and Oetzel, 2004) and poor management practices (Dippel et al., 2009).

Video surveillance (Cook, Nordlund and Oetzel, 2004; Gomez and Cook, 2010b), motion sensors (Lubaba et al., 2015) and data loggers have been used to monitor cow behavior (Ito, Weary and von Keyserlingk, M A G, 2009; Bewley et al., 2010). They can also be used to predict health risks, such as lameness (Mazrier et al., 2006; Ito et al., 2010).

In Kenya, dairy cattle milk contributes about 70% of the total gross value of the livestock sector (Behnke et al., 2013). Importantly, majority of the dairy farms in Kenya are small holder dairy farms (Global Forum On Agricultural Research, 2016). We know that poor comfort of dairy cows in industrialized countries leads to: decreased lying time (Fregonesi, von Keyserlingk, M A G and Weary, 2009), reduced milk production (Uzal and Ugurlu, 2010), increased risk of lameness (Dippel et al., 2009) and increased risk of mastitis (Dohmen, Neijenhuis and Hogeveen, 2010). However, little is known about the prevalence and risk factors of cow comfort issues in dairy cows on SDFs in tropical countries such as Kenya (Aleri, Nguhiu-Mwangi and Mogoa, 2011; Richards, 2017). The objective of this cross-sectional study was to assess aspects of cow comfort and to determine stall design and management practices affecting lying time, and stall and cow cleanliness in smallholder dairy cows in Kenya.

3.3 Materials and Methods

3.3.1 Ethical approval

The study was approved by the Research Ethics Board and the Animal Care Committee of the University of Prince Edward Island, while the Naari Dairy Farmers Co-operative Society (NDFCS) and Farmers Helping Farmers, a partnering non-governmental organization endorsed the study. Consent was obtained from all the participants in the study.

3.3.2 Study design and sampling method

The study was carried out in the Naari region of Meru County in Kenya, where small holder dairy farming is mainly practiced with zero-grazed and pasture grazed farming systems. The area receives about 1600mm of rainfall annually and is considered a high potential area. The full list of 500 active farmers in the Naari Dairy Farmers Co-operative Society (NDFCS) was used as the initial sampling frame. An initial simple random sample of 200 farms was selected, using computer-generated random numbers, from 500 farms. Of these 200 farms, 100 were randomly selected to participate in this study, using the following inclusion criteria: 1) only farms with zero-grazing units; 2) up to four cows per farm; 3) at least one milking cow. Of the 100 selected farms, 73 met all of the eligibility criteria and their owners agreed to participate in the study.

On the first visit to the farms, a description of the study was given to the farmer, outlining the expectations and the requirements for the researchers and the farmers. An assessment of the stall design, stall cleanliness and cow cleanliness was done for cows and their stalls on the farm, and a questionnaire on cow characteristics and farm management practices was administered (details provided below). Launched accelerometer data loggers (HOBO Pendant G Acceleration Data Logger (UA-004-64); Onset Computer Corporation, MacArthur Blvd, Bourne, MA) were attached to the left hind limb distal to the hock joint and above the fetlock joint to determine the lying time of cows. California Mastitis Test was done on all the teats of the udder of the milking cows in each farm. A second visit to the same farms was done three days later to remove the data loggers and transfer the recorded data into a computer.

3.3.3 Data collection

The cow level information collected included: cow identification, age in years, and weight (kg) and height (cm) measured using a Wintape professional cattle weighband weight and height tape measure (China Wintape Co., Ltd; White Swan building, Huangqi). The breeds were described as exotic if the cows were visibly and predominantly Friesian, Guernsey, Ayrshire or Jersey, or indigenous if they were visibly and predominantly Zebu or another local breed. The body condition score was described using the 5-score chart (Wildman et al., 1982) that ranged from 1(very thin) to 5 (excessively fat), with quarter-point increments. The daily milk yield of the cows was estimated as the total milk produced by the cows in all the milkings of the day (two or three depending on the farmers).

A physical examination of each cow performed by a licenced veterinarian or trained animal health technician that included but was not limited to: heart rate and quality, respiratory rate and quality, color of mucous membranes, and palpation of superficial lymph nodes, rumen movements, skin condition, joints and feet examination to assess health status. Lameness in the cows was assessed as absent, mild or severe using a modified 5-point scoring system (Sprecher, Hostetler and Kaneene, 1997). Cows with a CMT score greater than one were categorized as positive for subclinical mastitis (SCM).

Some farms used a combination of zero-grazing, partial zero-grazing, and tethering of cows, meeting the inclusion criterion of zero-grazing, however, because not all cows were zero-grazed, housing type for each cow on the farm was included as an additional variable. The type of stall each cow lied down in was categorized as: present (complete zero-grazing unit), partial (an incomplete and/or paddock-like stall with no distinct lying area) or absent (cows tethered to a tree or in the open field).

For cows lying down in stalls, the stall they usually lied down in was measured for various dimensions (Table 3-1). The total length of the stall was measured and categorized as: 1) insufficient length, 2) adequate length, or 3) too long. The total width was similarly categorized as: 1) insufficient width, 2) adequate width, or 3) too wide so the cow could turn around in the stall. Availability and positioning of the neck rail and brisket board were assessed and categorized as: 1) present but not well-positioned, 2) present and well-positioned, or 3) not present in the stall.

For some dimensions such as lunge space and side leg space, characteristics were categorized by their appropriateness where three general categories for the characteristics were used: 1) insufficient space and/or railings present but in the wrong location; 2) appropriate space and/or railing positions; and 3) too much space and/or railings not present. The middle category was considered the optimal category of these categories.

The availability and adequacy of a forward and/or side lunge space was classified as: 1) lunge space not available, 2) lunge space available but not adequate or 3) adequate lunge space available. Leg space was assessed and categorized as: 1) no leg space available, 2) leg space available but not adequate and 3) adequate leg space available.

The type of floor was recorded as: 1) dirt, 2) concrete and/or wooden, and 3) others. The floor flatness was categorized as: 1) flat (<5% of the floor uneven) or 2) lumpy (≥ 5% of the floor uneven). The type of bedding available was categorized as: 1) sawdust, 2) wood shavings, 3) crop waste and 4) others. The knee impact test (from a crouched position on your feet, tipping forward so your knees contact the floor surface) was used to determine how soft the stall surface was, and was categorized into three possible levels: normal, marginal and hard. If the floor was soft and did not cause any level of discomfort on the knees, the floor was categorised as normal which indicated a passing grade on the knee impact test. If the floor was somewhat uncomfortable on the knees, such as a cement floor with a modest amount of bedding or a dirt floor that was compacted, then it was classified as marginal. If the floor caused extreme discomfort on the knees on impact, the floor was classified as hard and this indicated failure of the knee impact test.

The degree of wetness on the floor surface was assessed using the knee wetness test, which was categorised as normal if the knee was completely dry after about 10-15 seconds of knee contact on the floor, marginal if the knee had some noticeable moisture, and wet if the knee was completely wet after the contact with the floor. The knee wetness and impact tests have been used elsewhere to assess floor conditions for cattle (McFarland, 1991). We included a marginal category to the knee tests to adapt the tests to the highly variable stall management conditions that exist in Kenya where dirt (not sand) and crop waste are commonly used for floor surfaces.

The adequacy of the roof (yes or no) was determined based on a visual assessment of the roof, confirming that the roof was adequately covering the entire length of the stall, plus an extra foot at the udder end, with a roof that was not allowing water to enter the stall because of roof holes. Adequate drainage of the stall (yes or no) was judged by determining if water could gravitationally flow along the ground from outside the stall into the stall.

The stall, udder and leg cleanliness scores were assessed using a 5-score system (Reneau et al., 2005b) where the categories included: 1 (very clean), 2 (clean), 3 (fair), 4 (dirty) and 5 (very dirty). Stall cleanliness score was based on the proportion of the entire lying surface that had manure (wet or dry) and wet bedding. Udder cleanliness score was based on the degree of soiling on the udder and the teats. The leg cleanliness score was based on the soiling and matting of the outer upper flank of the two hind legs. With scores from 2 hind legs and two sides of the udder, an average of the two scores was recorded.

The condition of the alley was categorized based on the amount of manure at the time of assessment, and the three possible categories were: 1) clean (no manure), 2) fairly clean (small amount of manure-can easily walk to avoid manure) and 3) muddy (a large amount of manure on the alley-cannot avoid walking in manure).

Farm-level parameters assessed (over the last 6 months)included: number of milking cows on the farm; frequency of hoof trimming; stall manure removal frequency; use of bedding on lying surfaces; frequency of adding new bedding in the stalls; and frequency of cleaning the alley. The data on the above parameters were acquired using a questionnaire that was administered to the farmers face-to-face by the investigator in the native language (Kimeru). Assessment for abnormal lying and standing behaviours at the herd level were determined for each farm in two ways: 1) observations while on the farm, including (but not limited to): perching, standing idle in the stall, standing backwards in the stall and lying in places other than the stall; and 2) farmer-reported abnormal behaviours acquired using the questionnaire, since it was possible that cows may not exhibit these behaviours between farm visits.

3.3.3.1 Accelerometers

The data loggers that record x-, y- and z- axis acceleration were used to record the lying time of cows. The specifications, calibration and operation of the data loggers were done as per the manufacturer's manual (HOBO Pendant G Acceleration Data Logger (UA-004-64) Manual). The loggers were connected to an optic USB base station and coupler (HOBO Waterproof Shuttle) and launched using the HOBOware installed to record data at logging intervals of one minute. Once launched on normal mode with the red light blinking every 5 seconds, the data loggers were wrapped in disposable foam to prevent any injury to the cows on attachment, then secured in airtight disposable Ziploc bags preventing fluid from reaching the pendants, and finally, they were inserted in Velcro straps which were attached on the inside of the left hind leg below the hock joint but above the fetlock joint while ensuring the cow's blood flow was not compromised by the strap. The loggers were placed such that the y-axis was perpendicular to the ground pointing dorsally towards the cow's back and they were removed after 3 days.

3.3.4 Data management and analysis

All data were entered, cleaned and coded using Microsoft excel® 2013 (Microsoft, Sacramento, California, USA) and analyzed using Stata 14.2® (StataCorp, College Station, Texas, USA). Standardization of lying time data involved calculating lying time of each cow for a 72-hour period, excluding the first hour after attachment of loggers and the last hour before detachment because the cows were disturbed during attachment and detachment. Lying behaviour data were converted to time per cow per day over the 3 days of monitoring. Abnormal behaviours were classified as: 0) no abnormal behaviour; and 1) at least one abnormal lying behaviour was observed or reported.

For the cow's age, there were 14 cows that were purchased with no age provided; therefore the owners could not give an age. Based on the ages provided for the other 92 cows, we dichotomized age at the median of 5.25 years. These 14 cows were equally and randomly allocated to the two age categories (0≤5.25 years; 1>5.25 years).

According to the Shapiro-Wilk normality test, the daily lying time was not normally distributed ($p=0.001$). However, visually the data had a relatively normal distribution and a theta of 0.9 using the Box-Cox transformation and thus we kept lying time on its original scale. To describe the lying time, mean, median, standard deviation and ranges were used.

Proportions and their 95% confidence intervals were used to describe lameness and mastitis occurrence at the cow level. Stall, udder and leg cleanliness scores were described using their means, standard deviations and ranges, then further categorized into binary outcomes (0=clean which included scores ≤ 2.5, 1=dirty which included scores >2.5) and subsequently described using proportions and confidence intervals.

Comparison of lying time means over binary variables was done using a t-test and significant differences ($p<0.35$) were reported. Univariable linear regression was used to determine unconditional associations of predictors with lying time at the cow level, and the significant predictors ($p\leq 0.25$) were fit manually into multivariable linear regression models using backward elimination to determine their impact on variation of lying time. Quadratic terms of continuous predictor variable were added to the model to test for significance, if necessary. Linearity between continuous predictor variables and the continuous outcome variables (lying time) was assessed using a scatter plot of the variable and outcome, with a Lowess smoother line fitted to the plot.

Mixed multivariable linear regression models with farm as a random effect were also fit using the eligible predictors ($p\leq 0.25$), and the superiority of this model over a simple multivariable linear regression model was also assessed. Potential confounders were identified and controlled for while two –way interactions were assessed and the significant ($p<0.05$) effect modifiers and confounders were added to the models. Normality (Shapiro-Wilk test), homoscedasticity (Breusch-Pagan test) and linearity (scatter plots) were assessed on the final multivariable linear regression models for lying time using residuals, normal quantile plots and tests, while outlying and influential observations were assessed for all the models using standardized residuals, leverage, Cook's distance and delta-beta values. If random effects were not significant, robust errors that were adjusted for clustering at the farm level were reported.

For subclinical mastitis, stall and cow cleanliness, unconditional associations of predictors with these outcomes were initially assessed using univariable logistic regressions. Eligible factors ($p\leq0.25$) were fit manually into multivariable logistic regression models using backward elimination to determine risk factors for occurrence of mastitis, stall cleanliness and cow cleanliness. Random effect logistic regression models were also used to determine the potential effects of predictors ($p<0.25$) on outcome variables while accounting for clustering at the farm level and a likelihood ratio test was used to assess the significance ($p<0.05$) of the mixed model versus the simple multivariable logistic regression model. For all the multivariable logistic regression models, confounding variables were controlled for, and two-way interactions were assessed and included or excluded from the models based on their significance ($p<0.05$). Goodness of fit tests were carried out for multivariable logistic regression models for mastitis, stall cleanliness and udder cleanliness using the Hosmer-Lemeshow goodness-of-fit tests. Outlying and influential observations were assessed for all the models using leverage and Cook's distance values. Predictive ability of the final models was evaluated using ROC (receiver operating characteristics) curves and the reliability of the model was assessed using the leave in and out protocol (Dohoo, Martin and Stryhn, 2012).

Pearson correlation coefficient was used to assess any significant correlations ($-0.35 < r \geq 0.35$) between predictors to aid in model-building.

3.4 Results

3.4.1 Demographics of farms and cows

There were a total of 106 lactating cows on the 73 farms in the final study population, giving an average number of milking cows per farm of 1.45 with a minimum and a maximum of 1 to 4 cows per farm, respectively. The cows, on average, were: 6 ± 3 years old, weighed 363.5 ± 55.4 kg, and had a body condition score of 2.4 ± 0.4, with 94% of them categorized as predominantly exotic breeds and 6% predominantly indigenous breeds. The mean daily milk yield per cow was 6.6 ± 3.3 liters, ranging from 1 to 21 litres per cow per day.

Eighty-five percent of the cows (90/106) on 58 farms were kept in complete zero-grazing units, 12% of cows (13/106) on12 farms were kept in partial stalls, and 3% of cows (3/106) on 3 farms were tethered outside all day long, even though the farms had a zero-grazing unit, albeit somewhat dilapidated. No cows were categorized as lame in the study population, and therefore risk factors associated with lameness were not identified due to lack of variability of the outcome.

Of the 103 cows in stalls on 70 farms, 78% (80/106) on 54 farms had at least one of the abnormal behaviours observed on site or reported by the farmer. A total of 33% of the cows that had abnormal behaviours (n=80 cows) were seen, or reported to be seen standing idle and/ or standing backwards in the stall during the study period, while 67%

of the cows were lying down on other places (e.g., alley) and/or perching in addition to either standing idle or standing backwards in the stalls.

3.4.2 Stall descriptive and analytical statistics

For the stall assessments, the 3 cows that were tethered outside on the 3 farms with dilapidated stalls were not included since they did not reflect zero-grazing conditions. The average cleanliness score for the 90 complete stalls and 13 partial stalls was 2.4 ± 0.9 and 2.8 ± 1.2, respectively. Out of the 103 stalls, 36 (35%) were categorized as dirty (>2.5). A total of 29 of the 90 complete stalls (32%) and 7 of the 13 partial stalls (54%) were categorised as dirty (>2.5). Only 3 of the stalls had a well-positioned neck rail and all three had a stall cleanliness score of 1 (clean). The average stall cleanliness score of stalls with a poorly positioned neck rail in relation to neck rail height and distance from the rear curb was 2.3, while the mean stall cleanliness score of stalls without a neck rail was 2.5.

Inadequate roofing and poor drainage were seen in 8% and 19% of the 103 stalls, respectively. A total of 79% of the 103 stalls had optimal length, while 26% had optimal width, based on the body weight of the cows. Neck rail, brisket board, lunge space and leg space were absent in 84%, 97%, 40% and 26% of the 103 stalls, respectively. Of the 103 cows in stalls, 90 (87%) were kept in stalls with dirt floors, 62% of which were categorized as lumpy. Thirteen cows (12%) had concrete or wooden floored stalls, 38% of which were considered lumpy, due to lumps of compacted manure on top of the concrete or cross-boards on top of the wooden floors. Sawdust or wood shavings were used as bedding in 33% (34/103) of the stalls, crop waste was used in 39% (40/103) of the stalls, and 28% (29/103) of the stalls had no bedding. Knee impact and knee wetness tests failed in 13% and 11% of the stalls respectively. Out of 69 alleys assessed between stalls and mangers (one missing data point), 39% (27/69) of them were classified as muddy and 40% (28/69) as fairly clean, with the remaining 21% being clean.

According to the farmers' responses to the management questionnaire, 94% (95/101) of the cows have never had their hooves trimmed over the last 6 months, while only 6% of the cows had their hooves trimmed at least once over the past 6 months. For 2 cows on 2 farms, the owner/manager was not home at the time of the farm visit, and the farmhand did not know the answers to some management questions, such as hoof trimming. Stalls on 53% (37/69) of the farms had manure removed at least once a day, while alleys on 67% (46/69) of the farms were cleaned at least once a day. A total of 72% (50/69) of the farms used bedded stalls with sawdust, wood shavings or crop waste and 56% (28/50) of these farms added new dry bedding to the stalls at least once a day. One farm hand could not answer these management questions.

The variability in the stall cleanliness outcome brought about by farm effects was negligible hence simple logistic regression models with robust errors were preferred over mixed models.

Stall cleanliness had a strong correlation with wetness of the stall surface determined using the knee test ($r=0.8021$). Univariable logistic regression models indicated that the following variables were associated with stall dirtiness ($p<0.25$): availability of bedding, stall length, frequency of alley cleaning, abnormal cow behaviours, and presence and positioning of a neck rail. A multivariable logistic regression model of stall dirtiness showed that bedding availability, frequency of cleaning the alley and presence of abnormal resting behaviours in cows were associated with dirty stalls. In addition, the length of the stall had a confounding effect on the association between frequencies of alley cleaning and stall dirtiness, thus it was kept in the model, and was close to significant as well, with short stalls being protective against dirty stalls (Table 3-2). Failure to use any bedding on the lying surface increased the odds of stall dirtiness by 4.9 times (p=0.008). Delays to cleaning the alley (less than once a week) increased the odds of stall dirtiness by 6.6 times (p=0.032). Standing backwards in the stall, and idle standing and lying in other places other than the stall increased the odds of stall dirtiness by 6.2 times (Table 3-2). The final model had 103 observations because 3 tethered cows in 3 farms had no stalls. The model fit the data well (goodness-of-fit; χ^2=11.85, p=0.540) and explained 21.1% of the variation observed in stall dirtiness.

3.4.3 Cow lying time descriptive and analytical statistics

The median and mean (± SD) daily lying time of cows was 10.6 and 10.9 ± 2.2 hours, respectively, ranging between 2.9 - 19.0 hours. The mean daily lying times by different categorical predictor variables are summarised in Table 3-3, for variables that met the cut-off and criteria for multivariable modelling. Using a significance level of p<0.35, univariable linear regression models showed that lying time of the cows was associated with the following cow-level variables: age, body condition score, stall length, poor positioning of the neck rail, adequacy of stall leg space, flatness of the stall floor, adequate stall drainage, wetness of the lying surface and stall cleanliness. The following farm-level variables also met the cut-off for multivariable modelling: abnormal behaviours, alley cleanliness, frequency of stall manure removal and the frequency of adding new stall bedding. Substantive correlations (-0.35<r>0.35) were: stall cleanliness and wetness of the lying surface (r=-0.802); adequate stall drainage and alley cleanliness (r=0.568); alley cleanliness and frequency of alley cleaning (r=0.496); and frequency of alley cleaning and frequency of stall manure removal (r=0.399).

The variability in the lying time outcome brought about by farm effects was negligible; hence simple linear regression models with robust errors were preferred over mixed models. The final multivariable linear regression model of lying time indicated the following factors were significantly associated with lying time: age of the cow; neck rail positioning; stall cleanliness; frequency of manure removal; and frequency of adding new bedding. The lying time of cows older than 5.25 years was 1 hour more than the lying time of cows younger than or equal to 5.25 years (Table 3-4). Stalls with poorly positioned neck rails in regard to neck rail height and distance from the rear curb resulted in cows lying down 1.6 hours less compared with cows in stalls without a neck rail and those with a well-positioned neck rail (p=0.039). In stalls with cleanliness scores categorized as dirty (>2.5), cows spent 1 hour less lying down per day (p=0.008), compared with cows in clean stalls. Frequency of stall manure removal and frequency of adding new bedding had a significant interaction (p=0.040). When considered together, addition of new bedding at least once a day without removing stall manure at least once a day, decreased the daily lying time of the cows by 1.5 hours, while failure to add new bedding at least once a day but removing stall manure at least once a day decreased the lying time of the cows by 1.2 hours (Table 3-4). Removing stall manure less than once a day and adding new bedding less than once a day decreased the lying time by 1.1 hours (-1.483 + (-1.187) + 1.536) (Table 3-4 and Figure 3-1). The final model was significant ($p=0.002$) and had 103 observations because 3 tethered cows in 3 farms did not have stalls. Using residuals, normality, homoscedasticity and linearity for goodness-of –fit were evaluated and found to be fulfilled. Two influential observations were identified and on evaluation of the model with and without the observations, the observations were retained in the model due to their negligible effect on the model significance. The model explained 21.6% of the variation observed in lying time.

3.4.4 Cow cleanliness descriptive and analytical statistics

The mean udder and leg cleanliness scores for the 106 cows were 1.9 ± 0.7 and 2.5 ± 1.1, respectively, and ranged from 1 to 4 for the udder and 1to 5 for the legs. A total of 13% and 47% of the cows had udders and legs categorized as dirty (>2.5), respectively. Cows in complete (90) and partial (13) stalls had cleanliness scores that averaged 1.9 ± 0.6 and 2.0 ± 0.7, respectively, for the udders, and 2.5 ± 1.1 and 3.0 ± 1.0, respectively, for the legs. Lameness was absent in the 106 cows examined, although on some farms it was difficult to assess lameness due to the limited space for walking or uneven slope to the walking area.

Because the variability in the udder cleanliness outcome brought about by farm effects was negligible, simple logistic regression models with robust errors were preferred over mixed models. For factors associated with dirty udders, univariable logistic regression models indicated the following variables met the cut-off for multivariable modelling ($p<0.25$): availability of bedding, wetness of lying surface, stall cleanliness and frequency of adding new dry bedding. The final multivariable logistic regression model for dirty udders contained the following results: cows in stalls categorized as dirty (>2.5) had 2.9 times higher odds of having dirty udders (p=0.041) in comparison to cows in stalls categorized as clean (≤2.5); and failure to use any bedding on the lying surface increased the odds of udder dirtiness by 2.7, compared with using bedding (p=0.065). The final model of udder dirtiness fit the data (goodness-of-fit; χ^2=0.11, p=0.743) with 103 observations because 3 cows were tethered and not kept in stalls. The model explained 9.7% of the variation in udder dirtiness.

For factors associated with dirty upper hind legs, univariable logistic regression models indicated that the following variables met the cut off for multivariable modelling (p<0.25): type of stall (partial or complete); bedding availability; stall length and stall cleanliness. A mixed logistic regression model of upper leg dirtiness was superior to a simple multivariable logistic model (p=0.018). The final mixed logistic regression model of upper leg dirtiness found that only cows in stalls categorized as dirty had higher odds (2.3 times) of having dirty upper legs (p=0.043) versus cows in stalls categorized as clean. Using residuals, criteria for goodness-of-fit were evaluated and found to be fulfilled. The model had 103 observations and farm random effects explained 46% of the variability in upper hind leg dirtiness, with the residual variation being explained by the observations.

3.4.5 Subclinical mastitis descriptive and analytical statistics

Subclinical mastitis was present (CMT score>1) in 42% (95%CI: 32-52) of the cows tested (44/106). The variability in the SCM outcome brought about by farm effects was negligible; hence simple logistic regression models with robust errors were preferred over mixed models.

On assessment of univariable associations for subclinical mastitis, the following variables met the cut-off for multivariable modeling ($p<0.25$): udder dirtiness; type of stall; type of stall floor; softness of the stall floor; neck rail positioning; adequate drainage of the stall; frequency of alley cleaning; and stall cleanliness. A multivariable logistic regression model of SCM occurrence indicated the following significant results: cows with udders that were categorized as dirty (>2.5) had 5.9 times higher odds of having SCM compared with cows with udders categorized as clean (p=0.023); concrete or wooden stall floors (OR=5.5; p=0.037) were risk factors for SCM infections; and cows kept in stalls with poor drainage had 9.4 times higher odds of testing positive for SCM relative to cows in stalls with good drainage (p=0.008). There were no significant interaction terms. The final model was significant (p=0.026) with 103 observations and missing information on only 3 cows that were tethered and did not have stalls. The final model fit the data (goodness-of-fit; χ^2=4.14, p=0.388) and explained about 12.1% of the variation observed in subclinical mastitis prevalence.

Table 3-1: Definitions of stall characteristics assessed in 73 smallholder dairy farms in Kenya

Stall dimension	Definition
Stall length	Horizontal distance from the front point of the stall rear curb or stall edge to the boards at the front of the stall
Body length in stall	Horizontal distance from the front point of the rear curb to the brisket board. If no brisket board was present: the distance from the front point of the rear curb to the neck rail. If no neck rail, use stall length
Stall width	Horizontal distance between the stall dividers at the narrowest point where the body is located
Neck rail height	Vertical distance from below neck rail to the top of the brisket board, or stall surface (bedding surface) if there was no brisket board.
Distance from neck rail to rear curb	Horizontal distance from rear edge of neck rail to front point of rear curb, or back of the stall if no rear curb.
Brisket board height	Vertical distance from below neck rail to the top of the brisket board, or stall surface (bedding surface) if there was no brisket board.
Distance from brisket board to rear curb	Horizontal distance from the rear edge of brisket board to front point of rear curb, or back of the stall if no rear curb.
Lunge space	Forward lunge: horizontal distance from the brisket board (or neck rail if no brisket board) to the front end of the stall (i.e. stall length) Side lunge: if applicable, vertical distance between the side rails
Side leg space	Vertical distance between the lowest side boards and the floor or bedding surface.
Floor flatness	Visual assessment that the floor is flat (<5% of floor uneven); or lumpy (≥5% of the floor uneven)
Roof adequacy	Visual assessment that roof is covering the entire length of the stall, plus an extra foot at the udder end, and with no holes
Drainage adequacy	Visual assessment that no water could flow along the ground from outside the stall into the stall by gravity.

Table 3-2: Final multivariable logistic regression model of factors associated with dirty stalls used by 103 cows on 70 smallholder dairy farms in Kenya, 2017.

Factor	**Categories**	**No. of cows**	**Odds ratio**	**Robust errors**	**95% CI**	**p-value**
Bedding	Sawdust, wood shavings or crop waste	74	Reference			
	None	29	4.97	2.95	(1.53,16.15)	0.008
Stall length	Optimal length	87	Reference			
	Too short	16	0.06	0.09	(0.01,1.13)	0.060
Frequency of alley cleaning	≥once/week	87	Reference			
	< once/week	16	6.63	5.85	(1.18,37.35)	0.032
Abnormal behaviour	None	23	Reference			0.007*
	Standing idle and/or backwards	26	10.47	8.07	(2.31,47.43)	0.002
	Standing idle, standing backwards, lying on the alley and /or perching	54	6.23	4.26	(1.63,23.83)	0.008

P-value: Global P-value*

Table 3-3: Descriptions and significance levels of differences in mean lying time in univariable analyses of lactating cows on smallholder farms in Kenya, 2017.

			Lying time (hours)	
Factor	**Categories**	**# of cows**	**Mean ± SD**	**p-value**
Cow-level variables (n=106 cows on 73 farms)				
Cow age (years)	≤5.25	53	10.46 ± 2.06	
	>5.25	53	11.42 ± 2.24	0.024
Body condition score	≤2.5	77	10.76 ± 2.26	
	>2.5	29	11.40 ± 1.98	0.181
Stall-related variables (n=103 cows on 70 farms)				
Stall length	Optimal length	87	11.07 ± 2.20	
	Too short	16	10.36 ± 1.97	0.238
Neck rail positioning	Not available or well-positioned	89	11.07 ± 1.94	
	Not well-positioned	14	10.22 ± 3.32	0.176
Stall leg space	Available	76	11.18 ± 2.21	
	Not available	27	10.32 ± 1.98	0.077
Stall floor flatness	Flat	42	11.35 ± 1.74	
	Lumpy	59	10.69 ± 2.4	0.128
Stall drainage	Adequate	64	11.41 ± 2.18	
	Poor	39	10.20 ± 1.97	0.006
Stall wetness on knee test	Dry	42	11.47 ± 2.18	
	Wet	61	10.61 ± 2.12	0.048
Stall cleanliness	Clean (≤2.5)	67	11.35 ± 2.17	
	Dirty (>2.5)	36	10.22 ± 2.01	0.011
Farm-level variables (n=103 cows on 70 farms)				
Abnormal behaviours	None	23	11.39 ± 2.27	
	Standing idle, backwards, lying on the alley and/ or perching	80	10.83 ± 2.14	0.276
Alley cleanliness	Clean	65	11.38 ± 2.06	
	Muddy	38	10.23 ± 2.19	0.009
Frequency of manure removal	≥once a day	69	11.21 ± 2.08	
	< once a day	34	10.45 ± 2.30	0.141
Frequency of addition of new bedding	≥once a day	61	11.13 ± 2.09	
	< once a day	42	10.70 ± 2.29	0.324

Table 3-4: Final multivariable linear regression model of factors associated with lying time of 103 cows from 73 smallholder farms in Kenya in 2017.

Factor	**Coefficient**	**95% CI**	**p-value**
Age (years)			
≤5.25	Reference		
>5.25	1.004	(0.318,1.690)	0.005
Neck rail			
Not available and well positioned	Reference		
Not well-positioned	-1.637	(-3.187,-0.087)	0.039
Stall cleanliness			
Clean	Reference		
Dirty	-0.969	(-1.676,-0.261)	0.008
Frequency of manure removal			
≥once/day	Reference		
<once/day	-1.482	(-2.415,-0.550)	0.002
Frequency of addition of new bedding			
≥once/day	Reference		
<once/day	-1.187	(-2.154,-0.221)	0.017
Interaction variable for frequency of manure removal and frequency of addition of new bedding	Reference		
Manure removal and addition of new bedding ≥once/day	1.536	(0.071,3.000)	0.040
Manure removal and addition of new bedding <once/day			

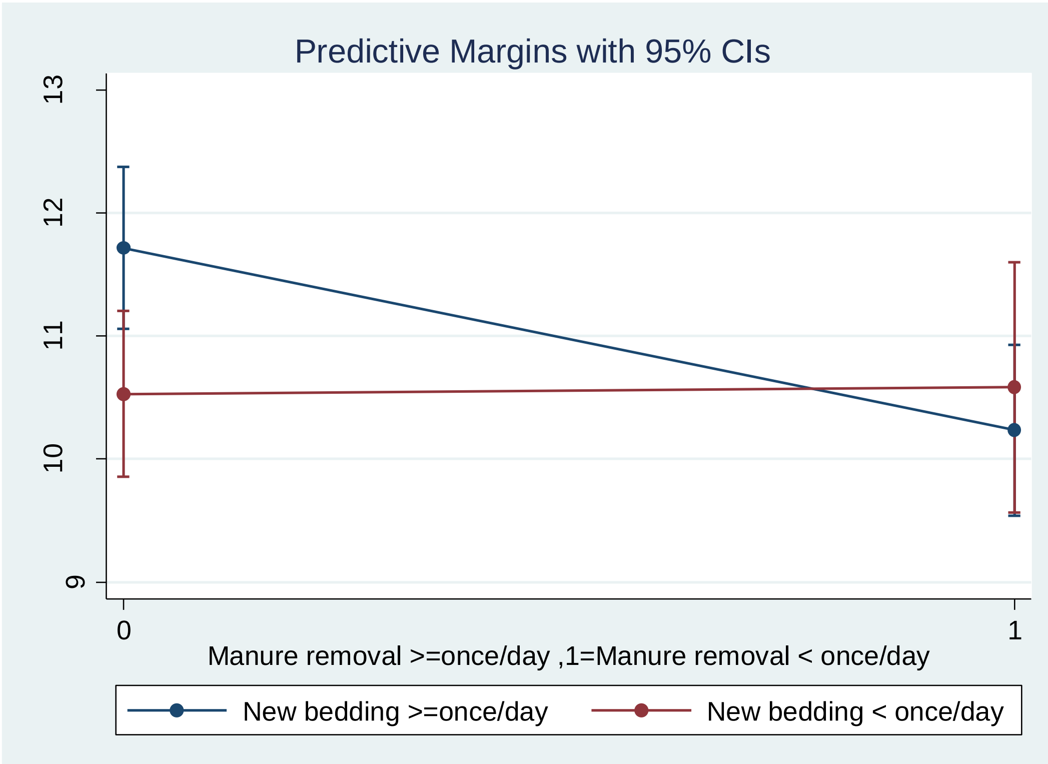


Figure 3-1: Interaction plot between frequency of stall manure removal and frequency of addition of new bedding on daily lying time of cows on 70 SDFs in Kenya

3.5 Discussion

Few studies on lying time and behaviour of cows in smallholder dairy farms have been done in developing countries (Aleri, Nguhiu-Mwangi and Mogoa, 2011; Richards, 2017). This is the first study done to describe and determine factors of lying time, stall cleanliness, cow cleanliness and subclinical mastitis done in the same cows on smallholder dairy farms in developing countries. Risk factors associated with lameness were not identified due to lack of variability of the outcome.

In this population of smallholder dairy farms, the number of milking cows per farm was small (1.4 milking cows), which explains why the random farm effects anticipated while designing the study were essentially negligible. Daily milk yield of 6.6 Kg/cow was similar to findings elsewhere which reported daily yields of 6.4 Kg/cow in Kiambu district of Kenya (Gitau et al., 1994) but lower than findings in the Mukurweini district of Kenya which showed daily yields of 9.3 Kg/cow (Richards, 2017). The variation could be attributed to improved quality of feed, feeding practices and management practices on the farms in the Mukurweini district because there was a long-standing (over 10 years) cattle health management and development project in that area.

The design and management of both the stall and alley were associated with stall cleanliness. Firstly, we found that stall length increased the likelihood of stalls being dirty. If stalls are too short, the cows are likely to lie down in the alley rather than in the stall, which may lead to less contamination of the stall. In Norwegian farms (Ruud et al., 2011), stalls that were too long allowed cows' faeces to fall inside the stall rather than the alley, increasing the likelihood of stalls being dirty. We had no stalls that were categorized as too long in our study.

Stalls without neck rails were more likely to be dirty in comparison to stalls with neck rails in our study, and these findings are similar to those reported by Tucker et al. (2005) who stipulated the reason to be the longer standing time of the cows in these stalls. Neck rails were absent in 84% of the 103 zero-grazing units, therefore there is ample opportunity to improve stall cleanliness on smallholder dairy farms through proper neck rail installation.

Use of bedding materials, such as sawdust and wood shavings, improved stall cleanliness in the present study, and also in Norwegian farms (Ruud, 2011). Bedding materials such as sawdust may have high moisture absorbency relative to dirt, wooden or concrete floors without bedding, thus improving stall cleanliness. In addition, good management practices, such as frequent removal of soiled bedding and addition of new dry bedding, are important (DeVries, Aarnoudse, Barkema, Leslie and Keyserlingk, 2012), and these were done in 61% and 71% of the study farms, respectively.

Frequent cleaning of the alley was also associated with clean stalls in this study, and this finding is supported by similar findings that indicated improved stall cleanliness with cleaner alleys (Magnusson, Herlin and Ventorp, 2008). We speculate that accumulated manure on the alley could be transferred to the stall by a cow's feet during movement into the stall, and possibly when a cow is using her tail to flick away flies while lying down.

The average cleanliness score of the upper legs was 2.5 using the 5-score system while Devries et al. (2012) found an average upper leg cleanliness score of 2.9 using the 4-score system. The mean udder cleanliness score (1.9) in our study was lower in comparison to findings from studies in Canada (DeVries, Aarnoudse, Barkema, Leslie and von Keyserlingk, M A G, 2012) and the Netherlands (Dohmen, Neijenhuis and Hogeveen, 2010). It is possible that cows in Canada and the Netherlands, with an average daily milk yield of 35.3 and 24.8 litres, respectively, had larger udders that were prone to getting soiled when the cows were standing and lying down, in comparison to cross-bred and indigenous cows in this study that had a daily milk yield of 6.6 ± 3.3 litres. The finding in our study that udders were cleaner than upper legs in the same cows are similar to those reported in cows in Ontario, Canada (Zurbrigg et al., 2005).

Udder cleanliness was associated with stall cleanliness and poor management practices specifically failure to provide bedding in the stalls. Leg cleanliness was only associated with stall cleanliness. These findings are supported by results from various studies (Magnusson, Herlin and Ventorp, 2008; DeVries, Aarnoudse, Barkema, Leslie and Keyserlingk, 2012). With large portions of the stall are dirty and wet, through contamination and failure to provide clean bedding, the likelihood of cows getting soiled increases.

In the present study, cows spent an average of 10.9 hours per cow per day lying down. This time was somewhat shorter than the 11.4 hours per cow per day recorded by Devries et al. (2012) and the 11.9 hours per cow per day reported by Gomez and Cook (2010). However, our daily lying time was much longer than the 9.0 hours per cow per day reported in cows in Mukurweini, Kenya (Richards, 2017), which may reflect a group of farmers who were less informed on good cow comfort management. The variation between cows in Canada and those in Kenya may be attributed to differing housing systems and management practices, such as feeding intervals suggested elsewhere (Ito et al., 2014). In our study, the shorter lying times compared with developed countries are likely due to sub-optimal stall designs, availability of new bedding and management practices, as found in our final multivariable model of lying time. Addition of dry bedding on stalls without removing manure may negate the aim of keeping the stall dry, clean and comfortable for the cows because moisture from the wet manure will seep easily to the new bedding, and this may explain the better lying time of cows, when new bedding is added less than once a day, but manure is removed once a day, compared with cows in farms where new bedding is added once a day but manure is removed less than once a day. In the smallholder dairy farms, small amounts of bedding are used on the stall at a given time, which could mean that adding new bedding very frequently (once/day) translates to adding very small amounts of bedding each day. It could be that if new bedding is added less frequently (<once/day), a larger amount may be used, and comfort

of the cow would be improved. Unfortunately, we did not measure amounts of bedding used. As observed in other studies elsewhere (Fregonesi et al., 2007), cows lie down more on deep-bedded stalls than in stalls with little bedding, which may explain the improvement on lying time observed when manure is removed less than once a day and new bedding added less than once a day.

It is unclear why adding bedding at least once a day and removing manure from the stall at least once a day had a shorter lying time than if only one of those two management practices occurs on a farm. However, it is possible that with small amounts of bedding used, removing dry manure from the stall daily could reduce the softness of the stall floor, while improving the cleanliness of the stall.

Lying time in our study increased with age, and this finding is consistent with findings from a study carried out on Holstein cows in Israel (Steensels et al., 2012). It is unclear why older cows might lie down more than younger cows. The higher prevalence of lameness and feet lesion reported in older cows led to their increased lying time (Mason, 2017). However, this association could not be assessed in our study due to absence of observable clinical lameness.

We found that cows in stalls with poorly positioned neck rails spent less time lying down in agreement with findings from a study carried out in French dairy farms (Veissier, Capdeville and Delval, 2004). However, these findings contrasted results from two studies that found no association between lying down time and neck rail position (Bernardi et al., 2009; Abade et al., 2015). A possible explanation for reduced lying time could be due to restricted movement during lying down and standing up by poorly positioned neck rails, which makes the cow prefer to stand rather than lie down, especially during the day time when the cows would be expected to feed at different times of the day.

With the high correlation between wetness and cleanliness of the stall (r=0.8021), we speculated that dirty stalls had a wet stall base and/or wet bedding, and therefore cows spent less time lying down in dirty stalls. A study carried out in dairy farms in Canada reported similar results and indicated that cows prefer dry stalls relative to wet stalls (Fregonesi et al., 2007). To ensure cleanliness of stalls, good management practices including; frequent manure removal and addition of new dry bedding, need to be carried out as shown in our final model.

The cow-level prevalence of subclinical mastitis (41%) was similar to the prevalence (40%) observed in the Kabete area of Kenya (Muthee, Gakuya and Nduhiu, 2005), but lower than in the Thika area of Kenya (Mureithi and Njuguna, 2016), and higher than in the Rift Valley (20%) of Kenya (Shitandi et al., 2004). The variation in the prevalence may be attributed to varying milking practices and management of the farms, such as: udder cleaning, and gender and experience of the milkers, as found by Asmare and Kassa (2017).

The higher odds of subclinical mastitis prevalence on concrete or wooden floors versus dirt floors in our study may be due to the higher moisture absorbency of soil relative to concrete or wood. These findings are similar to those reported in Bangladesh (Hossain et al., 2016), where the prevalence of SCM was higher in cows kept in brick-block floored stalls (10.4%) in comparison to those in stalls with a soil floor (6.5%). Similar findings were observed in India, where the incidence of mastitis was higher in cows kept in poorly drained stalls (Saharia, Saikia and Dutta, 1997). Cows with udders categorized as dirty also had higher odds of mastitis and these results are similar to those observed in Thika, Kenya in 2016 (Mureithi and Njuguna, 2016).

One limitation of our study is the subjective nature of some of the outcome assessments (e.g. cleanliness and CMT) and some of the predictor assessments (e.g. stall and alley conditions).

Data collection was done by the principal investigator with the help of two veterinary students and due to the impossibility of blinding the status of the outcomes with respect to the predictors and vice versa, the subjectivity of some measures may have introduced some level of bias into the data. However, during the training phase of the research project, the principal investigator and the two veterinary students all underwent the same training. Furthermore, consistency of assessments was examined and found to be good among the research team, reducing the level of bias in the data due to subjectivity.

Another limitation of our study was that it was cross-sectional in nature, which prevents making conclusive statements regarding observed associations due to the inherent lack of temporality between predictors and outcomes. Future research would benefit from a cohort study or randomized controlled trial to confirm the validity and importance of the observed factors associated with the various aspects of cow comfort involved in our study.

3.6 Conclusion and Recommendations

First, one-third of the stalls assessed were categorized as dirty. Lack of bedding, failure to clean the alley floor at least once a week and abnormal cow behaviour, such as standing backwards in the stall and lying down in other places other than the stall, were all risk factors associated with stall dirtiness, while, short stalls were protective for stall dirtiness.

A larger proportion of cows had clean udders compared to the proportion of cows that had clean upper hind legs. Additionally, half of the cows had clean udders and clean upper hind legs and stall dirtiness was a risk factor for udder and upper leg dirtiness.

Less than half of the cows tested positive for subclinical mastitis, and the risk factors for SCM were udder dirtiness, concrete or wooden floors, and poor drainage.

The cows in the study spent an average of 10.9 hours lying down every day and this lying time was higher in older cows (>5.25 years) than younger cows. Lying time was associated negatively with stall design (poorly positioned neck rail) and poor management practices (dirty stalls, failure to remove stall manure at least once a day and failure to add new dry bedding at least once a day).

Together, these results show that smallholder dairy farmers in Kenya, and elsewhere with similar management, could benefit from improved stall design, in particular having dry dirt flooring, well-positioned neck rails, proper stall lengths and good stall drainage. Best and management practices include providing new bedding and removing manure from the stall at least every day, and cleaning the alley once a week or more often, as needed. These recommendations should have a positive effect on comfort and cleanliness of cows in smallholder farms in Kenya, and lead to better performance and health of dairy cows.

3.7 Acknowledgements

We are grateful to the primary funding program for this research, the Canadian Queen Elizabeth II Diamond Jubilee Scholarships (QES) which are managed through a unique partnership of Universities Canada, the Rideau Hall Foundation (RHF), Community Foundations of Canada (CFC) and Canadian universities. This program is made possible with financial support from the Government of Canada, provincial governments and the private sector. We acknowledge the University of Nairobi that provided resources aiding in selection, orientation, training and supervision of QES Scholars and interns who participated in the program. We also acknowledge the large contribution made by volunteers and staff of Farmers Helping Farmers, a non-governmental organization – their existing relationships and agricultural efforts and inputs provided a strong foundation for the work and the entry point to the Naari community. We acknowledge the leadership and members of the Naari Dairy Cooperative Society in Meru for their co-operation in the study. We appreciate the help offered by Shauna Richards with the analysis of the accelerometer data, and Ren Chamberlain and Julia Kenny for their help in data collection in the field.

3.8 References

Abade, C.C., Fregonesi, J.A., von Keyserlingk, M A G and Weary, D.M., 2015. Dairy cow preference and usage of an alternative free-stall design, Journal of Dairy Science, 98, 960-965

Aleri, J.W., Nguhiu-Mwangi, J. and Mogoa, E.M., 2011. Housing-design as a predisposing factor for injuries and poor welfare in cattle within smallholder units in periurban areas of Nairobi, Kenya, Livestock Research for Rural Development, 23, 53

Asmare, A.A. and Kassa, F., 2017. Incidence of dairy cow mastitis and associated risk factors in Sodo town and its surroundings, Wolaita Zone, Ethiopia, Slovak Journal of Animal Science, 50, 77-89

Behnke, R., Centre, O., Wolford, G. and Muthami, D., 2013. A Living from Livestock IGAD Livestock Policy Initiative The Contribution of Livestock to the Kenyan Economy

Bernardi, F., Fregonesi, J., Winckler, C., Veira, D.M., von Keyserlingk, M A G and Weary, D.M., 2009. The stall-design paradox: Neck rails increase lameness but improve udder and stall hygiene, Journal of Dairy Science, 92, 3074-3080

Bewley, J.M., Boyce, R.E., Hockin, J., Munksgaard, L., Eicher, S.D., Einstein, M.E. and Schutz, M.M., 2010. Influence of milk yield, stage of lactation, and body condition on dairy cattle lying behaviour measured using an automated activity monitoring sensor, Journal of Dairy Research, 77, 1-6

Bradley, A.J. and Green, M.J., 2001. Aetiology of clinical mastitis in six Somerset dairy herds, Veterinary Record, 148, 683-686

Breen, J.E., Green, M.J. and Bradley, A.J., 2009. Quarter and cow risk factors associated with the occurrence of clinical mastitis in dairy cows in the United Kingdom, Journal of Dairy Science, 92, 2551-2561

Colam-Ainsworth, P., Lunn, G.A., Thomas, R.C. and Eddy, R.G., 1989. Behaviour of cows in cubicles and its possible relationship with laminitis in replacement dairy heifers

Cook, N.B., Nordlund, K.V. and Oetzel, G.R., 2004. Article: Environmental Influences on Claw Horn Lesions Associated with Laminitis and Subacute Ruminal Acidosis in Dairy Cows, Journal of Dairy Science, 87, E46

DeVries, T.J., Aarnoudse, M.G., Barkema, H.W., Leslie, K.E. and Keyserlingk, M.A.G., 2012. Associations of dairy cow behavior, barn hygiene, cow hygiene, and risk of elevated somatic cell count, Journal of Dairy Science, 95, 5730-5739

DeVries, T.J., Aarnoudse, M.G., Barkema, H.W., Leslie, K.E. and von Keyserlingk, M A G, 2012. Associations of dairy cow behavior, barn hygiene, cow hygiene, and risk of elevated somatic cell count, Journal of Dairy Science, 95, 5730-5739

Dippel, S., Dolezal, M., Brenninkmeyer, C., Brinkmann, J., March, S., Knierim, U. and Winckler, C., 2009. Risk factors for lameness in freestall-housed dairy cows across two breeds, farming systems, and countries, Journal of Dairy Science, 92, 5476-5486

Dohmen, W., Neijenhuis, F. and Hogeveen, H., 2010. Relationship between udder health and hygiene on farms with an automatic milking system, Journal of Dairy Science, 93, 4019-4033

Dohoo, I.R., Martin, S.W. and Stryhn, H., 2012. Methods in Epidemiologic Research, (Charlottetown, P.E.I. : VER, Inc., c2012)

Drissler, M., Gaworski, M., Tucker, C.B. and Weary, D.M., 2005. Freestall maintenance: effects on lying behavior of dairy cattle, Journal of Dairy Science, 88, 2381-2387

El-Tarabany, M. and Ali, M.A., 2015. Incidence, production and economic losses of clinical mastitis in Egyptian Holstein cows, Iranian Journal of Applied Animal Science, 5, 813-818

Fregonesi, J.A., von Keyserlingk, M A G and Weary, D.M., 2009. Cow preference and usage of free stalls compared with an open pack area, Journal of Dairy Science, 92, 5497-5502

Fregonesi, J.A., Veira, D.M., von Keyserlingk, M A G and Weary, D.M., 2007. Effects of Bedding Quality on Lying Behavior of Dairy Cows, Journal of Dairy Science, 90, 5468-5472

Fulwider, W.K., Grandin, T., Garrick, D.J., Engle, T.E., Lamm, W.D., Dalsted, N.L. and Rollin, B.E., 2007. Article: Influence of Free-Stall Base on Tarsal Joint Lesions and Hygiene in Dairy Cows, Journal of Dairy Science, 90, 3559-3566

Galindo, F., Broom, D.M. and Jackson, P.G.G., 2000. A note on possible link between behaviour and the occurrence of lameness in dairy cows, Applied Animal Behaviour Science, 67, 335-341

Gitau, G.K., McDermott, J.J., Adams, J.E., Lissemore, K.D. and Waltner-Toews, D., 1994. Factors influencing calf growth and daily weight gain on smallholder dairy farms in Kiambu District, Kenya, Preventive veterinary medicine, 21, 179-190

Global Forum On Agricultural Research, 2016. Improving the economic lives of smallholder farmers

Gomez, A. and Cook, N.B., 2010a. Time budgets of lactating dairy cattle in commercial freestall herds, Journal of Dairy Science, 93, 5772-5781

Gomez, A. and Cook, N.B., 2010b. Time budgets of lactating dairy cattle in commercial freestall herds, Journal of Dairy Science, 93, 5772-5781

Haskell, M.J., Rennie, L.J., Bowell, V.A., Bell, M.J. and Lawrence, A.B., 2006. Housing system, milk production, and zero-grazing effects on lameness and leg injury in dairy cows, Journal of Dairy Science, 89, 4259-4266

Hossain, S., Reza, M.A., Hasan, M.N., Sorwar, M.G. and Billah, M., 2016. Impact of clinical mastitis in dairy farming at Keshabpur upazilla in Jessore in Bangladesh, Bangladesh Journal of Veterinary Medicine, 14, 59-64

Houben, E.H.P., Brand, A., Dijkhuizen, A.A. and R.B.M. Huirne, 1994. Economics of mastitis and mastitis control in dairy cattle

Ito, K., Chapinal, N., Weary, D.M. and Von Keyserlingk, M A G, 2014. Associations between herd-level factors and lying behavior of freestall-housed dairy cows, Journal of Dairy Science, 2081

Ito, K., von Keyserlingk, M A G, LeBlanc, S.J. and Weary, D.M., 2010. Lying behavior as an indicator of lameness in dairy cows, Journal of Dairy Science, 93, 3553-3560

Ito, K., Weary, D.M. and von Keyserlingk, M A G, 2009. Lying behavior: Assessing within- and between-herd variation in free-stall-housed dairy cows, Journal of Dairy Science, 92, 4412-4420

Jensen, M.B., Pedersen, L.J. and Munksgaard, L., 2005. The effect of reward duration on demand functions for rest in dairy heifers and lying requirements as measured by demand functions, Applied Animal Behaviour Science, 90, 207-217

Jensen, M.B., Munksgaard, L., Pedersen, L.J., Ladewig, J. and Matthews, L., 2004. Prior deprivation and reward duration affect the demand function for rest in dairy heifers, Applied Animal Behaviour Science, 88, 1-11

Lubaba, C.H., Hidano, A., Welburn, S.C., Revie, C.W. and Eisler, M.C., 2015. Movement Behaviour of Traditionally Managed Cattle in the Eastern Province of Zambia Captured Using Two-Dimensional Motion Sensors, PLoS ONE

Magnusson, M., Herlin, A.H. and Ventorp, M., 2008. Effect of alley floor cleanliness on free-stall and udder hygiene, Journal of Dairy Science, 91, 3927-3930

Mason, W., 2017. Association between age and time from calving and reported lameness in a dairy herd in the Waikato region of New Zealand, New Zealand veterinary journal, 65, 163-167

Mazrier, H., Tal, S., Aizinbud, E. and Bargai, U., 2006. A field investigation of the use of the pedometer for the early detection of lameness in cattle

McFarland, D.F., 1991. Experiences with free stall design in Pennsylvania, Paper - American Society of Agricultural Engineers, 17

Miller-Cushon, E. and DeVries, T.J., 2017. Short communication: Associations between feed push-up frequency, feeding and lying behavior, and milk yield and composition of dairy cows, Journal of Dairy Science, 100, 2213-2218

Mureithi, D.K. and Njuguna, M.N., 2016. Prevalence of subclinical mastitis and associated risk factors in dairy farms in urban and peri-urban areas of Thika Sub County, Kenya, Livestock Research for Rural Development, 28, Article 13

Muthee, J.K., Gakuya, D.W. and Nduhiu, J., 2005. Preliminary investigation of the status of bovine mastitis in a medium scale dairy farm in Kabete area, Kenya, The Kenya Veterinarian, 29, 57-59

Norring, M., Valros, A. and Munksgaard, L., 2012. Milk yield affects time budget of dairy cows in tie-stalls, Journal of Dairy Science, 95, 102-108

Norring, M., Manninen, E., Passille, A.M.d., Rushen, J., Munksgaard, L. and Saloniemi, H., 2008. Effects of sand and straw bedding on the lying behavior, cleanliness, and hoof and hock injuries of dairy cows, Journal of Dairy Science, 91, 570-576

Reneau, J.K., Seykora, A.J., Heins, B.J., Endres, M.I., Farnsworth, R.J. and Bey, R.F., 2005a. Association between hygiene scores and somatic cell scores in dairy cattle, Journal of the American Veterinary Medical Association, 227, 1297-1301

Reneau, J.K., Seykora, A.J., Heins, B.J., Endres, M.I., Farnsworth, R.J. and Bey, R.F., 2005b. Association between hygiene scores and somatic cell scores in dairy cattle, Journal of the American Veterinary Medical Association, 227, 1297-1301

Richards, S.M., 2017. Productivity and welfare of cows in smallholder dairy farms in Kenya, PhD Dissertation, University of Prince Edward Island, Charlottetown

Rollin, B.E., 2004. Animal agriculture and emerging social ethics for animals, Large animal.Proceedings of the North American Veterinary Conference, Volume 18, Orlando, Florida, USA, 17-21 January 2004

Ruud, L.E., 2011. The Optimal Free Stall for Dairy Cows - Effects of Free-Stall Design on Cleanliness, Milk Yield, Health, and Behaviour, (Norwegian University of Life Sciences, Department of Animal and Aquacultural Sciences)

Ruud, L.E., Kielland, C., Esteres, O. and Boe, K.E., 2011. Free-stall cleanliness is affected by stall design, Livestock Science, 135, 265-273

Saharia, J., Saikia, S. and Dutta, G.N., 1997. Effect of housing on the incidence of sub-clinical mastitis in dairy cows, Indian Veterinary Journal, 74, 436-438

Schreiner, D.A. and Ruegg, P.L., 2002. Effects of tail docking on milk quality and cow cleanliness, Journal of Dairy Science, 85, 2503-2511

Sepelveda-Varas, P., Weary, D.M. and Keyserlingk, M.A.G., 2014. Lying behavior and postpartum health status in grazing dairy cows, Journal of Dairy Science, 97, 6334-6343

Shitandi, A., Anakalo, G., Galgalo, T. and Mwangi, M., 2004. Prevalence of bovine mastitis amongst smallholder dairy herds in Kenya, Israel Journal of Veterinary Medicine, 59, 20-23

Sprecher, D.J., Hostetler, D.E. and Kaneene, J.B., 1997. A Lameness Scoring System That Uses Posture and Gait to Predict Dairy Cattle Reproductive Performance, Theriogenology, 1179

Steensels, M., Bahr, C., Berckmans, D., Halachmi, I., Antler, A. and Maltz, E., 2012. Lying patterns of high producing healthy dairy cows after calving in commercial herds as affected by age, environmental conditions and production, Applied Animal Behaviour Science, 136, 88-95

Tucker, C.B., Zdanowicz, G. and Weary, D.M., 2006. Brisket boards reduce freestall use, Journal of Dairy Science, 89, 2603-2607

Tucker, C.B., Weary, D.M. and Fraser, D., 2005. Influence of neck-rail placement on free-stall preference, use, and cleanliness, Journal of Dairy Science, 88, 2730-2737

Tucker, C.B. and Weary, D.M., 2004. Article: Bedding on Geotextile Mattresses: How Much is Needed to Improve Cow Comfort?, Journal of Dairy Science, 87, 2889-2895

Tucker, C.B., Weary, D.M. and Fraser, D., 2003. Article: Effects of Three Types of Free-Stall Surfaces on Preferences and Stall Usage by Dairy Cows, Journal of Dairy Science, 86, 521-529

Uzal, S. and Ugurlu, N., 2010. The time budget of dairy cows as affected by season and housing system, Journal of International Environmental Application & Science, 5, 638-647

Vanegas, J., Overton, M., Berry, S.L. and Sischo, W.M., 2006. Effect of rubber flooring on claw health in lactating dairy cows housed in free-stall barns, Journal of Dairy Science, 89, 4251-4258

Vasseur, E., Gibbons, J., Rushen, J., Pellerin, D., Pajor, E., Lefebvre, D. and de Passillé, A.M., 2015. An assessment tool to help producers improve cow comfort on their farms, Journal of Dairy Science, 98, 698-708

Veissier, I., Capdeville, J. and Delval, E., 2004. Cubicle housing systems for cattle: comfort of dairy cows depends on cubicle adjustment, Journal of animal science, 82, 3321-3337

Vokey, F.J., Guard, C.L., Erb, H.N. and Galton, D.M., 2001. Article: Effects of Alley and Stall Surfaces on Indices of Claw and Leg Health in Dairy Cattle Housed in a Free-Stall Barn, Journal of Dairy Science, 84, 2686-2699

Wildman, E.E., Jones, G.M., Wagner, P.E., Boman, R.L., Troutt, H.F., J. and Lesch, T.N., 1982. A dairy cow body condition scoring system and its relationship to selected production characteristics, Journal of Dairy Science, 65, 495-501

Zadoks, R.N., Allore, H.G., Barkema, H.W., Sampimon, O.C., Wellenberg, G.J., Grahn, Y.T. and Schukkent, Y.H., 2001. Cow- and quarter-level risk factors for streptococcus uberis and staphylococcus aureus mastitis

Zurbrigg, K., Kelton, D., Anderson, N. and Millman, S., 2005. Stall dimensions and the prevalence of lameness, injury, and cleanliness on 317 tie-stall dairy farms in Ontario, Canadian Veterinary Journal, 46, 902-909

Chapter 4: Assessment of farmers' compliance to implement cow comfort changes recommended, and their effects on lying time, stall and cow cleanliness on smallholder dairy farms in Kenya.

4.1 Abstract

It is important to understand the reasons for not following recommendations on stall dimensions and housing management practices, which can affect lying time and cow cleanliness, among other outcomes. Our study objective was to evaluate the degree of compliance in implementing farm-specific cow comfort changes recommended, and the effects of implementing the recommendations on lying time, stall cleanliness and cow cleanliness. A randomized controlled trial was carried out on 73 smallholder dairy farms (SDFs) in Kenya involving a total of 106 cows with an average herd size of 1.4 ± 0.6 cows. A total of 62 farms (90 cows) were retained in the intervention group and received farm-specific recommendations on a maximum of 12 cow comfort parameters, while 11 farms (16 cows) were retained as controls and received no recommendations. The 12 cow comfort parameters that could be potentially changed were: roof status, drainage of surface water, floor softness, floor flatness, stall width, stall length, leg space, lunge space, neck rail, brisket board, alley cleaning and sharps fixing. Each of the comfort parameters could be recommended for a major change or minor change based on the estimated duration of time it would take to complete the change, labour input required and cost incurred.

On the first visit to all the farms, baseline cow comfort data was collected, data loggers attached to the hind legs of the cows to determine daily lying time, and face-to-face

questionnaires administered in the native language (Kimeru) to evaluate the management practices on the farms. Three days after the first visit, data loggers were detached from cows on all cows on the second visit, while farm-specific recommendations were given to the intervention group farmers orally and in written form using the language of their choice (Kimeru, Swahili or English). After 39±7 days, a third visit was done where data loggers were again attached on cows on all the farms and compliance was assessed and a post-intervention questionnaire administered face-to-face in Kimeru in intervention farms. A fourth visit was done on all the farms where data loggers were detached.

Data analysis was carried out on Stata 14.2® where proportions were used to describe the compliance of the farmers to implement the proposed changes while medians and ranges were used to describe the daily cow lying time and cleanliness scores (stall, udder and upper hind legs) reported on a scale of 1-5. Proportion tests and Kruskal-Willis rank test were used to assess the differences cleanliness scores and lying time respectively, within and between groups, over the assessment time. Univariable and multivariable mixed logistic regression models with farm random effects were used evaluate factors that were associated compliance. To assess the interaction between treatment groups and visits, a multivariable mixed linear regression model of the natural log of lying time and multivariable mixed logistic regression models of cleanliness scores (stall, udder and upper hind leg) with farm random effects were used. On adjusting for compliance using a combined variable, interaction between this variable and the visits was assessed using similar models of the 4 outcomes (lying time, stall cleanliness, udder cleanliness and upper hind leg cleanliness) that were fit for each of the 12 comfort parameters.

The farmers' overall compliance was 74% (46/62). The odds of compliance were higher when: major changes were recommended relative to minor changes (OR=6.3, p=0.004); and changes recommended were related to floor characteristics (floor softness and flatness) in comparison to changes related to stall design (p=0.047). The odds of compliance were lower in: farms where the farm-hands received the recommendations compared to farms that had the wife receive the recommendations (OR=0.01, p=0.023); and farms that had proposed changes related to roof, alley and sharps fixes relative to stall design fixes (OR=0.1, p=0.004). The farm effects explained about 84.4% of the variation observed in compliance.

For farms that implemented at least one recommended change (46 farms), the odds of compliance were lower if: the farmers reported at least one recommendation was hard to implement (OR=0.3, p=0.021); if the recipients of the recommendations were men (OR=0.4, p=0.037) or farm hands (OR=0.1, p=0.016) compared to women receiving recommendations. The odds of compliance higher if: the changes recommended were major relative to minor changes (OR=4.0, p=0.002); and the proposed changes were of floor characteristics (floor softness and flatness) in comparison to stall design (OR=4.2, p=0.036).

Post-intervention, stall, udder and upper hind leg cleanliness scores improved significantly (p<0.0001, p=0.021 and p=0.017 respectively) in the intervention farms but remained relatively similar in the control farms. The change in daily lying time over the assessment time was not significant within and between intervention and control groups.

Giving farm-specific cow comfort recommendations to smallholder dairy farmers in Kenya and providing them with a participatory role in the formulation and implementation of improvement recommendations ensured good acceptance and a high degree of implementation and led to a subsequent improvement in their welfare in terms of cow comfort and cleanliness.

4.2 Introduction

With the rapid growth of the dairy industry globally, concerns around the welfare of dairy cows have been raised (Rollin, 2004) and a number of welfare standards have been set by various participants in the dairy industry (Rushen, Butterworth and Swanson, 2011). These animal welfare standards include requirements for stall dimensions and management practices that are based on research findings e.g. (Bickert, 2000; Tucker, Weary and Fraser, 2004). Tools used for assessment of welfare on dairy farms have been developed and used in various parts of the world to assure consumers of humane treatment of animals and to identify critical aspects of cow comfort that need to be addressed on farms (Vasseur et al., 2015).

Researchers have shown that stall configuration and dimensions such as stall length and width (Tucker, Weary and Fraser, 2004), neck rail positioning (Tucker, Weary and Fraser, 2005) and brisket availability (Tucker, Zdanowicz and Weary, 2006), in addition to management practices, such as frequent new bedding provision (Fregonesi et al., 2007), influence lying patterns of cows, an indicator of cow comfort and animal welfare

(Cook, Bennett and Nordlund, 2005a). Findings indicate that stall and cow cleanliness are also influenced by stall design (Bernardi et al., 2009), as well as management practices such as bedding availability (Norring et al., 2008) and frequency of manure removal (DeVries et al., 2012).

In an effort to improve animal welfare on dairy farms, approaches have included education of farmers, legislation, and/or voluntary programs of encouragement of farmers to implement changes (Whay and Main, 2015). For example, transfer of knowledge to farmers using a top-down approach was used to introduce a lameness control plan on UK dairy farms, but the implementation rates of components of the control plan were poor (Bell et al., 2009). However, in 2012, a 12% decrease in lameness prevalence was reported in UK dairy herds when farmers were given information, and then they were involved in formulating farm-specific lameness plans rather than implementing broad pre-defined control measures (Main et al., 2012). Similarly, the incidence of mastitis decreased by one-third in Swiss dairy farms when the farmers were integrated in the development of measures for prevention and treatment of mastitis (Ivenleyer, 2008). Both dissemination of knowledge and integration of farmers in the development and implementation of such action plans has been shown to be important in successful interventions (Whay and Main, 2015).

Animal welfare programs to improve cow comfort, health and cleanliness have been implemented in large dairy herds in Canada and Australia kept in free stalls and tie stalls (Tremetsberger, Leeb and Winckler, 2015; Bouffard et al., 2017). In smallholder dairy farms in Kenya, cows are typically kept in zero-grazing units, and little research has been reported on attempts to improve the health and welfare of cows by dissemination of knowledge using top-down or farmer integration approaches. The present study aimed to evaluate: 1) the compliance rate of farm-specific cow comfort changes recommended to farmers; and 2) how the recommendations and the farmers' compliance affected stall cleanliness, cow cleanliness and daily lying time of cows in smallholder dairy farms.

4.3 Materials and Methods

4.3.1 Ethical approval

The study was approved by the Research Ethics Board and the Animal Care Committee of the University of Prince Edward Island, the Naari Dairy Farmers Co-operative Society, and Farmers Helping Farmers, a partnering non-governmental organization.

4.3.2 Study design and sampling method

The study was carried out in the Naari region of Meru County in Kenya. This is a high potential area where small holder dairy farming is widely practiced, with zero-grazed and pasture-grazed farming systems. The study was a randomized controlled trial where farms were classified as intervention or control farms. The full list of 500 active farmers in the Naari Dairy Farmers Co-operative Society (NDFCS) was used as the initial sampling frame.

An initial simple random sample of 200 farms for another part of the project was selected using computer generated random numbers. Of these 200 farms, the following inclusion criteria were used to further narrow the sampling frame of farms for this controlled trial: 1) farms with zero grazing units; 2) a maximum of four cows per farm; and 3) at least one milking cow. A total of 73 farms with 106 milking cows met these inclusion criteria; of these 62 farms with 90 milking cows were randomly assigned to the intervention group while the remaining 11 farms with 16 milking cows were randomly assigned to the control group. It was expected that between a quarter and a third of the intervention group would not comply with cow comfort recommendations, balancing out the two groups somewhat when making the comparisons around the impact of compliance.

Four visits were made to the two groups of farms on different days but the time between the visits was similar for both groups. California Mastitis Test was carried out on all the milking cows on every farm during each visit, and any cow with a CMT score of 1 or higher was given intra-mammary treatment with Cefapirin. Also, deworming was administered to all the milking cows (Cydectin® pour-on at 0.5mg/kg) on all farms, and additional treatment was provided to any cases of illness observed on any of the visits to minimize the possible effects of health status on the outcomes of interest.

4.3.2.1 Intervention group

On the first visit, we introduced and described the study to the farmer, outlining the expectations and the requirements for the researcher and the farmers. A general survey on cow welfare on the farm was carried out, and an initial questionnaire on welfare management was administered. Details of the questionnaire can be found in chapter 3. Accelerometer data loggers (Onset HOBO, MacArthur Blvd, Bourne, MA) were attached on all milking cows to determine their lying behaviour before any intervention was carried out. The second visits were done three days later to remove the data loggers and recommend changes to the stall design (only recommendations which did not require substantial investment were made) and management to improve cow comfort on each of the farms in the intervention group. On the third visit, which was carried out approximately three weeks later, a post-intervention questionnaire was administered and the cow welfare assessment was repeated to determine whether the recommended changes had been made (compliance) and, if so, how well they were adhered to. Time given to implement the changes was described as the number of days between the second and third visit. The data loggers were again attached on the same pre-intervention milking cows to determine the lying behaviour of cows post-intervention. The fourth visit was carried out three days later to remove the data loggers and help the farmers implement any changes that they had left incomplete over the three-week implementation period.

4.3.2.2 Control group

This group did not receive cow comfort recommendations during the first three visits, but all other activities undertaken on the intervention farms were also carried out on these farms. On the fourth visit, cow comfort changes similar to those conducted on the intervention farms were implemented, so that these farms did not feel disadvantaged from having been members of the control group.

4.3.3 Data collection

The cow level information on 106 milking cows collected included: cow identification, age in years, and weight as estimated in kg using a dairy cow heart girth weight tape. The height was measured using a height stick with a level that was placed at the withers. The breeds were described as exotic if the cows were visibly and predominantly Friesian, Guernsey, Ayrshire or Jersey, and indigenous if they were visibly and predominantly Zebu, Boran or other local breeds. The body condition score was described using the 5-score chart (Wildman et al., 1982) that ranged from 1(very thin) to 5 (excessively fat), with quarter-point increments.

The health status of the cows was determined by conducting a physical examination of the cow that included, but was not limited to: heart rate and quality, respiratory rate and quality, color of mucous membranes, and palpation of superficial lymph nodes, rumen movements, skin condition, and joints and feet examination. Lameness status in the cows was classified as absent, mild or severe; a modification of the typical 5-point score system (Sprecher, Hostetler and Kaneene, 1997). Neck, carpal and hock lesions were recorded as part of the post-intervention physical exams only (for descriptive purposes) because of the short time between pre-intervention and post-intervention assessments and that these lesions would not be different at the two time points.

Some farms used a combination of zero-grazing, partial zero-grazing, and tethering of cows, meeting the inclusion criterion of zero-grazing. However, because not all cows were zero-grazed, the following variable was required to document the housing categorization for each cow on the farm. The type of stall each cow lied down in was categorized as: present (complete zero-grazing unit), partial (an incomplete and/or paddock-like stall with no distinct lying area) or absent (cows tethered to a tree or in the open field).

For cows lying down in stalls, the stall they usually lied down in was measured for various dimensions (Table 3-1). Then, for each dimension, various characteristics were categorized on their appropriateness, based on recommendations associated with the cow's estimated weight (appropriate if within ±10% of the recommendation for the weight). Three general categories for the characteristics were used: 1) insufficient space and/or railings present but in the wrong location, leading to cramped spacing, but good stall cleanliness; 2) appropriate space and/or railing positions, leading to both adequate spacing and cleanliness for good overall cow comfort; and 3) too much space and/or railings not present, leading to good cow space but poor stall cleanliness. Therefore, the middle category was considered the optimal category for these characteristics.

The total length and body length of each stall was measured and categorized as: 1) insufficient length, 2) adequate length, or 3) too long. The total width was similarly categorized as: 1) insufficient width, 2) adequate width, or 3) too wide so the cow could turn around in the stall. Availability and positioning of the neck rail and brisket board were assessed and categorized as: 1) present but not well positioned, 2) present and well positioned, or 3) not present in the stall.

The following measurements or assessments were not based on the weight of the cow, and could not have an "excessive" category, therefore they had different categorizations. The availability and adequacy of a forward and/or side lunge space was classified as: 1) lunge space not available, 2) lunge space available but not adequate and 3) adequate lunge space available. Leg space was assessed and categorized as: 1) no leg space available, 2) leg space available but not adequate and 3) adequate leg space available.

The type of floor was recorded as: 1) dirt, 2) concrete and wooden, or 3) other. The floor flatness was categorized as: 1) flat ($<5\%$ of the floor uneven) or 2) lumpy ($\geq 5\%$ of the floor uneven). The type of bedding available was categorized as: 1) sawdust, 2) wood shavings, 3) crop waste, or 4) other. The knee impact test (from a crouched position on your feet, tipping forward so your knees contact the floor surface) was used to determine how soft the stall surface was, and was categorized into three possible levels: normal, marginal and hard. If the floor was soft and did not cause any level of discomfort on the knees, the floor was categorised as normal which indicated a passing grade on the knee impact test. If the floor was somewhat uncomfortable on the knees, such as a cement floor with a modest amount of bedding or a dirt floor that was compacted, then it was classified as marginal. If the floor caused extreme discomfort on the knees on impact, the floor was classified as hard and this indicated failure of the knee impact test.

The degree of wetness on the floor surface was assessed using the knee wetness test, which was categorised as normal if the knee was completely dry after about 10-15 seconds of knee contact on the floor, marginal if the knee had some noticeable moisture, and wet if the knee was completely wet after the contact with the floor. The knee wetness and impact tests have been used elsewhere to assess floor conditions for cattle (McFarland, 1991). We included a marginal category to the knee tests to adapt the tests to the highly variable stall management conditions that exist in Kenya where dirt (not sand) and crop waste are commonly used for floor surfaces.

The adequacy of the roof (yes or no) was determined based on a visual assessment of the roof, confirming that the roof was adequately covering the entire length of the stall, plus an extra 30cm at the udder end, with a roof that was not allowing water to enter the stall because of roof holes. Adequate drainage of the stall (yes or no) was judged by determining whether or not water could flow along the ground from outside the stall into the stall by gravity.

The stall, udder and leg cleanliness scores were assessed using a 5-score system (Reneau et al., 2005) where the categories were: 1 (very clean), 2 (clean), 3 (fair), 4 (dirty) and 5 (very dirty). Stall cleanliness score was based on the proportion of the entire lying surface that had manure (wet or dry) or wet bedding. Udder cleanliness score was based on the degree of soiling on the udder and the teats. The leg cleanliness score was based on the soiling and matting of the outer upper flank of the two hind legs. Where two scores were taken, from the hind legs or two sides of the udder, an average of these scores was recorded.

The condition of the alley was categorized based on the amount of manure at the time of assessment, with three possible categories: 1) clean (no manure), 2) fairly clean (small amount of manure - can easily walk to avoid manure), and 3) muddy (a large amount of manure on the alley - cannot avoid walking in manure).

Farm-level parameters assessed (over the last 6 months)included: number of milking cows in the farm; frequency of hoof trimming; stall manure removal frequency; use of bedding on lying surfaces; frequency of adding new bedding in the stalls; and frequency of cleaning the alley. These parameters were acquired using a questionnaire that was administered to the farmers face-to-face by the investigator in the native language (Kimeru). Assessment for abnormal lying and standing behaviours at the herd level were determined for each farm in two ways: 1) observations made while on the farm, including (but not limited to): perching, standing idle in the stall, standing backwards in the stall and lying in places other than the stall; and 2) farmer-reported behaviours acquired using the questionnaire, since it was possible that cows may not exhibit these behaviours during the interruption of the farm visit.

For each intervention farm, there were twelve possible comfort parameters around which recommendations could be made for change (Table 4-1). The recommended comfort changes were specific to each farm based on the survey carried out during the initial visit. For each of the comfort parameters, there were three recommendation possibilities: 0) no recommendation (no change required); 1) minor recommendation (required little time to implement); and 2) major recommendation (change requires substantial time and/or may incur some costs). The changes recommended were written down in double copies of

English and Kimeru (the native language for the area), for ease of understanding and to provide a copy for the farmer and the investigator to avoid loss of information. The comfort recommendations for each of the farm were explained orally to the person attending to the farm on the day of the second visit, in Kimeru. The rationale (e.g. cow comfort, health) for the recommendations was also provided. Questions regarding the recommendations were answered, to provide the opportunity to make sure the recommendations were clear to the person receiving them, and to allow a discussion on how to go about implementing the changes, if desired by the farmers receiving the recommendations.

Table 4-1: Examples of minor and major stall changes recommended to smallholder dairy farms in Kenya. 2017.

Factor	Example of minor change	Example of major change
Roof (RF)	Patch holes on roof	Replace section of the roof
Drainage of surface water (SW)	Improve on an existing drainage system, such as adding to a section of a berm	Dig a trench outside the stall to facilitate and improve drainage around the stall
Floor softness (FS)	Add bedding to already bedded surface	Avail bedding to a non-bedded surface
Floor flatness (FF)	Level a small portion of floor (<25%) surface	Level a large portion (≥25%) or the entire floor surface
Stall width (SW)	Move a side board from one side of the vertical post to the other	Add new side boards to reduce width
Stall length (SL)	Remove 1-2 front boards to increase length	Remove all front boards to increase length
Leg space (LeS)	Remove the lowest sideboard on one side of the stall	Remove the lowest side boards on both sides of the stall
Lunge space (LuS)	Move a sideboard lower or higher to create enough side lunge space	Move or remove multiple boards on the front or side to create enough lunge space
Neck rail (NR)	Repositioning an existing neck rail	Placing and positioning a new neck rail
Brisket board (BB)	Repositioning an existing brisket board	Placing and positioning a new brisket board
Alley clean (AC)	Clean an alley with 2-6 days' manure	Clean an alley with a least a week's manure
Sharps fix (SF)	Bend and/or remove 1-3 sharps	Bend and/or remove > sharps

Compliance was assessed for each type of comfort parameter recommended for change on all farms on the intervention group. A farmer's perspective on how many of the given recommendations they felt they had completed was recorded as: 1) none, 2) some, and 3) all. In addition, the farmer's stated how well they thought they had carried out the recommendations and their responses were categorised as: 1) poor, 2) fairly good and 3) excellent. The investigator carried out an assessment on whether each of the recommended change had been implemented and how well this had been done. The investigator's assessment was used in the data analysis. For each comfort parameter recommended, compliance was categorized as: 0) no compliance (not done), 1) partial compliance (change attempted but not completed and/or change done incorrectly), and 2) total compliance (change done completely and correctly).

4.3.3.1 Pre- and Post- Intervention Questionnaires

The initial questionnaire was administered on the first visit to farmers in both groups and was used to gather information on the cows and management-based parameters that potentially impact cow comfort on the farm. The post-intervention questionnaire was administered on the third visit to the intervention farms only to assess compliance to implementation of the recommended cow comfort changes. Farmers who attempted at least one of the recommended changes, were asked the following: whether any recommendations were hard to implement (to which they provided yes or no responses); if they incurred any cost during implementation (yes or no), and, if they did spend money, how much in Kenya shillings (Ksh). They were also asked whether any challenges were observed after implementation of the changes (yes or no), and if yes, they were asked to list some of the challenges e.g. cows fighting for a stall or cows with a phobia to lie down with any new stall additions (e.g. a neck rail). Finally, they were asked whether they felt were well-versed in cow comfort changes after implementation (yes or no), and whether they advised other farmers on cow comfort after implementation (yes or no), and if not, what the reasons for not giving advice were. All of these were asked using an open-ended question format. For farmers who did not attempt any of the recommended changes, they were asked to give reasons why, in an open-ended question. Both pre- and post-intervention questionnaires were administered in the native language of Kimeru.

4.3.3.2 Accelerometers

The data loggers that record x-, y- and z- axis acceleration were used to record the lying time of cows. The specifications, calibration and operation of the data loggers were done as per the manufacturer's manual (HOBO Pendant G Acceleration Data Logger (UA-004-64) Manual). The loggers were connected to an optic USB base station and coupler (HOBO Waterproof Shuttle) and launched using the HOBOware installed to record data at logging intervals of one second. Once launched on normal mode with the red light blinking every 5 seconds, the data loggers were wrapped in disposable foam to prevent any injury to the cows on attachment, then secured in airtight disposable Ziploc bags preventing fluid from reaching the pendants, and finally, they were inserted in Velcro straps which were attached on the inside of the left hind leg below the hock joint but above the pastern joint. Two fingers were inserted between the strap and the leg to ensure cow's blood flow was not compromised by the strap. The loggers were placed such that, the x-axis was parallel to the ground pointing cranially toward the head, the y-axis was perpendicular to the ground pointing dorsally towards the cow's back, and the z-axis was parallel to the ground pointing left away from the cow.

On detachment, the data were downloaded from the loggers using the HOBO ware, plotted and saved as hobo files using the pendant serial number, farm number and cow identification. Launch, attachment and detachment dates and times were recorded to allow standardization of time frames for lying behaviour data during analysis to avoid bias. The loggers and straps were cleaned with antiseptic and stored for further use.

4.3.4 Data management and analysis

Data were entered, cleaned and coded using Microsoft Excel® 2013 (Microsoft, Sacramento, California, USA) and analyzed using Stata 14 (StataCorp, College Station, Texas, USA). Standardization of lying behaviour data involved calculating time components of each cow for exactly 72 hours, excluding the first hour after attachment of loggers and the last hour before detachment because the cows are disturbed during attachment and detachment; thus data one hour after attachment and before detachment would be biased.

Lying behaviour data were converted to lying time per cow per day, lying bouts per cow per day, and lying time per bout. While number of lying bouts and lying time per bout are indicators sometimes reported in cow comfort studies (Cook, Bennett and Nordlund, 2005b), we focused on lying time because it is more clearly interpreted than the number of lying bouts and lying time per bout.

Due to the large number of possible stall changes recommended to the farmers for analysis, a combined comfort parameter variable was generated that aggregated the 12 comfort parameters into 4 combined comfort parameters. The new variable had four categories; 1) stall design included lunge space (LuS), side leg space (LeS), neck rail (NR) and brisket board (BB); 2) stall size included stall length and stall width; 3) floor characteristics included floor softness (FS) and floor flatness (FF); and 4) “other” category that included roof adequacy (RF), drainage of surface water (SW), cleanliness of the alley (AC) and sharps fixes (SF).

Descriptive analyses

Due to the skewed distribution of the number of lying bouts and duration of each bout, these variables were described using their medians and ranges. Abnormal standing and lying behaviours (e.g., perching and standing backwards in the stall) were classified as: 0) no abnormal behaviour; and 1) at least one abnormal lying behaviour observed or reported on the farm (farm-level variable).

Medians and ranges were used to describe the daily cow lying time and cleanliness scores (stall, udder and upper hind legs) reported on a scale of 1-5, among the intervention (n=62 farms) and control (n=11 farms) groups, pre- and post- intervention. Due to the lack of normality of these outcome variables, the Kruskal-Willis rank test was used to assess the significance of the differences in lying time and cleanliness scores in each of the groups (intervention and control), over the assessment time (pre-and post-intervention).

Proportions of clean (≤2.5) and dirty (>2.5) stalls, udders and upper hind legs were also used to describe cleanliness scores in the groups by the assessment time (pre-and post-intervention).

Proportions were used to describe the prevalence of subclinical mastitis (SCM) within and between the intervention and control groups, pre-and post-intervention. Proportion tests (e.g. Chi-squared test) were used to assess the difference in SCM prevalence between the groups and the assessment times. No further analyses were carried out on subclinical mastitis prevalence due to lack of information on other management factors such as milking practices.

4.3.4.1 Differences between intervention groups, irrespective of compliance

To evaluate the effects of the treatment and visits on the daily lying time, a multivariable mixed linear regression model of the natural log of lying time, with treatment (groups), visit (pre-and post-intervention) and their interaction as predictors and farm random effects, was fit. The significance of the interaction was assessed statistically ($p<0.05$), and using interaction plots of the predicted means of log of lying time. Similar evaluations of interaction effects on cleanliness scores (stall, udder and upper leg) categorized as binary outcomes (clean ($\leq$2.5) and dirty (>2.5) were conducted using multivariable mixed logistic regression models with farm random effects. Marginal analyses and interaction plots were used to further illustrate any significant interaction effects.

4.3.4.2 Compliance assessment

Compliance with the intervention was expected to have a bearing on the effect of the intervention for the 62 intervention farms, and is needed to be taken into account in the modelling. Due to a large number of zeros on partial compliance to implementing minor changes for 10 of the 12 comfort parameters and to implementing major changes for 30% of the 12 comfort parameters, the compliance variable (on each of the recommended change) was collapsed to two groups namely: 0) no compliance and 1) compliance (partial or full). Descriptive statistics on farmer compliances to the recommended changes in stall design and management, and their feedback on the recommendations, were determined using simple proportions on categorical data.

To evaluate the factors that were associated with farmers' compliance to implement recommended changes (objective 1), data were shaped to a long structure to allow inclusion of specific comfort parameters (maximum 12) recommended for change in each of the intervention farm. Chi-square tests and mixed univariable logistic regression models with farm random effects were used to determine unconditional associations ($p<0.25$) associated with farmers' compliance with implementing recommended changes.

A mixed multivariable logistic regression model was fit with the eligible factors ($p<0.25$) to determine their association with compliance on all the 62 intervention farms while controlling for clustering at the farm level. A second mixed multivariable logistic regression model with farm random effects was used for the farms that attempted at least one of the given recommendations (n=46). Pearson correlation coefficients were used to identify correlated predictors and to aid in model building. Potential confounders and two-way interactions were evaluated and the final model reported with significant confounders and interactions. The goodness-of-fit test was done for the final models.

4.3.4.3 Differences between intervention groups, considering compliance

To further estimate the effects of the intervention on the mentioned outcomes (lying time and cleanliness scores), while adjusting for compliance, a new grouping variable was generated where the intervention farms that implemented at least one of the recommended changes were retained as the "intervention and compliant" group (n=46 farms), and the intervention farms that did not implement any of the given changes were combined with the original controls (n=27 farms), and called the "control and non-compliant" group. The description of the outcomes and evaluation of the differences between these two new groups was similar to that mentioned above.

To evaluate the effects of compliance with the specific comfort parameter recommendations on the outcomes, the data were reshaped to include the pre- and post-intervention assessments and outcomes, compliance data, and interactions between pre- and post- intervention outcomes and compliance. For these analyses, a variable combining the need for a recommendation of a specific comfort parameter and the implementation of the change by the farmer was generated. The new variable had three levels: 0) the comfort parameter needed no change and therefore no recommendation was given; 1) the comfort parameter needed a change, a recommendation was given, and the farmer partially or completely complied; 2) the comfort parameter needed a change, a recommendation was given, but the farmer did not comply at all. To fulfill normality assumption, lying time was transformed using natural log for the following analytical statistics.

Multivariable mixed logistic regression models were used to determine the effects of visits (pre-and post-intervention), compliance to implement the needed changes, and their interaction, on stall cleanliness, udder cleanliness and upper leg cleanliness scores. Similarly, the significance of these effects on log of lying time was determined using multivariable mixed linear regression models with farm as a random effect.

For cows on the 46 farms that implemented at least one of the recommended changes, similar mixed regression models were fit to identify the effects of compliance, visits and their interaction on log of lying time, stall cleanliness, udder cleanliness and upper leg cleanliness. Significant interactions ($p<0.3$) were determined and reported using interaction plots made using margins predictions.

Standardized residuals were used to evaluate the assumptions of normality, linearity and homoscedasticity for the linear regression models. In addition outliers were identified, and leverage, Cooks distance, delta-beta values were used to identify influential observations. Models with and without these observations were fit and the model differences evaluated to determine whether to leave the observations in the model or remove them.

Intra-class correlation values were used to assess the random effects of farms on the variability observed in the outcomes post-intervention.

4.4 Results

A total of 18 intervention and 9 control farms were lost before the third visit due to death, culling, selling and drying of the cows, as well as relocation of some farmers to other regions of the country, leaving 62 intervention and 11 control farms retained for the study.

These 73 farms had 106 cows, with the number of milking cows, ranging from 1 to 4 per farm. For the 106 cows, the mean milk production per cow per day was 6.6 ± 3.3 litres pre-intervention. Mean stall, udder and upper leg cleanliness scores pre-intervention were 2.4 ± 1.0, 1.9 ± 0.7, and 2.5 ± 1.1, respectively. The overall prevalence of subclinical mastitis in cows was 42% (44/106) pre-intervention and 33% (35/106) post-intervention, with no significant difference in prevalence in the intervention group pre- and post-intervention ($p=0.577$), or between intervention and control farms pre-intervention ($p=0.454$) or post-intervention ($p=0.226$). Before cow comfort recommendations were made, milking cows in all the farms were non-lame, and only one mild case of lameness was observed post-intervention. Neck, carpal and hock lesions were present in 15%, 13% and 15% of the cows (106) post-intervention.

The mean daily lying time for the cows in the study pre- and post-intervention was 10.9 ± 2.2 and 11.5 ± 2.3 hours, respectively. The median number of lying bouts per cow per day was 12.3 and 19.3 pre-intervention and post-intervention, respectively. Lying bouts had a median duration of 51.2 minutes, ranging from 10.5 to 105.5 minutes pre-intervention, and 32.1 minutes ranging from 10.0 to 104.8 minutes post-intervention.

There were no significant differences in bout numbers or bout lengths between groups pre-intervention, or within groups when comparing pre- and post-intervention.

4.4.1 Compliance assessment

With a total of 12 comfort parameters that could be identified for change, the number of recommendations given to each intervention farm ranged from 1 to 10, based on the number of comfort parameters that required change on each of the farms. Compliance was evaluated on the 62 intervention farms after an average of 39 days which was the time farmers were given to implement the recommended changes.

A total of 324 cow comfort changes were recommended to the 62 farms, with 79% of the changes being major while the rest (21%) were minor, and 63% (204/324) of the recommended changes were implemented. Of all the changes recommended (324), the largest percentage was related to changes to the lunge space (16.4%) and to neck rail availability and /or positioning (16.1%) while the lowest proportions related to the roof, total stall length and bending and/or removal of sharps (2.2%) and surface water drainage (1.9%) as indicated in Table 4-2. Lunge space, neck rail and brisket board improvements were recommended in 53, 52 and 48 farms, respectively with 85%, 89% and 92% of these changes being major (Table 4-2). About 70% of the farmers implemented changes related to lunge space, neck rail and brisket board (Table 4-3). Softening and flattening of the lying surface was recommended in 45 and 33 of the 62 farms, respectively and compliance was 71% and 73%, respectively (Table 4-3). Major and minor changes to roofs were recommended on 3 and 4 farms respectively, and total compliance for the major roof changes was observed in 2 farms while no farmers complied with the minor changes partially or fully.

Table 4-2: Major and minor changes recommended to 62 smallholder dairy farmers in Meru, Kenya, in 2017.

Factor	**# of changes**	**% of all changes (n=324)**	**# of minor changes**	**# of major changes**
Roof	7	2.2	4	3
Surface water	6	1.9	3	3
Floor soft	45	13.9	14	31
Floor flat	33	10.2	6	27
Total width	29	9.0	4	25
Total length	7	2.2	0	7
Leg space	22	6.8	8	14
Lunge space	53	16.4	8	51
Neck rail	52	16.1	6	46
Brisket board	48	14.8	4	44
Alley clean	15	4.6	5	10
Sharps fix	7	2.2	6	1
Total	**324**	**100**	**68**	**256**

Table 4-3: Number of farms given recommendations for each of the 12 possible comfort parameters and the number (and percentage) that implemented the changes in Meru, Kenya, in 2017.

Comfort parameter	**Number of farms given recommendations**	**Number of farms that implemented the changes**	**Percentage compliance (%)**
Roof	7	2	28.6
Surface water	6	1	16.7
Floor softness	45	32	71.1
Floor flatness	33	24	72.7
Stall width	29	16	55.2
Stall length	7	1	14.3
Leg space	22	16	72.7
Lunge space	53	37	69.8
Neck rail	52	38	73.1
Brisket board	48	27	56.3
Alley condition	15	6	40.0
Sharps fix	7	4	57.1

The overall proportion of the 62 intervention group farmers that implemented at least one of the recommended changes was 74% (46/62). Recipients of cow comfort recommendations were women in 50% (31/62) of the farms, men in 42% (26/62) of the farms and farm hands in 8% (2/62) of the farms. Most or all changes (>50%) were made on 64% of the farms, some changes (<50%) were made on 10% (6/62) of the farms, while no changes were made on 26% (16/62) of the farms. On 26 farms, 100% of the recommended changes were implemented partially or fully, with a mean of 4 changes and a range of 1 to 8 changes for these completely compliant farms.

Nearly half (47%) of the 46 farms that implemented changes started within 24 hours of the recommendations being made, while 18% and 6% of the farms started implementation within the first week and later than the first week post-recommendation, respectively. Sixty-three percent (29/46) of the farmers completed the implementation of changes within 24 hours (regardless of the day they started making the changes), while 32% (15/46) took a few days, and 4% (2/46) took one week or more to complete the changes. Of the 46 farmers that implemented at least one recommended change, 15% (7/46) felt that they had made the changes fairly well, 72% (33/46) felt that they had made the changes well, while 13% (6/46), felt that they had made the changes very well.

At the end of the trial, we received feedback from the 62 farmers in the intervention group. Five farmers (11%) reported that some recommendations, such as total length and brisket board improvements, were hard to implement (Table 4-4). Only (33%) of the 46 compliant farmers incurred costs of implementing changes, and an average cost of Ksh. 344±222 was estimated among the 15 farmers.

For the 46 farmers who implemented changes, 96% (44/46) felt well-versed in cow comfort post-intervention (Table 4-4). However, 57% (26/46) did not advise other farmers about stall changes they could make on their farms. Of these 26 non-advising farmers, 42% (11/26) had no valid reason for not doing so, while 58% had reasons that included: lack of nails, poor stall stability and plans to rebuild stalls. Challenges were observed on 8 farms after improvements were made to cow comfort including: fighting of cows for stalls, in-ability to lie down in the stall (when changes were not done properly), and preference for lying down on the alley.

Table 4-4: Descriptive statistics of feedback regarding the stall recommendations among 46 smallholder farmers that made at least one cow comfort change in response to recommendations in Kenya in 2017

Factor	**Yes Number (%)**	**95% CI of Yes Percent**	**N**
Hard recommendations	5 (11%)	(3.6, 23.6)	46
Cost incurred	15 (33%)	(19.5, 48.1)	46
Well versed with cow comfort	44 (96%)	(85.2, 99.5)	46
Advised others on cow comfort	20 (44%)	(28.9, 58.9)	46
Reason for not advising	15 (58%)	(36.9, 76.6)	26
Challenges after changes	8 (17%)	(7.8, 31.4)	46

4.4.2 Risk factor analysis for farmers' compliance

As a binary outcome (no=0, yes=1), unconditional associations using mixed univariable logistic regression models with farm as a random effect identified the following factors associated with the farmers' compliance to implement changes ($p<0.25$) which were eligible for multivariable modeling: type of recommendation given (minor or major); recipient of the recommendations (woman, man or farm hand); type of combined comfort parameter identified for change (1- 4); and whether the recommendations were hard or not (yes or no).

A mixed multivariable logistic regression model of the 62 intervention farms, with farm as a random effect, determined that type of recommendations, recipient of the recommendations and the type of combined comfort parameter identified for change (1-4) were factors ($p<0.05$) associated with compliance to implement changes (Table 4-5). Higher odds of compliance were observed when major recommendations were given relative to minor recommendations (OR=6.3, p=0.004). On the farms where farm hands received the written and oral recommendations, the odds of compliance were much lower at 0.01 times the odds when the wife received the recommendations, with no significant difference in odds between the wife and husband receiving the recommendations. Combined comfort parameters related to the lying surface (FS and FF) had 3.1 times higher odds of being implemented compared to combined comfort parameters related to stall design (NR, BB, LeS and LuS).The odds of implementation of roof, alley, drainage of surface water, and sharps fix changes were lower relative to changes related to stall design (OR=0.13, p=0.004). Combined comfort parameters related to stall size were not significantly different from stall design. For this final compliance model, given that a recommended change for a given comfort parameter was made in a given farm, the probability of another recommended change being implemented on the same farm was 84.4% (ICC=0.844).

The final model had 324 observations for 62 farms and no missing data. A likelihood ratio test indicated that the mixed model was superior to a logistic regression model (χ^2=133.33, p=<0.0005) and the Wald test confirmed the significance of the model (Wald χ^2=23.58, p=0.0006).

Since only 46 of the 62 intervention farms actually made any recommended changes, factors of compliance on those farms could be different from factors for all intervention farms. Therefore, to assess factors associated with compliance in the intervention farms that attempted to implement at least one recommendation (n=46 farms), a second multivariable logistic regression model was used and identified the following significant variables (Table 4-5): type of recommendation given, recipient of the recommendations, if there were recommendations deemed hard to implement by the farmers, and the type of combined comfort parameter identified for change (1-4). For this model, the odds of compliance were only 4.0 times higher if the recommendation given was major relative to minor. The odds of compliance were lower on farms where a man or a farm hand received the oral and written recommendations in comparison to farms where a woman received the recommendations. If farmers had at least one recommendation that they considered was hard for them to implement, the odds of compliance in these farms was significantly lower (OR=0.32, p=0.021), compared to farms where no recommendations were considered hard. There were only minor differences in the combined comfort parameter variable between this model and the model for 62 farms.

The final model had 238 observations for 46 farms and no missing data. The final logistic model was superior to a mixed model (χ^2=0.28, p=0.299) and the farm effects were not significant at the 5% significance level. The final model was significant (χ^2=44.54, p=<0.0001) and explained 22.02% of the variation seen in the observed compliance to implement recommended changes. The model fit the data (Goodness-of-fit test: χ^2=25.42, p=0.439).

Table 4-5: Multivariable logistic regression models of factors associated with farmers' compliance to implement cow comfort changes recommended in smallholder dairy farms in Kenya in 2017.

Factor	**Category**	**Odds Ratio**	**[95 CI]**	**P-value**
n=62 intervention farms				
Type of recommendations	Minor	Reference		
	Major	6.28	1.779,22.141	0.004
Recipient of	Wife	Reference		0.046*
recommendations	Husband	1.78	0.235,13.445	0.578
	Farm hand	0.01	0.001,0.340	0.023
Combined comfort	Stall design	Reference		0.002*
parameters recommended for	Stall size	0.46	0.117,1.797	0.263
change	Floor	3.14	1.015,9.697	0.047
	characteristics	0.13	0.033,0.312	0.004
	Others			
n= 46 intervention farms that implemented at least one of the recommended changes				
Type of recommendations	Minor	Reference		
	Major	3.98	1.637, 9.652	0.002
Any hard recommendations	None	Reference		
	At least one	0.32	0.123,0.843	0.021
Recipient of	Wife	Reference		0.023*
recommendations	Husband	0.39	0.161,0.945	0.037
	Farm hand	0.12	0.022,0.679	0.016
Combined comfort	Stall design	Reference		0.003*
parameters recommended for	Stall size	0.51	0.140,1.821	0.297
change	Floor	4.20	1.098,16.059	0.036
	characteristics	0.26	0.087,0.770	0.015
	Others			

P-value*: Global p-value

4.4.3 Differences between intervention groups, irrespective of compliance

The median lying times were not significantly different between the intervention and control groups pre- and post-intervention (Table 4-6). However, numerically, both groups improved between the pre- and post-intervention measurements. Furthermore, the intervention group was a mixture of farms that complied with the recommendations and farms that did not comply with the recommendations, biasing the results of this comparison. Therefore, in the second part of Table 4-6, we have comparisons between the 71 cows on the 46 farms that complied with at least one of the recommendations versus the 35 cows in the 27 remaining farms which was a combination of the 12 control farms and 16 intervention farms where farmers made no effort to comply to the recommendations. From these altered group results, the median lying times were not significantly different within and between the intervention and control groups, pre-and post-intervention (Table 4-6). In the intervention and complied group, the median lying time per cow per day increased from 11.0 hours to 11.3 hours over the assessment period. However, the median lying time per cow per day was also 11.3 hours in the control and non-compliant group post-intervention.

Regarding stall cleanliness, in the 62 intervention farms the median stall cleanliness score was significantly lower post-intervention then pre-intervention (p=0.0001) but remained similar on initial 11 control farms (p=0.122). The median udder and leg cleanliness scores also decreased significantly in the intervention group cows post-intervention but remained similar in control farms (Table 4-6). From these altered group results, stall, udder and upper hind leg cleanliness scores were again significantly improved pre- to post-intervention among the intervention and compliant group. However, among the control and non-compliant group, stall cleanliness scores were also significantly improved from pre- to post-intervention, while the udder and leg cleanliness scores remained similar over the time.

In the 62 intervention farms, the proportion of stalls that were categorized as dirty (>2.5) pre-intervention was 35% (31/88), which declined significantly (p=0.0002) to 11%

(10/88) post-intervention. In the control farms, the stalls categorized as dirty remained relatively similar pre-intervention (5/15; 33%) and post-intervention (4/15; 27%). The proportion of cows with udders categorized as dirty was 13% in both intervention (12/90) and the control (2/16) groups, pre-intervention. Post-intervention, the proportion was slightly lower numerically in both groups (intervention=12% and control=6%) but statistically similar (p>0.05). In the intervention farms, 50% of the cows (45/90) had their upper hind legs categorized as dirty (>2.5), while 31% of the 16 cows on control farms had upper hind legs categorized as dirty pre-intervention. Post-intervention, the proportion of cows with upper hind legs categorized as dirty was similar in both groups (intervention=38% and control=37%).

The observed differences described in Table 4-6 provide a useful descriptive summary of the outcome variables of interest, with and without compliance adjustments. However, because the post-intervention assessments were on the same cows as the pre-intervention assessments, multivariable mixed modeling was conducted to determine whether the observed differences in outcomes remained statistically significant when adjusting for the clustering of pre- and post-intervention assessments within the cows. First, we present results for models without adjustment for compliance, but with adjustment for clustering of pre- and post-intervention assessments within cows.

To evaluate the effects of giving cow comfort recommendations to farmers, irrespective of the degree of compliance, on the **daily lying time** of cows, a multivariable mixed linear regression model was used while considering the interactions between visits (pre-and post-intervention) and the study groups (intervention and control). Random farm effects were not significant but retained in the model to distribute farms randomly when making predictions and generating interaction plots. The model indicated that there was no interaction between the groups and the visits as illustrated on Figure 4-1.

To evaluate the effects of giving cow comfort recommendations to farmers, irrespective of the degree of compliance, on the **stall** cleanliness, a multivariable mixed logistic regression model with significant random farm effects (σh=2.849, p=0.0002) was used while considering the interactions between visits (pre- and post-intervention) and the study groups (intervention and control). The model indicated that an interaction effect between groups and visits was not significant (p=0.180), but the interaction plot illustrated an improvement in stall cleanliness in the treatment group post-intervention in comparison to the control group (Figure 4-2).

To evaluate the effects of giving cow comfort recommendations to farmers irrespective of the degree of compliance on the **cow** cleanliness, two multivariable mixed logistic regression models on udder cleanliness and upper leg cleanliness were used while considering the interactions between visits (pre- and post-intervention) and the study groups (intervention and control). The udder cleanliness model with non-significant random effects (σ_h=0.269, p=0.337), found that groups, visits and their interaction effects were not significant (p>0.05). The upper leg cleanliness model with significant random farm effects (σ_h=1.528, p=0.0006) indicated that effect of groups, visits and the interaction effects between groups and visits were not significant (p>0.05).

4.4.4 Differences between intervention groups, considering compliance

Table 4-7 provides results of the changes in daily lying time in the intervention group (n= 90 cows on 62 farms) pre- and post-intervention, by comfort parameter, from the multivariable mixed linear regression models with farm random effects, and with interaction adjustments for compliance and clustering of pre-and post-intervention assessments within cows. The models for each recommended comfort parameter change found that 7 of the 12 interactions were eligible for further analysis, including: drainage of surface water, floor flatness, stall width, stall length, lunge space, alley condition and sharps fixing. Out of the 7 eligible comfort parameters, only alley condition had a significant interaction ($p<0.05$), and this model also approached statistical significance ($p=0.069$). When the alley condition was good on the pre-intervention assessment, and therefore no change was recommended, the lying time remained unchanged. However, lying time increased for the farms where the alley condition was poor regardless of whether farmers complied with recommended changes (Figure 4-3).

Similar multivariable mixed linear regression models with farm random effects and adjustment for compliance and clustering of pre- and post-intervention assessments were determined for changes in stall and cow cleanliness in the intervention group (n=90 cows on 62 farms) pre and post-intervention. Only one comfort parameter had an interaction that was potentially significant ($p=0.188$), and only for stall cleanliness. The stall cleanliness improved on farms that did not have a neck rail, were recommended to have one, and the farmer placed a neck rail. However, on farms that had a poorly positioned neck rail, and recommendations were given to better position it but were not implemented, stall cleanliness had only a modest improvement (Figure 4-4).

Farms that made at least one of the recommended changes (46/62) were suspected to produce different results for these modeling efforts than if all 62 intervention farms were included. Therefore, for these 71 cows in 46 farms, similar multivariable mixed linear regression models with farm random effects and adjustment for compliance and clustering of pre- and post-intervention assessments were determined for changes in lying time, stall and cow cleanliness pre- and post-intervention. Only one comfort parameter had an interaction that was potentially significant ($p=0.39$), an only for lunge space. Failure to implement the proposed changes on forward and/or side lunge space in the stalls (category 2 of our combined variable) led to a decline in the log of lying time of the cows from pre- to post-intervention assessments, relative to the other two interaction categories (Figure 4-5).

Table 4-6: Description (median; (range)) of various outcomes and the significance of their differences within and between groups, pre- and post-intervention, using the Kruskal-Willis test in 73 smallholder farms in Kenya, 2017.

	Intervention (n=90 cows on 62 farms)			**Control (n=16 cows on 11 farms)**			**Differences between intervention and control groups (P-values)**	
Outcome	**Pre-intervention**	**Post-intervention**	**P-value**	**Pre-intervention**	**Post-intervention**	**P-value**	**Pre-intervention**	**Post-intervention**
Lying time (hrs)	10.85 (2.89-19.02)	11.45 (6.28-19.82)	0.068	10.38 (5.75-14.96)	10.61 (6.67-19.82)	0.386	0.177	0.215
Stall cleanliness score (1-5)	2 (1-5)	2 (1-5)	0.0001	2 (1.5-5)	1.5 (1-4)	0.122	0.616	0.794
Udder cleanliness score (1-5)	2 (1-4)	2 (1-3)	0.019	2 (1-3)	1 (1-3)	0.079	0.538	0.181
Leg cleanliness score (1-5)	2.75 (1-5)	2 (1-4)	0.029	2 (1-4)	2 (1-4)	0.546	0.047	0.743
	Intervention and complied (n=71 cows on 46 farms)			**Control and non-compliant (n=35 cows on 27 farms)**			**Differences between intervention and control groups (P-values)**	
Outcome	**Pre-intervention**	**Post-intervention**	**P-value**	**Pre-intervention**	**Post-intervention**	**P-value**	**Pre-intervention**	**Post-intervention**
Lying time (hrs)	10.98 (2.89-19.02)	11.29 (6.28-16.68)	0.160	10.46 (5.75-17.24)	11.31 (6.67-19.82)	0.171	0.208	0.545
Stall cleanliness score (1-5)	2 (1-5)	2 (1-5)	0.0001	2 (1.5-5)	1.5 (1-4)	0.001	0.554	0.974
Udder cleanliness score (1-5)	2 (1-4)	2 (1-3)	0.028	2 (1-3)	1.5 (1-3)	0.068	0.215	0.245
Leg cleanliness score (1-5)	3 (1-5)	2 (1-4)	0.032	2 (1-5)	2 (1-4)	0.880	0.044	0.672

Table 4-7: Multivariable mixed linear regression models for effects of implementing each of 12 cow comfort parameters on log of lying time for the intervention group of 90 cows on 62 smallholder dairy farms in Meru, Kenya in 2017, adjusting for clustering of pre- and post-intervention assessments within cows, whether stall changes were needed, and whether the changes were done.

Treatments	**Assessment time**[c]			**Combined variable of change needed and implemented**[d]			**Interactions between assessment time and combined variable**			**Farm effects**	**Model significance**
Parameter	**Category**	**Coefficient**	**P-value**	**Category**	**Coefficient**	**P-value**	**Category**	**Coefficient**	**P-value**	**Variance σ_h (P-value)**	**P-value**
Roof adequacy				0	Reference	0.405[a]	0 0	Reference	0.590[b]		
	0	Reference		1	-0.099	0.445	1 1	0.172	0.337	0.001	0.758
	1	0.003	0.936	2	-0.096	0.252	1 2	0.049	0.674	(0.406)	
Drainage of				0	Reference	0.101[a]	0 0	Reference	0.100[b]		
surface water	0	Reference		1	-0.021	0.907	1 1	0.282	0.250	0.002	0.210
	1	-0.009	0.774	2	-0.176	0.302	1 2	0.210	0.063	(0.346)	
Floor softness				0	Reference	0.640[a]	0 0	Reference	0.581[b]		
	0	Reference		1	0.051	0.346	1 1	-0.036	0.626	0.001	0.764
	1	0.021	0.729	2	0.029	0.655	1 2	0.048	0.602	(0.404)	
Floor flatness				0	Reference	0.680[a]	0 0	Reference	0.244[b]		
	0	Reference		1	0.024	0.621	1 1	0.022	0.745	0.001	0.493
	1	-0.019	0.677	2	-0.032	0.643	1 2	0.156	0.096	(0.365)	
Stall width				0	Reference	0.264[a]	0 0	Reference	0.228[b]		
	0	Reference		1	0.027	0.621	1 1	-0.002	0.976	0.002	0.579
	1	-0.015	0.731	2	-0.078	0.183	1 2	0.131	0.103	(0.345)	
Stall length				0	Reference	0.852[a]	0 0	Reference	0.108[b]		
	0	Reference		1	0.093	0.599	1 1	-0.114	0.642	0.001	0.187
	1	-0.007	0.841	2	-0.014	0.848	1 2	0.213	0.042	(0.361)	
Side leg space				0	Reference	0.658[a]	0 0	Reference	0.756[b]		
availability and	0	Reference		1	0.003	0.995	1 1	0.007	0.929	0.000	0.437

adequacy	1	0.003	0.948	2	0.070	0.369	1 2	0.082	0.456	(0.483)	
Lunge space				0	Reference	0.426[a]	0 0	Reference	0.156[b]		
availability and	0	Reference		1	0.071	0.289	1 1	-0.129	0.156	0.002	0.561
adequacy	1	0.140	0.087	2	0.096	0.196	1 2	-0.196	0.054	(0.313)	
Neck rail				0	Reference	0.849[a]	0 0	Reference	0.992[b]		
placement	0	Reference		1	-0.021	0.748	1 1	0.004	0.965	0.001	0.700
	1	0.007	0.930	2	-0.042	0.572	1 2	0.012	0.906	(0.408)	
Brisket board				0	Reference	0.571[a]	0 0	Reference	0.982[b]		
placement	0	Reference		1	-0.032	0.592	1 1	0.012	0.883	0.005	0.777
	1	0.007	0.920	2	-0.065	0.295	1 2	0.003	0.997	(0.453)	
Alley condition				0	Reference	0.091[a]	0 0	Reference	0.007[b]		
	0	Reference		1	-0.091	0.232	1 1	0.210	0.038	0.004	0.069
	1	-0.041	0.235	2	0.126	0.048	1 2	0.223	0.009	(0.203)	
Sharps fix				0	Reference	0.199[a]	0 0	Reference	0.222[b]		
	0	Reference		1	-0.085	0.353	1 1	0.206	0.106	0.001	0.350
	1	-0.006	0.852	2	-0.167	0.111	1 2	0.106	0.469	(0.383)	

[a]: global p-value for the combined variable

[b]: global p-value for the interaction variable

[c]: 0=pre-intervention; 1=post-intervention

[d]: 0=good so no change needee;1=poor, change recommended, and change done;2=poor, change recommended, and change not done

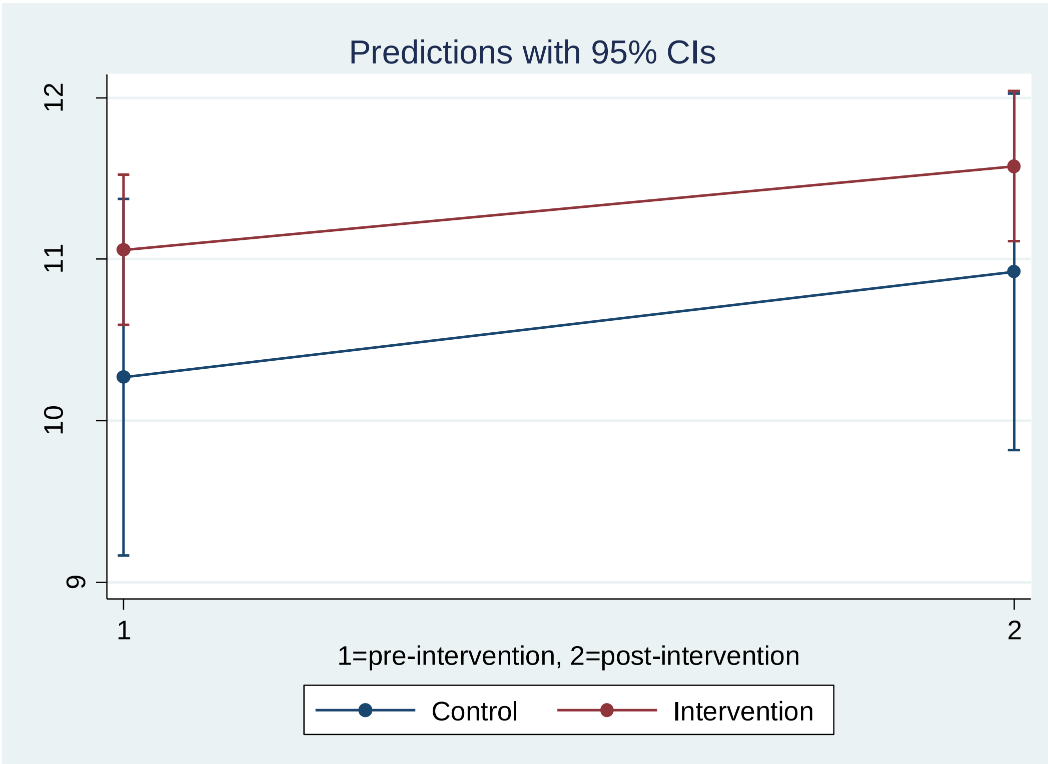


Figure 4-1: Lack of an interaction effect between groups and visits on lying time of 106 cows on 73 smallholder dairy farms in Meru, Kenya in 2017

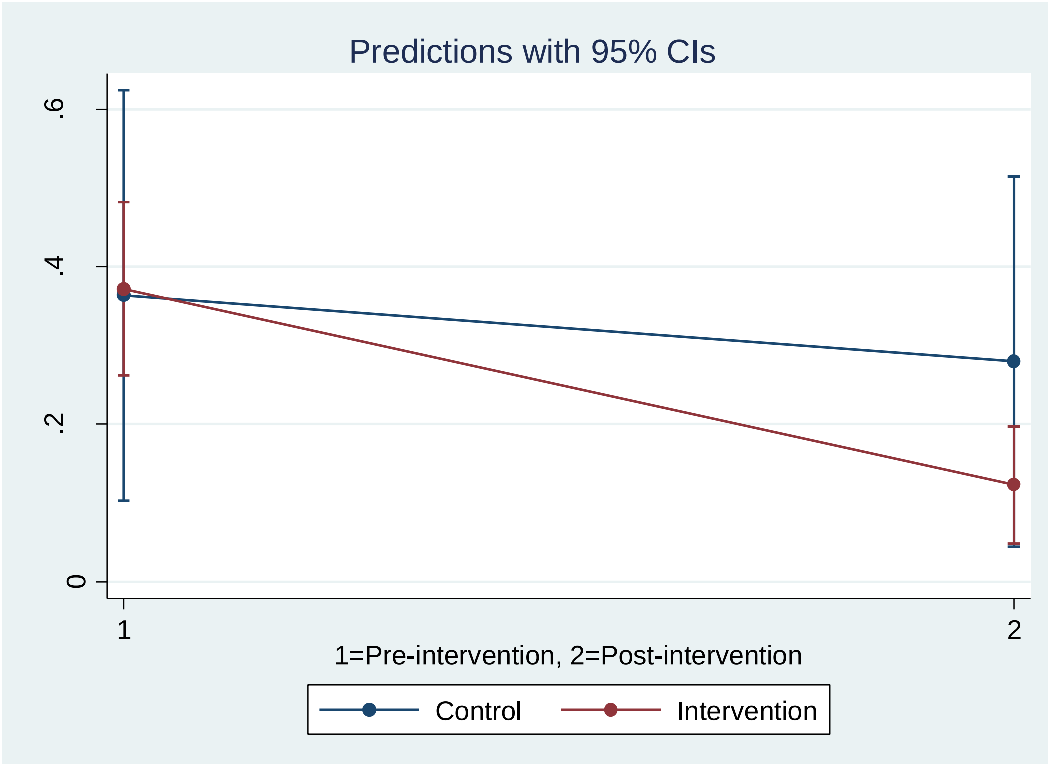


Figure 4-2: Interaction effect between groups and visits on stall cleanliness in 103 cows on 70 smallholder dairy farms in Meru, Kenya in 2017.

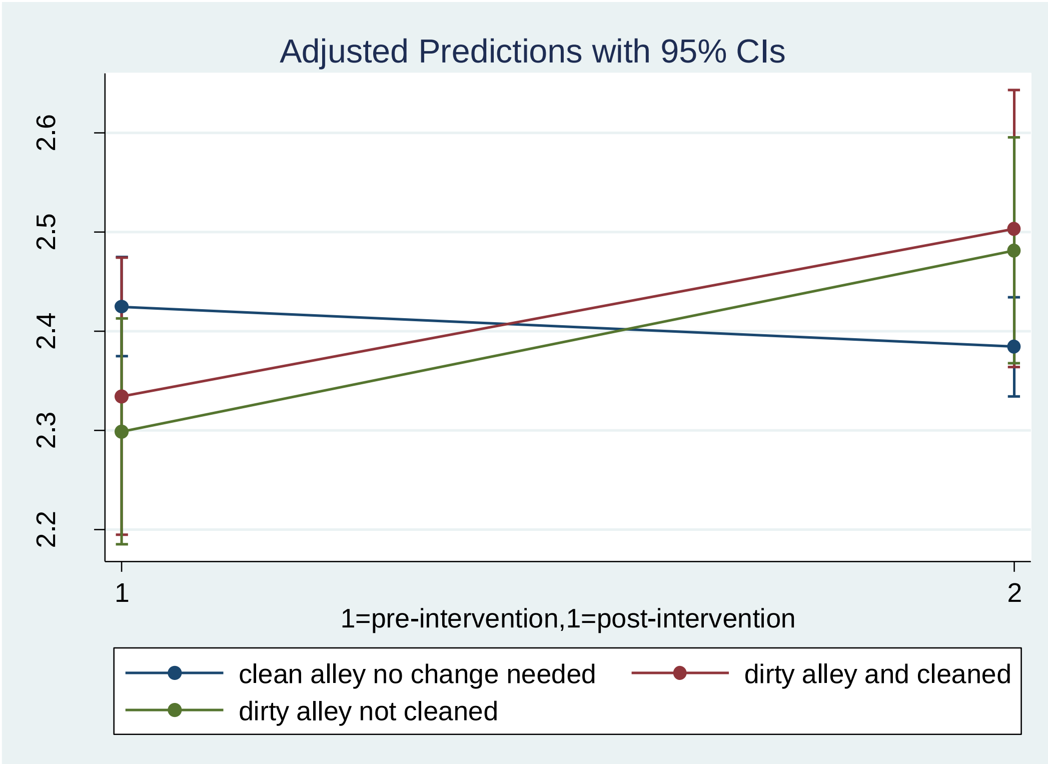


Figure 4-3: **Interaction effect between implementing alley condition changes proposed and visits on log of lying time of 90 cows in 62 smallholder dairy farms in Meru, Kenya in 2017.**

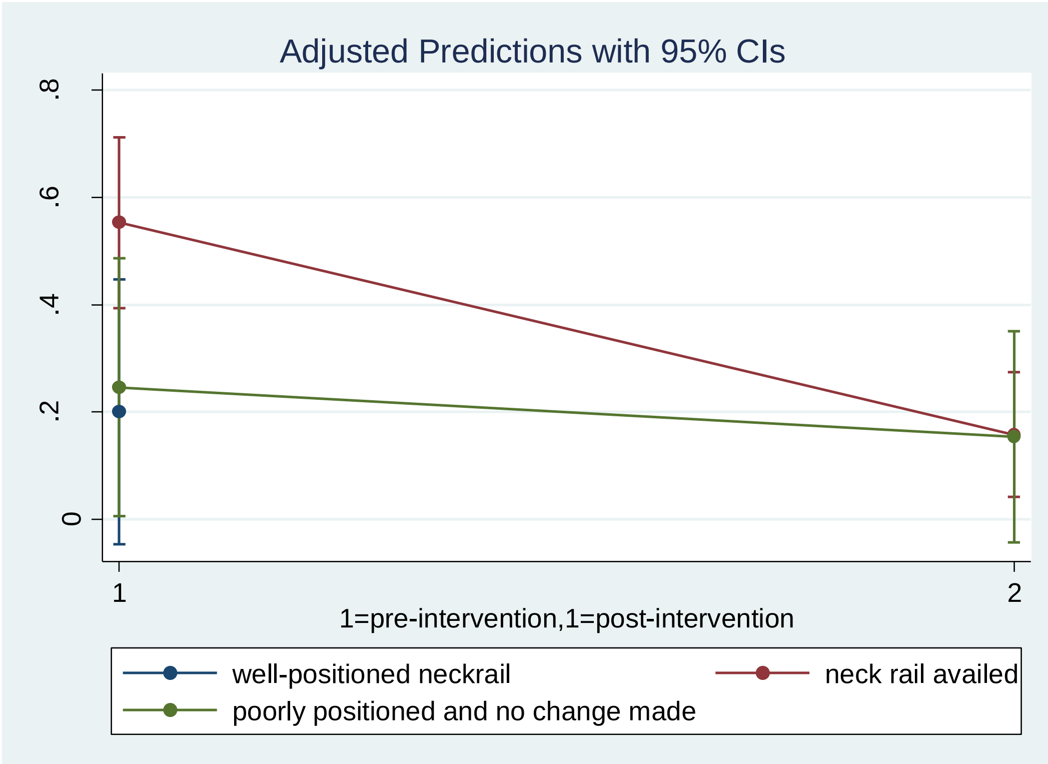


Figure 4-4: Interaction effect between implementing neck rail changes proposed and visits on stall cleanliness of 90 cows in 62 smallholder dairy farms in Meru, Kenya in 2017.

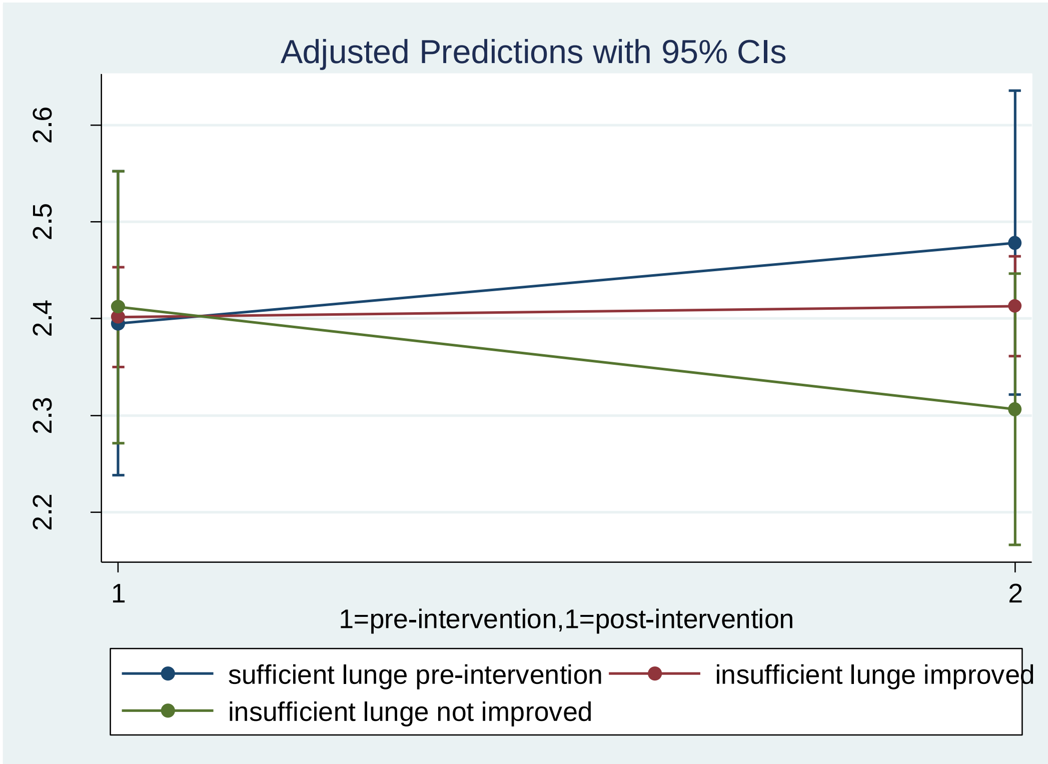


Figure 4-5: Interaction plot of improving proposed changes on stall forward and /or side lunge space on log of lying time in 71 cows on 46 smallholder dairy farms in Meru, Kenya in 2017.

4.5 Discussion

This is the first study to assess farmers' compliance to implementing recommended cow comfort changes in smallholder dairy farms in Kenya. The preference to give recommendations over making the changes for the farmers is to ensure sustainability of the project, where farmers can be relied upon to make the required changes and advice others even after the project is completed, thereby improving cow comfort and welfare in SDFs and subsequently cow productivity and health.

The overall proportion of farmers that implemented at least one of the recommended changes (74%) was higher than that reported in Australian dairy herds (57%) (Tremetsberger, Leeb and Winckler, 2015). The relatively good acceptance of recommended changes and the implementation may be attributed to the integration of farmers in the formulation of improvement measures, which enables the farmers to feel that their opinions are respected in the process, and therefore, they are more likely to accept the changes and implement the changes. In addition, the recommendations given could be implemented using readily accessible and available resources, such as recommended use of: timber from their farms to improve on stall design; dirt to improve on floor characteristics; and crop-waste as bedding. The use of the native language of Kimeru to give the recommendations and giving both oral and written changes to the farmers may also have contributed to better response, acceptance and willingness to implement the changes. The findings indicated that only 15 of the 46 farms that implemented at least one of the recommended changes incurred costs that ranged from Ksh.122 to 566. This amount is manageable when considering the estimated monthly income of a smallholder household in Kenya (Ksh.15,842) as reported by the Food and Agricultural Organization in 2016 (Global Forum On Agricultural Research, 2016).

Whether the farmers made the required changes or not was influenced by the type of recommendation given. We would expect that farmers were more likely to implement minor changes relative to major changes, but in this study, farmers complied to implement major changes more in comparison to minor changes (OR=6.28, p=0.004). This could be due to direct proportionality assumption that a major change on cow comfort parameters would lead to a bigger change in cow productivity and vice versa irrespective of being blinded on whether the change recommended to them was minor or major.

Out of the 12 comfort parameters assessed, changes to improve: floor softness and flatness; leg space, lunge space and neck rail availability and positioning were implemented more relative to the changes to roof, stall length and drainage of surface water (Table 4-3 and 4-5). Considering that dirt floored stalls are common in smallholder dairy farms in Kenya (Chapter 3) and most dairy farmers also produce crops (Mugambi et al., 2015), dirt is readily available and accessible thus can be added to the dirt floors to flatten and soften the surfaces regularly in addition to use of bedding to further soften the lying surface. Implementation of recommended roof and stall length changes could have been limited by the land area available to extend the stalls to create enough stall length due to the small sizes of the farms (0.47 hectares) available to smallholder dairy farmers in Kenya (Global Forum On Agricultural Research, 2016), while replacing roofs or covering the holes to prevent water getting into the stall may have been expensive to the farmers thus reducing their compliance. Recommended changes to create or increase leg space and lunge space involved repositioning of side rails that were already in the stall which meant that farmers incurred no cost at all to make the changes. With the increased forest plantations in rural Kenya, timber is easily accessible and commonly used as a building material for stalls and other structures (Rudel, 2009) which would explain the higher likelihood of implementing neck rail changes compared to the roof changes. In addition, few recommendations were given to improve roof adequacy, drainage of surface water, alley condition and sharps fix (Table 4-3) and which could explain why their compliance was also low.

The complete non-compliance in 26% (16/62) of the intervention farms may have resulted in significant farm effects on the model with all the farms and the compliance to at least one given recommendation may have removed the variability caused by the farms leaving only variability due to the other predictors when compliance was evaluated on only the farms (46) that complied.

Interestingly, compliance was lower in farms that implemented at least one of the recommended changes when husbands or farm hands received the recommendations relative to the wives (Table 4-5). This could possibly be due to the more active role of women in smallholder dairy farms especially on labour input in comparison to their male counterparts. Similarly, an earlier study in Kenyan smallholder dairy farms reported that women carried out 70% of all the activities in the farm (Nyongesa et al., 2016). As expected, having recommendations that farmers deemed hard to implement reduced the level of compliance for the specific comfort parameters.

The mean daily lying time for the 90 cows on the intervention farms, pre- and post-intervention, were 11.1 and 11.6 hours respectively. Our findings contrast those made by Richards. (2017) who reported a mean daily lying time of 9.0, 10.2 and 10.2 hours on visits one to three for cows kept in smallholder dairy farms in Mukurweini, in Kenya. Moreover, the relatively similar lying times pre- and post-intervention in the intervention group contrasted findings by Richards (2017) who reported a significant increase in lying time in the intervention group ($p<0.001$). The difference in the studies may be attributed to the study design and type of intervention, where the duration of the earlier study was longer (2 years) and the cow comfort changes identified were implemented by the investigator whereas in the present study, the duration of the study was shorter (4 months) and the changes identified were recommended for farmers to implement. In addition, the mean and median lying time pre-intervention was on the margin of the recommended lying times of cows, which could mean that regardless of the time allowed, we could not expect to find a substantial increase in lying time whether or not the farmers complied with the recommendations given.

After the recommendations were made and implemented, the number of lying bouts per cow per day in the intervention group in the present study (8.7-65.7) was higher than that reported in smallholder dairy cows in Mukurweini (3.3-13.8); while the duration of each bout was shorter in the present study (10.5-105.5 minutes) compared to that observed in Mukurweini smallholder dairy farms (46-179 minutes) (Richards, 2017). The number of lying bouts in the present study had a very skewed distribution with some cows having very high numbers that may be attributed to interruptions in their sleeping patterns by factors not related to cow comfort including; feeding practices such as feeding intervals per day, combination of stall feeding and grazing of the cows away from the household as observed on some farms. The skewed distribution of lying bouts lead to subsequent skewing of the duration of bout length because number of lying bouts is used to generate the bout length using the total time.

Improvement of stall design and stall management practices has been found to improve stall cleanliness and cow cleanliness in earlier studies (Tremetsberger, Leeb and Winckler, 2015; Bouffard et al., 2017; Richards, 2017) and in the present study (Table 4-6; Figure 4-2 and 4-4). Whether the farmers implemented the changes given partially or fully, stall design changes such as neck rail placement and positioning improved stall cleanliness (Figure 4-4). The similarity between the udder cleanliness in the treatment group cows pre- and post-intervention could be attributed to the relatively low udder scores (clean) before any recommendations were given (Table 4-6) which did not leave a lot of leeway for improvement.

Even though we would expect lying time to improve in the treatment group in comparison to the control group, other factors like the short time available for the changes to occur and the time taken by the cows to acclimate to any new changes made especially in regard to stall design may have led to slower improvement in lying patterns of the cows (Figure 4-1). The relative similarity in lying time between the intervention group farmers that implemented the changes and those that did not implement all or some changes, could be explained by the similarity between lying time pre-and post-intervention observed in the intervention group, and the farm-specific changes giving which meant that different farmers were given different changes and some comfort parameters were recommended in more farms than others and the degree of compliance differed per comfort parameter and farm which increased the parameters to be considered on a relatively small sample size (n=62) thus less significant relationships observed. As described on chapter 3 of this thesis, the daily lying time was associated with some stall design and management practices before any changes were recommended to the farmers which gives a baseline on what we sought to improve on the farms to achieve better cow comfort.

The trend of declining daily lying time in the intervention farms that did not implement recommended changes on forward and/or side lunge space (Figure 4-5) is in agreement with the biological applicability of lunge space, where cows find it difficult to stand up without adequate lunge space which hinders their lying patterns in addition to earlier findings on need for adequate lunge space in cow stalls (Ceballos, 2003).

Long term effects of improving cow comfort such as increased milk production were not observed in the intervention farms due to the short duration that the farmers were given to implement the recommendations (39 ± 7) and the shorter period between finishing implementing changes and the third visit to assess the milk yield. This is not to say that implementing recommended changes did not improve cow comfort and welfare because irrespective of the allotted time, outcomes such as stall, udder and upper leg hygiene improved post-intervention.

In regard to limitations of our study, in addition to those mentioned on chapter 3 of this thesis, the loss of 27% of the farms during the study, decreased the initial the sample size of 100 farms and may have resulted in fewer significant relationships. The short study period of about 5 months led to a very short period of interest where the effects of compliance to the recommended changes could be observed. In addition, the study period was further reduced due to the national elections that occurred in the final month of the study which inclined the investigators to finish the study a few weeks earlier than earlier planned. The measure of productivity on the farms (daily milk yield) changes long term and is affected by other influential factors such as feeding practices and lack of those data limited further analysis to determine how cow comfort truly impacted milk production. Small holder dairy farmers in the study area are a closely knit community and knowledge is shared widely; this may have led to the un avoidable knowledge transfer of recommendations given to the control farms which may have led to the improvements observed on the control farms.

4.6 Conclusions and Recommendations

Overall, giving smallholder dairy farmers recommendations to improve cow comfort improved the stall cleanliness and upper leg cleanliness of cows in the farms but not the daily lying time. The study suggests that the smallholder dairy farmers' compliance with implementing cow comfort changes recommended was above average (74%). The compliance was higher when major changes were recommended rather than minor changes. Importantly, women had a higher compliance to implement recommended cow comfort changes than men and farm-hands. Some cow comfort features like neck rail, brisket board, lunge space and leg space were more likely to be implemented in comparison to others e.g., roof, stall length and sharps fix. In the short term, outcomes such as stall, udder and upper leg hygiene scores improved when recommended cow comfort changes were implemented. Placement of a neck rail on the stalls regardless of the positioning improved stall cleanliness scores (lower scores) in the treatment group. In farms that implemented at least one of the recommended changes, making proposed changes to stall lunge space increased lying time of cows. Giving farm-specific cow comfort recommendations to smallholder dairy farmers in Kenya and providing them with a participatory role in the formulation and implementation of improvement measures resulted in good acceptance and high degree of implementation and subsequently improvement of welfare of the cows.

In future, a longitudinal study on the long term effects of implementing recommended cow comfort changes on dairy farms in Kenya including but not limited to: lying patterns, milk production and mastitis prevention; and the economic profitability and sustainability of giving recommendations to the farmers instead of making the changes for them.

4.7 Acknowledgements

We are grateful to the primary funding program for this research, the Canadian Queen Elizabeth II Diamond Jubilee Scholarships (QES) which are managed through a unique partnership of Universities Canada, the Rideau Hall Foundation (RHF), Community

Foundations of Canada (CFC) and Canadian universities. This program is made possible with financial support from the Government of Canada, provincial governments and the private sector. We also acknowledge the large contribution made by volunteers and staff of Farmers Helping Farmers, a non-governmental organization – their existing relationships and agricultural efforts and inputs provided a strong foundation for the work and the entry point to the Naari community. We acknowledge the leadership and members of the Naari Dairy Cooperative Society in Meru for their co-operation in the study. We appreciate the help offered by Shauna Richards with the analysis of the accelerometer data, and Ren Chamberlain and Julia Kenny for their help in data collection in the field.

4.8 References

Bell, N.J., Bell, M.J., Knowles, T.G., Whay, H.R., Main, D.J. and Webster, A.J.F., 2009. The development, implementation and testing of a lameness control programme based on HACCP principles and designed for heifers on dairy farms, The Veterinary Journal, 180, 178-188

Bernardi, F., Fregonesi, J., Winckler, C., Veira, D.M., von Keyserlingk, M A G and Weary, D.M., 2009. The stall-design paradox: Neck rails increase lameness but improve udder and stall hygiene, Journal of Dairy Science, 92, 3074-3080

Bickert, W.G., 2000. Freestall Design, Natural resource, agriculture and engineering service - publications nraes, 205-213

Bouffard, V., de Passille, A.M., Rushen, J., Vasseur, E., Nash, C.G.R., Haley, D.B. and Pellerin, D., 2017. Research: Effect of following recommendations for tiestall configuration on neck and leg lesions, lameness, cleanliness, and lying time in dairy cows, Journal of Dairy Science, 100, 2935-2943

Ceballos, A., 2003. How cows lie down : a 3-D kinematic evaluation of the lying down behaviour of holstein dairy cows

Cook, N.B., Bennett, T.B. and Nordlund, K.V., 2005a. Monitoring indices of cow comfort in free-stall-housed dairy herds, Journal of Dairy Science, 88, 3876-3885

Cook, N.B., Bennett, T.B. and Nordlund, K.V., 2005b. Monitoring Indices of Cow Comfort in Free-Stall-Housed Dairy Herds*, Journal of Dairy Science, 88, 3876-3885

DeVries, T.J., Aarnoudse, M.G., Barkema, H.W., Leslie, K.E. and von Keyserlingk, M A G, 2012. Associations of dairy cow behavior, barn hygiene, cow hygiene, and risk of elevated somatic cell count, Journal of Dairy Science, 95, 5730-5739

Fregonesi, J.A., Veira, D.M., von Keyserlingk, M A G and Weary, D.M., 2007. Effects of Bedding Quality on Lying Behavior of Dairy Cows, Journal of Dairy Science, 90, 5468-5472

Global Forum On Agricultural Research, 2016. Improving the economic lives of smallholder farmers

Ivenleyer, S., 2008. Effects of a two-year dairy herd health management programme on udder health, use of antibiotics and longevity, Schweizer Archiv fur Tierheilkunde, 150, 499-505

Main, D.C.J., Leach, K.A., Barker, Z.E., Sedgwick, A.K., Maggs, C.M., Bell, N.J. and Whay, H.R., 2012. Evaluating an intervention to reduce lameness in dairy cattle, Journal of Dairy Science, 95, 2946-2954

McFarland, D.F., 1991. Experiences with free stall design in Pennsylvania, Paper - American Society of Agricultural Engineers, 17

Mugambi, D.K., Mwangi, M., Wambugu, S.K. and Gitunu, A.M.M., 2015. Assessment of performance of smallholder dairy farms in Kenya: an econometric approach, Journal of Applied Biosciences, 85, 7891-7899

Norring, M., Manninen, E., Saloniemi, H., de Passille, A.M., Rushen, J. and Munksgaard, L., 2008. Effects of sand and straw bedding on the lying behavior, cleanliness, and hoof and hock injuries of dairy cows, Journal of Dairy Science, 91, 570-576

Nyongesa, D., Mwirigi, M.K., Yongo, D. and Makokha, S., 2016. Gender-Concerns: Do They Matter in Smallholder Dairy Groups in Kenya?, International Journal of Agricultural Resources, Governance and Ecology, 12, 1-17

Reneau, J.K., Seykora, A.J., Heins, B.J., Endres, M.I., Farnsworth, R.J. and Bey, R.F., 2005. Association between hygiene scores and somatic cell scores in dairy cattle, Journal of the American Veterinary Medical Association, 227, 1297-1301

Richards, S.M., 2017. Productivity and welfare of cows on smallholder dairy farms in Kenya, PhD Dissertation, University of Prince Edward Island, Charlottetown

Rollin, B.E., 2004. Animal agriculture and emerging social ethics for animals, Large animal.Proceedings of the North American Veterinary Conference, Volume 18, Orlando, Florida, USA, 17-21 January 2004

Rudel, T.K., 2009. Tree farms: driving forces and regional patterns in the global expansion of forest plantations, Land Use Policy, 26, 545-550

Rushen, J., Butterworth, A. and Swanson, J.C., 2011. Animal behavior and well-being symposium: farm animal welfare assurance: science and application, Journal of animal science, 1219

Sprecher, D.J., Hostetler, D.E. and Kaneene, J.B., 1997. A Lameness Scoring System That Uses Posture and Gait to Predict Dairy Cattle Reproductive Performance, Theriogenology, 1179

Tremetsberger, L., Leeb, C. and Winckler, C., 2015. Animal health and welfare planning improves udder health and cleanliness but not leg health in Austrian dairy herds, Journal of Dairy Science, 98, 6801-6811

Tucker, C.B., Zdanowicz, G. and Weary, D.M., 2006. Brisket boards reduce freestall use, Journal of Dairy Science, 89, 2603-2607

Tucker, C.B., Weary, D.M. and Fraser, D., 2005. Influence of neck-rail placement on free-stall preference, use, and cleanliness, Journal of Dairy Science, 88, 2730-2737

Tucker, C.B., Weary, D.M. and Fraser, D., 2004. Free-Stall Dimensions: Effects on Preference and Stall Usage, Journal of Dairy Science, 87, 1208-1216

Vasseur, E., Gibbons, J., Rushen, J., Pellerin, D., Pajor, E., Lefebvre, D. and de Passille, A.M., 2015. An assessment tool to help producers improve cow comfort on their farms, Journal of Dairy Science, 98, 698-708

Whay, H.R. and Main, D.C.J., 2015. Improving animal care and welfare: practical approaches for achieving change, Improving animal welfare: a practical approach

Wildman, E.E., Jones, G.M., Wagner, P.E., Boman, R.L., Troutt, H.F., J. and Lesch, T.N., 1982. A dairy cow body condition scoring system and its relationship to selected production characteristics, Journal of Dairy Science, 65, 495-501

Chapter 5: Discussion

5.1 Introduction

This research carried in the Naari region of Meru County in Kenya, was proposed due to the limited information available on cow comfort assessment and the compliance of farmers to implement changes recommended to them to improve the welfare of cows in smallholder farms in the country. An earlier study by Richards (2017) found that lying behaviour of dairy cows in Kenya improved when cow comfort changes were made to the stalls by the investigator. However, to the best of our knowledge, there is no information on the degree of compliance of farmers to accept and implement cow comfort changes recommended to them and the effects of these recommendations and farmers' compliance on lying behaviour of cows in smallholder dairy farms in Kenya.

A total of 73 members of the Naari Dairy Co-operative in Meru with a total of 106 dairy cows in zero-grazing units on smallholder farms (≤ 4 cows per farm) participated in the study. Cows and calves in these farms were selected for at least one of the three objectives of the study using specific inclusion criteria for each objective. Based on the specified objectives, two cross-sectional studies and one randomized controlled trial were carried out on cows and calves in the 73 farms.

The hypotheses formulated to achieve the three objectives of the study were: 1) calf cleanliness (upper leg hygiene scores) can be used as one indicator of calf welfare, with individual and/ or pen-level factors affecting welfare of the calves; 2) lying time of cows in smallholder dairy farms differ with stall design and housing management practices on the farms; 3a) the acceptance and willingness to implement farm-specific cow comfort changes recommended would differ between farmers, and the effect of these changes on lying time, stall cleanliness and cow cleanliness would vary with the farmers' compliance; and 3b) dairy cows in farms that received farm-specific recommendations on cow comfort would improve lying time, stall cleanliness and cow cleanliness if farmers comply with recommendations.

To prove or disapprove these hypotheses, three studies were carried out with the following objectives: 1) to describe calf comfort and determine the individual and pen-level factors that affect comfort (in particular, calf leg cleanliness) of smallholder dairy farms in Meru, Kenya; 2) to determine the factors associated with lying time, stall and cow cleanliness in smallholder dairy farms in Meru, Kenya; 3a) to assess farmers' compliance to implement cow comfort changes recommended; and 3b) to determine the effects of complying farmers regarding recommended cow comfort changes on cow lying time, stall cleanliness and cow cleanliness.

5.2 A cross-sectional study of welfare of calves kept in dairy farms in the Meru Region of Kenya in 2017.

For this cross-sectional study, 38 smallholder dairy farms (mean ± SD: herd size=1.7 ± 0.7 milking cows; milk production=6.7 ± 3.1 liters/day) in Meru, with calves that were one year old and younger (n=52 calves) were randomly selected. Calf comfort was assessed and factors associated with leg cleanliness as a summary parameter for calf comfort were determined. Calf biodata, health status and leg hygiene were assessed, along with pen characteristics, such as floor space area, hygiene, and knee impact and knee wetness scores, while a questionnaire was administered to the farmers face-to-face in the native language of Kimeru to gather information regarding calf housing management practices in the farm.

The calves had a mean body weight of 85.2±32.8 kilograms and average daily weight gain (ADG) of 0.50±0.45 kg per day. A total of 71% of calves had a good body condition score greater than or equal to 2.5, and each calf had a space allowance of 2.52±1.56m^2. Approximately 75% of the calves (39/52) were kept in pens and the rest were reared outdoors.

Sixty-five percent (34/52) of all the calves observed were categorized as clean, with a leg hygiene score less than or equal to 2.5. For the 39 pens, 23 of them (59%) were categorized as clean, and 23% and 33% of them had a failed knee impact and knee wetness test, respectively with 62% of pens having bedding and 26% of pen floors being wood or concrete.

In univariable analyses of the 52 calves, variables with a $p<0.2$ included: age, breed, BCS and the housing variable. Indoor housed calves had an increased odds of having dirty calf legs by 8.6 times (p=0.031), compared to outdoor-housed calves.Type of floor, type of bedding and pen hygiene score were variables with a $p<0.2$ on univariable analyses of 39 calves housed in pens.

In the final multivariable logistic regression model of 39 calves in pens, concrete or wood floors (OR=7.9, p=0.047), poor body condition (OR=17.1, p=0.020) and use of bedding (OR=12.5, p=0.046) were risk factors associated with dirty calf legs, compared to dirt floors, good body condition, and no bedding, respectively.

The average lying space of 2.5m^2 available for each calf in our study was higher than that recommended (1.4 m^2) for calves with an average weight of up to 160 kg in Germany (Kunz and Leimbacher, 1983). This optimal space allowance for these calves was anticipated as most of the farms had large calf pens because the pens could be used for both pre-weaned and post-weaned calves without need for moving the calves.

With the increase in calf body weight associated with increased body condition scores (p=0.019), and the likely association between body condition score and management factors such as feed intake and health status, we presumed that calves with higher body condition scores (>2.25) were less likely to have dirty leg scores due to better management practices by the farmers, and the findings supported that.

Interestingly, concrete or wooden floors on pens were risk factors for calf dirtiness when compared to dirt floors, and we attributed this to poor drainage of urine and/or wet manure on these floors in comparison to dirt floors. In the same regard, use of bedding had a negative effect on calf cleanliness, and this finding contradicted what would be expected and an earlier study which reported that calf cleanliness improved with use of bedding (Panivivat et al., 2004). We speculated that management practices such as manure removal may have affected these two associations and as such, a future cohort study should be carried out, to evaluate the on-going calf housing management practices and how they are associated with calf cleanliness over time on similar farms.

Overall, some calf comfort aspects were adequate for the majority of calves examined, but 69% of the pens were categorized as dirty, leading to dirty calves, especially in pens with wooden or concrete floors and poor bedding management. These data suggests that small holder dairy farmers in Kenya should be trained on best management practices on calf housing to improve calf comfort and productivity.

5.3 Risk factors associated with lying time, stall and cow dirtiness in smallholder dairy farms in Meru, Kenya in 2017.

To achieve this objective, a cross-sectional study evaluating lying time, stall dirtiness and cow dirtiness was carried out on 73 farms with an average herd size of1.4±0.6 milking cows and a total of 106 milking cows.

The cow level information collected included: cow identification, age in years, weight in kilograms, height in metres, and the body condition score was described using the 5-score chart (Wildman et al., 1982) that ranged from 1(very thin) to 5 (excessively fat), with quarter-point increments. The breeds were described as exotic if the cows were visibly and predominantly Friesian, Guernsey, Ayrshire or Jersey, and indigenous if they were visibly and predominantly Zebu, Boran or other local breeds.

The health status of the cows, determined by conducting a physical examination of the cow included but was not limited to: heart rate and quality, respiratory rate and quality, color of mucous membranes, palpation of superficial lymph nodes, rumen movements, skin condition, joints and feet examination, and lameness, classified as absent, mild or severe, which was a modification from a 5-point scoring system (Sprecher, Hostetler and Kaneene, 1997). The daily milk yield of the cows was estimated as the total milk produced by the cows in all the milkings of the day (two or three depending on the farmers). Cows with a CMT score greater than one were categorized as positive for subclinical mastitis (SCM).

Stall dimension characteristics were categorized based on recommendations associated with the cow's estimated weight (appropriate if within ±10% of the recommendation for the weight). The definitions and measured dimensions are summarized in Table 3-1.

The type of floor was recorded as: 1) dirt, 2) concrete and/or wooden, and 3) others. The floor flatness was categorized as: 1) flat (<5% of the floor uneven) or 2) lumpy (≥ 5% of the floor uneven). The type of bedding available was categorized as: 1) sawdust, 2) wood shavings, 3) crop waste and 4) others. The knee test for wetness had three possible outcomes: 1) wet (failed test), 2) moderately dry (marginally passed test), and 3) dry (passed the test). The knee test for impact also had three possible outcomes: 1) hard (failed test), 2) moderately soft (marginally passed test), and 3) soft (passed the test).

The adequacy of the roof (yes or no) was determined based on a visual assessment of the roof, confirming that the roof was adequately covering the entire length of the stall and not allowing water to enter the stall because of roof holes. Adequate drainage of the stall (yes or no) was judged by determining if water could flow along the ground from outside the stall into the stall by gravity.

The stall, udder and leg cleanliness scores were assessed using a 5-score system (Reneau et al., 2005b) where the categories included: 1 (very clean), 2 (clean), 3 (fair), 4 (dirty) and 5 (very dirty). With scores from 2 hind legs and two sides of the udder, an average of the two scores was recorded.

The condition of the alley was categorized based on the amount of manure at the time of assessment, and the three possible categories were: 1) clean (no manure), 2) fairly clean (small amount of manure-can easily walk to avoid manure) and 3) muddy (a large amount of manure on the alley-cannot avoid walking in manure).

Data on farm-level parameters assessed (over the last 6 months) were acquired using a questionnaire that was administered to the farmers face-to-face by the investigator in the native language (Kimeru), and included: number of milking cows in the farm; frequency of hoof trimming; stall manure removal frequency; use of bedding on lying surfaces; frequency of adding new bedding in the stalls; and frequency of cleaning the alley. Assessment for abnormal lying and standing behaviours (e.g. perching and standing backwards in the stall) at the herd level were determined for each farm in two ways: 1) observations while on the farm; and 2) farmer-reported abnormal behaviours acquired using the questionnaire.

To record lying time of cows, data loggers were calibrated and operated as per the manufacturer's manual (HOBO Pendant G Acceleration Data Logger (UA-004-64) Manual). Once launched, the data loggers were attached on the inside of the left hind leg below the hock joint but above the pastern joint, and were detached three days later, read out, and the data exported to MS Excel® 2013 and imported for further analysis to Stata 14®.

Age of the cows was dichotomized at the median of 5.25 years and the two age categories were 0≤5.25 years, and 1>5.25 years. The daily lying time was not normally distributed. However, a histogram, and a box-cox transformation gave a theta of 0.9, and therefore we kept lying time on its original scale. To describe the lying time, mean, median, standard deviation and ranges were used. Comparison of lying time means over binary variables was done using a t-test and significant differences ($p<0.35$) were reported.

Proportions and their 95% confidence intervals were used to describe subclinical mastitis occurrence at the cow level. Stall, udder and leg cleanliness scores were described using their means, standard deviations and ranges, then further categorized into binary outcomes (0=clean which included scores ≤2.5, 1=dirty which included scores >2.5) and subsequently described using proportions and confidence intervals.

Univariable linear models and logistic models were used to identify potential risk factors ($p<0.25$) for lying time and cleanliness (stall, udder and upper legs) respectively. Using these variables, multivariable linear and logistic regression models were fit manually through back ward elimination and variables that were significant ($p<0.05$), confounders or had interaction effects were retained in the models.

The mean daily milk yield per cow was 6.61 ± 3.32 liters and 44 cows (42%) had a CMT score of ≥1. The mean daily lying time was 10.9 ± 2.2 hours and the mean stall cleanliness score was 2.4 ± 1.0. The mean average cleanliness score of the udder and upper legs was 1.9 ± 0.7 and 2.5 ± 1.1 respectively. A total of 35% of the stalls were categorised as dirty (>2.5), while 13% and 47% of the cows had udder and leg cleanliness scores >2.5, respectively. Subclinical mastitis (SCM) was present (CMT score>1) in 42% (95%CI: 32-52) of the cows tested (44/106).

From the final multivariable models, daily lying time increased with cow age (β=1.00, p=0.005). Two cow-level and two farm-level variables decreased lying time: 1) poorly positioned neck rails (β=-1.64, p=0.039); 2) stall cleanliness scores >2.5 (β=-0.97, p=0.008; 3) delayed removal of manure (β=-1.48, p=0.002); and 4) delayed addition of new bedding (β=-1.19, p=0.017), respectively. There was an interaction between frequency of stall manure removal and frequency of adding new bedding (p=0.040). The longest lying time was predicted when manure was removed and new bedding added to the stalls at least once a day, while the shortest lying time was predicted when manure was removed from the stalls less than once an day and new bedding was added at least once a day. Therefore, the relationship between lying time and new bedding added at least once a day depended on the frequency of manure removal.

Farm-level risk factors for stall dirtiness included: delayed cleaning of the alley (OR=6.63, P=0.032), lack of bedding (OR= 4.92, p=0.008), and standing idle and/or backwards in the stall (OR=10.47, p=0.002).

Stalls categorized as dirty (OR=2.88, p=0.041) and lack of bedding (OR=2.73, p=0.065) were cow-and farm-level risk factors for dirtiness of the udder, respectively, while the stall being dirty (OR=2.3, p=0.043) was the only risk factor (cow-level) for dirtiness of the upper legs. Farm effects explained 45% of the variation observed in upper leg dirtiness.

Two cow-level and one farm-level risk factors for SCM included: udders that were categorized as dirty (OR=5.9, p=0.023); concrete or wooden stall floors (OR=5.5; p=0.037), and poor stall drainage (OR=9.4, p=0.008).

The daily milk yield of 6.6 Kg/cow was similar to milk yield in Kiambu district of Kenya (Gitau et al., 1994) but lower than yields in Mukurweini district of Kenya (Richards, 2017), where the higher yield in the latter could be due to a long-standing cattle health management and development project in Mukurweini for over 10 years.

As anticipated and evidenced earlier in Norwegian farms (Ruud et al., 2011), the design (short stalls) and management of both the stalls (use of bedding and frequency of cleaning) were associated with stall cleanliness and subsequently with udder and upper leg cleanliness. Frequent cleaning of the alley was also associated with clean stalls in this study, and this finding is supported by similar findings that indicated improved stall cleanliness with cleaner alleys (Magnusson, Herlin and Ventorp, 2008). We speculate that accumulated manure on the alley could be transferred to the stall by a cow's feet during movement into the stall, and possibly when a cow is using her tail to flick away flies while lying down.

The average cleanliness score of the upper legs was relatively similar to that found in Canadian farms Devries et al. (2012). The management of farms in the Kenya and Canada are seen to vary in terms of mechanization, but with the frequency of cleaning stalls being adequate in both farming systems, that may explain the similar upper leg and stall cleanliness scores. The udder cleanliness scores in our study were better compared to those reported in Canadian and Dutch farms (Dohmen, Neijenhuis and Hogeveen, 2010). This was contrary to what would be expected, in that farms in industrialized countries are probably better managed in terms of cleaning, in comparison to SDFs in Kenya. We speculated that cows in Canada and the Netherlands, with an average daily milk yield of 35.3 and 24.8 litres, respectively, had larger udders that were prone to getting soiled when the cows were standing and lying down, in comparison to cross-bred and indigenous cows in this study that had a daily milk yield of 6.6 ± 3.3 litres.

With the limited research and programs to improve cow comfort in SDFs in Kenya, we would expect to observe shorter lying times of the cows, but the average daily lying time of the cows was 10.9 hours, which is borderline to the recommended lying time of cows as described by Gomez and Cook in 2010. We can attribute this findings to the simplistic stall designs of zero-grazing units in the SDFs, and because most of the sub-optimal designs observed were more on unavailability of some stall structures such as neck rails and brisket boards in most stalls (84% and 97%, respectively), which ensured that the stalls (optimal or sub-optimal) were less restrictive, and hence adequate lying time.

As observed in earlier studies (Veissier, Capdeville and Delval, 2004), stall design (poor neck rail positioning), stall cleanliness and housing management practices (frequency of manure removal and addition of new bedding), were associated with lying time of cows. An interaction between frequency of manure removal and addition of new bedding was anticipated, however, it was interesting and unclear why adding bedding at least once a day and removing manure from the stall at least once a day had a shorter lying time than if only one of those two management practices occurs on a farm. We speculated that with small amounts of bedding used, removing dry manure from the stall daily could worsen the softness of the stall floor, while improving the cleanliness of the stall.

We recommend that farmers should pay attention to the specific factors identified regarding the stall design and housing management practices as they have a significant impact on cleanliness of cows and their lying time. Further research should be carried out to determine and quantify the effects of improving cow comfort on animal welfare and productivity in a randomized controlled trial.

5.4 Assessment of farmers' compliance to implement cow comfort changes recommended, and their effects on lying time, and stall and cow cleanliness on smallholder dairy farms in Kenya.

To determine the effects of given farm-specific recommendations on lying time, stall cleanliness and cow cleanliness; a randomized controlled trial was carried out on 73 smallholder dairy farms (n=106 cows) in Kenya with an average herd size of 1.4±0.6 cows. A total of 62 farms (n=90 cows) were grouped as intervention farms and received farm-specific recommendations on a maximum of 12 cow comfort focus areas and 11(n=16 cows) farms were used as controls and received no recommendations.

The 12 cow comfort parameters that could be potentially changed include: roof status, drainage of surface water, floor softness, floor flatness, stall width, stall length, leg space, lunge space, neck rail, brisket board, alley cleaning and sharps fix (Table 4-1). Each of the comfort parameters could be recommended for a major change or minor change based on duration of time it would take to complete the change, labour input required and cost incurred if any (Table 4-1). To assess the acceptance and willingness to implement the given changes, the factors that influenced the farmers' compliance, and the effect of compliance on lying time, stall cleanliness, udder cleanliness and upper leg cleanliness, the 62 farms allocated to the intervention group were used.

The baseline data on cow comfort status of all the farms was collected on the first visit including: stall dimensions (Table 3-1), stall hygiene scores, udder hygiene scores, upper leg hygiene scores, attachment of data loggers to determine daily lying time and face-to-face questionnaires administered to all the farmers in the native language (Kimeru) to evaluate the management practices on the farms. Data collection on cow-level information, cow health status, stall dimensions, farm-level parameters and lying time of cows is as described on part 5.3 of this chapter.

In the intervention farms, farm-specific recommendations based on baseline data were given to the farmers orally in Kimeru and in written form using the language of their choice (Kimeru, Swahili or English) on the second visit three days later in addition to detachment of the data loggers. After 39 ± 7 days, a third visit was done where data loggers were attached on all the farms and compliance was assessed and a post-intervention questionnaire administered face-to-face in Kimeru in intervention farms to gather information on: costs incurred, challenges faced, hard recommendations observed, understanding of cow comfort and knowledge transfer from the intervention farmers to other farmers in the area. A fourth visit was done on all the farms where data loggers were detached and lying time post-intervention determined.

Univariable and multivariable mixed logistic regression models with farm random effects were used to evaluate factors that were associated with compliance. To assess the interaction between treatment groups and visits, a multivariable mixed linear regression model of the natural log of lying time and multivariable mixed logistic regression models of cleanliness scores (stall, udder and upper hind leg), with farm random effects were used. On adjusting for compliance using a combined variable, interaction between this variable and the visits was assessed using similar models of the 4 outcomes (lying time, stall cleanliness, udder cleanliness and upper hind leg cleanliness) that were fit for each of the 12 comfort parameters.

The average daily lying time for the cows in the study pre- and post-intervention was 10.9 ± 2.2 and 11.5 ± 2.3 hours, respectively. The median number of lying bouts per cow per day was 12.3 and 19.3 pre-intervention and post-intervention, respectively. Lying bouts had a median duration of 51.2 minutes, ranging from 10.5 to 105.5 minutes pre-intervention, and 32.1 minutes ranging from 10.0 to 104.8 minutes post-intervention. There were no significant differences in bout numbers or bout lengths between groups pre-intervention, or within groups when comparing pre- and post-intervention.

The overall farmers' compliance was 74% (46/62) where the 46 farmers implemented at least one of the farm-specific cow comfort changes recommended before the third visit. The number of changes given for each of the 12 comfort parameters assessed and the farmers' compliance to implement them are summarised in Tables 4-2 and 4-3. Recipients of cow comfort recommendations were women in 50% (31/62) of the farms, men in 42% (26/62) of the farms and farm hands in 8% (2/62) of the intervention farms. Of these farms, most or all changes were made within the allotted time period in 64% of the farms, some changes were made in 10% (6/62) of the farms while no changes were made in 26% (16/62) of the farms.

About 47% of the farms that implemented changes started within 24 hours of the recommendations being made while 18% and 6% of the farms started implementation within the first week and later than the first week post recommendation respectively. Sixty three percent of the farmers completed the implementation of changes within 24 hours while 32% (15/46) took a few days and 4% (2/46) took one week or more to complete the changes. Of the 46 farmers that implemented at least one recommended change, 15% (7/46) felt that they had made the changes fairly well, 72% (33/46) felt that they had made the changes well, while 13% (6/46), felt that they had made the changes very well. About 33% of the farmers incurred costs of implementing changes and an average cost of Ksh. 344±222 was estimated among the 15 farmers. For the 46 farmers who implemented changes, 96% (44/46) felt well-versed in cow comfort post-intervention (Table 4-4). However, 57% (26/46) did not advise other farmers about stall changes they could make on their farms. Of these 26 non-advising farmers, 42% (11/26) had no valid reason for not doing so, while 58% had reasons that included: lack of nails, poor stall stability and plans to rebuild stalls. Challenges were observed on 8 farms after improvements were made to cow comfort including: fighting of cows for stalls, in-ability to lie down in the stall (when changes were not done properly), and preference for lying down on the alley. A summary of the knowledge and attitudes of farmers that implemented at least one of the recommended changes is given on Table 4-4.

Due to the large number of possible stall changes recommended to the farmers for analysis, a combined comfort parameter variable was generated that aggregated the 12 comfort parameters into 4 combined comfort parameters. The new variable had four categories; 1) stall design included lunge space (LuS), side leg space (LeS), neck rail (NR) and brisket board (BB); 2) stall size included stall length and stall width; 3) floor characteristics included floor softness (FS) and floor flatness (FF); and 4) “other” category that included roof adequacy (RF), drainage of surface water (SW), cleanliness of the alley (AC) and sharps fixes (SF).

With compliance as a binary outcome (no=0, yes=1), a mixed multivariable logistic regression model with farm as a random effect determined that type of recommendations, recipient of the recommendations and the type of combined comfort parameter identified for change (1-4)were factors ($p<0.05$) associated with compliance to implement changes in all the 62 intervention farms (Table 4-5). Higher odds of compliance were observed when major recommendations were given relative to minor recommendations (OR=6.3, p=0.004); and changes recommended were related to the lying surface (FS and FF) (OR=3.1, p=0.047) compared to parameters related to stall design (NR, BB, LeS and LuS).The odds of implementation were lower if : farm hands received the written and oral recommendations instead of the wife or husband (OR=0.01 , p=0.023) and changes recommended were related to roof, alley, drainage of surface water and sharps fix changes were lower relative to changes related to stall design (OR=0.13, p=0.004). Given that a recommended change for a given comfort parameter was made in a given farm, the probability of another recommended change being implemented on the same farm was 84.4% (ICC=0.844).

A similar model fit for the 46 farms that implemented at least one of the recommendations did not have significant farm random effects ($\chi2=0.28$, p=0.299). For this model, the odds of compliance were only 4.0 times higher if the recommendation given was major relative to minor. The odds of compliance were lower on farms where a man or a farm hand received the oral and written recommendations in comparison to farms where a woman received the recommendations. If farmers had at least one recommendation that they considered was hard for them to implement, the odds of compliance in these farms was significantly lower (OR=0.32, p=0.021), compared to farms where no recommendations were considered hard. There were only minor differences in the combined comfort parameter variable between this model and the model for 62 farms (Table 4-5).

Differences between intervention groups, irrespective of compliance

The median lying times were not significantly different between the intervention and control groups pre- and post-intervention (Table 4-6). However, numerically, both groups improved between the pre- and post-intervention measurements. In the intervention and complied group, the median lying time per cow per day increased from 11.0 hours to 11.3 hours over the assessment period. However, the median lying time per cow per day was also 11.3 hours in the control and non-compliant group post-intervention.

Regarding stall cleanliness, in the 62 intervention farms the median stall cleanliness score was significantly lower post-intervention then pre-intervention (p=0.0001) but remained similar on initial 11 control farms (p=0.122). The median udder and leg cleanliness scores also decreased significantly in the intervention group cows post-intervention but remained similar in control farms (Table 4-6).

In the 62 intervention farms, the proportion of stalls that were categorized as dirty (>2.5) pre-intervention was 35% (31/88), which declined significantly ($p=0.0002$) to 11% (10/88) post-intervention. In the control farms, the stalls categorized as dirty remained relatively similar pre-intervention (5/15; 33%) and post-intervention (4/15; 27%). The proportion of cows with udders categorized as dirty was relatively similar in both groups, pre- and post-intervention ($p>0.05$). Pre-intervention, 50% of cows (45/90) in intervention farms, and 31% of the 16 cows on control farms had upper hind legs categorized as dirty (>2.5), while post-intervention, the proportion of cows with upper hind legs categorized as dirty was relative similar in both groups (intervention=38% and control=37%), which indicates that numerically, the upper hind leg dirtiness scores improved in the intervention farms and worsened in the control farms even though the differences were not statistically significant.

To evaluate the effects of giving cow comfort recommendations to farmers, irrespective of the degree of compliance, on the **daily lying time** of cows, a multivariable mixed linear regression model was used while considering the interactions between visits (pre- and post-intervention) and the study groups (intervention and control). Random farm effects were not significant but retained in the model to distribute farms randomly when making predictions and generating interaction plots. The model indicated that the effects of group were potentially significant ($p<0.25$) but there was clearly no interaction between the groups and the visits, as illustrated in Figure 4-1.

To evaluate the effects of giving cow comfort recommendations to farmers, irrespective of the degree of compliance, on the **stall** cleanliness, a multivariable mixed logistic regression model with significant random farm effects (σ_h=2.849, p=0.0002) was used while considering the interactions between visits (pre- and post-intervention) and the study groups (intervention and control). The model indicated that an interaction effect between groups and visits was potentially significant (p=0.180), and the interaction plot illustrated an improvement in stall cleanliness in the treatment group post-intervention in comparison to the control group (Figure 4-2).

To evaluate the effects of giving cow comfort recommendations to farmers irrespective of the degree of compliance on the **cow** cleanliness, two multivariable mixed logistic regression models on udder cleanliness and upper leg cleanliness were used while considering the interactions between visits (pre- and post-intervention) and the study groups (intervention and control). The udder cleanliness model with non-significant random effects (σ_h=0.269, p=0.337), found that groups, visits and their interaction effects were not significant (p>0.05). The upper leg cleanliness model with significant random farm effects (σ_h=1.528, p=0.0006) indicated that effect of groups, visits and the interaction effects between groups and visits were not significant (p>0.05).

Differences between intervention groups, considering compliance

Table 4-7 provides results of the changes in daily lying time in the intervention group (n= 90 cows on 62 farms) pre- and post-intervention, by comfort parameter, from the multivariable mixed linear regression models with farm random effects, and with interaction adjustments for compliance and clustering of pre-and post-intervention assessments within cows. The models for each recommended comfort parameter change found that 7 of the 12 interactions were eligible for further analysis, including: drainage of surface water, floor flatness, stall width, stall length, lunge space, alley condition and sharps fixing. Out of the 7 eligible comfort parameters, only alley condition had a significant interaction ($p<0.05$), and this model also approached statistical significance ($p=0.069$). When the alley condition was good on the pre-intervention assessment, and therefore no change was recommended, the lying time remained unchanged. However, lying time increased for the farms where the alley condition was poor regardless of whether farmers complied with recommended changes or not (Figure 4-3).

Similar multivariable mixed linear regression models with farm random effects and adjustment for compliance and clustering of pre- and post-intervention assessments were determined for changes in stall and cow cleanliness in the intervention group (n=90 cows on 62 farms) pre and post-intervention. Only one comfort parameter had an interaction that was potentially significant ($p=0.188$), and only for stall cleanliness. The stall cleanliness improved on farms that did not have a neck rail, were recommended to have one, and the farmer placed a neck rail. However, on farms that had a poorly positioned neck rail, and recommendations were given to better position it, but they did not comply to implement the change, stall cleanliness had only a modest improvement (Figure 4-4).

Farms that made at least one of the recommended changes (46/62) were suspected to produce different results for these modeling efforts than if all 62 intervention farms were included. Therefore, for these 71 cows in 46 farms, similar multivariable mixed linear regression models with farm random effects and adjustment for compliance and clustering of pre- and post-intervention assessments were determined for changes in lying time, stall and cow cleanliness pre- and post-intervention. Only one comfort parameter had an interaction that was potentially significant (p=0.39), an only for lunge space. Failure to implement the proposed changes on forward and/or side lunge space in the stalls (category 2 of our combined variable) led to a decline in the log of lying time of the cows from pre- to post-intervention assessments, relative to the other two interaction categories (Figure 4-5).

The overall proportion of farmers that implemented at least one of the recommended changes (74%) was higher than that reported in Australian dairy herds (57%) (Tremetsberger, Leeb and Winckler, 2015), and those expected while designing the study where we hypothesized that half of the farmers would comply. With the limited information on compliance in SDFs in Kenya and Africa in general, we attributed this good acceptance of recommended changes and the implementation to various reasons including: integration of farmers in the formulation of improvement measures, which made them feel that their opinions were respected in the process; recommending changes that would require minimal investment as outlined in the methodology of chapter 4; using readily accessible and available resources, such as timber, dirt and crop-waste from their farms to improve on the proposed changes; use of the native language of Kimeru to give the recommendations; and giving both oral and written changes to the farmers which facilitated better understanding of the cow comfort requirements and minimized the potential loss of information. The incurred costs of implementation that ranged from 122 to 566 Kenya shillings and this amount is manageable when considering the estimated monthly income of a smallholder household in Kenya (Ksh.15 842) as reported by the Food and Agricultural Organization in 2016 (Global Forum On Agricultural Research, 2016).

For any given intervention, we would expect that the recommendations termed as minor would be preferred for implementation relative to “major” recommendations, when considering the labour and time input that was required to adequately implement the change. However, for the farmers in this study, the opposite was true where the odds of compliance were higher when major changes were proposed. This could have been solely due to chance or to a direct proportionality assumption or mentality, where the farmer would think that a “major” change on cow comfort would lead to a bigger change in cow productivity and vice versa irrespective of being blinded on whether the change recommended to them was minor or major.

In regard to the recipients of the recommendations in the farms, the lower odds of compliance to implement changes when farm-hands received recommendations was expected because they are presumed to be less invested in the farms compared to the owners. However, the lower odds of compliance in farms where husbands received the recommendations, versus farms where the wife received the recommendations, were interesting. It would have been expected that the husbands were more likely to implement the changes due to societal allocation of gender roles, where the men are expected to carry out the manual labour. In Kenyan SDFs households, this presumption was contradicted in our study and supported by findings from an earlier study in Kenyan smallholder dairy farms reported that women carried out 70% of all the activities in the farm (Nyongesa et al., 2016).

Improvement of stall design and stall management practices has been found to improve stall cleanliness and cow cleanliness in earlier studies (Tremetsberger, Leeb and Winckler, 2015; Bouffard et al., 2017; Richards, 2017) and in the present study (Table 4-6; Figure 4-2 and 4-4). Whether the farmers implemented the changes given partially or fully, changes to stall design such as neck rail placement and positioning improve stall cleanliness (Figure 4-4). The similarity between the udder cleanliness in the treatment group cows pre- and post-intervention could be attributed to the relatively low udder scores (clean) before any recommendations were given (Table 4-6) which did not leave a lot of leeway for improvement.

Even though we expected lying time to improve in the treatment group in comparison to the control group, as observed in the previous cow comfort study in Kenya, where Richards (2017) reported a significant increase in lying time in the intervention group ($p<0.0001$), other factors like the short time available for the changes to occur and the time taken by the cows to acclimate to any new changes made especially in regard to stall design may have led to slower improvement in lying patterns of the cows (Figure 4-1). The relative similarity in lying time between the intervention group farmers that implemented the changes and those that did not implement all or some changes, could be explained by the similarity between lying time pre-and post-intervention observed in the intervention group, and the farm-specific changes giving which meant that different farmers were given different changes and some comfort parameters were recommended in more farms than others and the degree of compliance differed per comfort parameter and farm which increased the parameters to be considered on a relatively small sample size (n=62) thus less significant relationships observed.

Overall, giving smallholder dairy farmers recommendations to improve cow comfort improved the stall cleanliness and upper leg cleanliness of cows in the farms but not the daily lying time. The study suggests that the smallholder dairy farmers' compliance to implementing cow comfort changes recommended was above average (74%). The compliance was higher when major changes are recommended rather than minor changes and women in smallholder dairy farms had a higher compliance to implement recommended cow comfort changes when they received them compared to men and farm-hands.

Some cow comfort parameters like neck rail, brisket board, lunge space and leg space were more likely to be implemented in comparison to other parameters e.g. roof, stall length and sharps fix. In the short run, outcomes such as stall, udder and upper leg hygiene scores improved when recommended cow comfort changes were implemented.

Placement of a neck rail on the stalls regardless of the positioning improved stall cleanliness scores (lower scores) in the treatment group. Farmers that implemented at least one of the recommended changes, making proposed changes to stall lunge space led to an increase in lying time of cows in these small-holder dairy farms.

Giving farm-specific cow comfort recommendations to smallholder dairy farmers in Kenya and providing them with a participatory role in the formulation and implementation of improvement measures ensured a good acceptance and high degree of implementation and subsequently improvement of welfare of the cows.

A longitudinal study on the effects of implementing recommended cow comfort changes on dairy farms in Kenya in the long run including but not limited to: lying patterns, milk production and mastitis prevention; and the economic profitability and sustainability of giving recommendations to the farmers instead of making the changes for them.

5.5 Linked conclusions

The findings from the cow cross-sectional study indicated that stall design and housing management practices were associated with the lying time, and cleanliness scores of stalls and cows in the smallholder dairy farms. In particular, the daily lying time was higher with advanced cow age, but decreased with poorly positioned neck rails, stall cleanliness scores >2.5, delayed removal of manure, and delayed addition of new bedding. The association between lying time and frequency of adding new bedding depended on the frequency of stall manure; adding bedding daily only improved lying time when manure was removed daily. However, there results are from a cross-sectional study with limited ability to establish causality, therefore the controlled trial results could provide useful supportive evidence of these associations.

From our trial, giving farm-specific recommendations to change various aspects of stall design and lying surfaces led to improved cleanliness scores of the stalls and cows in these farms. However the lying time was not significantly improved by the intervention, not even when farmers improved the variables which were significantly associated with lying time within the cow cross-sectional study of this thesis. However, with the limited time period of the study, large variability in the lying time data, and likely contamination of control farms with information on cow comfort, finding significant improvements in lying time among intervention farms versus control farms was a challenge.

Despite the lack of statistical significance, the mean daily lying time of cows in the intervention farms increased numerically after recommendations were given (pre-intervention=11.06, post-intervention=11.58 hours per cow). Similarly, in Australian herds, welfare improvement measures were given to farmers and the lying time did not change significantly when the welfare was assessed after a one year implementation period (Tremetsberger, Leeb and Winckler, 2015). The numerical improvement in lying time in the present study may be attributed to the recommendations given, while the lack of significance may be partly due to non-compliance of some of the farmers to implement some or all the given changes (Table 4-2). Improvement of stall design and stall management practices has been found to improve stall cleanliness and cow cleanliness in earlier studies (Tremetsberger, Leeb and Winckler, 2015; Bouffard et al., 2017; Richards, 2017) and in the present study (Table 4-6; Figure 4-2 and 4-4).

In a study done by Richards (2017) that reported a significant increase in lying time post-intervention, the researchers implemented the changes for the farmers which eliminated the issue of non-compliance. To support the likelihood that compliance had an influence on lying time on the intervention farms, Figure 4-5 illustrates that the lying time of cows was shorter on farms that did not implement the recommended improvements on stall lunge space compared to farms that implemented the recommended changes on stall lunge space. Findings from the present randomized controlled trial indicated that the average daily lying time of cows in the smallholder dairy farms (10-11 hours) was close to the recommended lying time of 12 hours a day

(Gomez and Cook, 2010a), perhaps leaving less room for significant improvements than the Richards (2017) study where the average lying time was 9.0 hours/ cow/day.

It is important to note that there were improvements in cow comfort when recommendations were given, and we speculate that the changes may have been significant if the farmers were given an implementation period longer than 39 ± 7 days so that the cows were given a longer time to acclimate to their new stalls.

Less than half of the cows in the cow cross-sectional study were categorized as dirty (udder and upper hind leg), and kept in dirty stalls. Similarly, in the calf cross-sectional study, more than half of the calves were categorized as clean, with adequately-sized pens that were relatively clean. Using these findings, we can speculate that a majority of the farms in the study were relatively well-managed with respect to animal hygiene, which could translate to an even higher acceptance of proposed changes to improve cow comfort, and subsequently cow productivity.

What is clear is that giving recommendations to farmers, discussing those recommendations with the farmers to make sure there are no misunderstandings, and having the farmers implement those changes themselves improves the acceptance levels of the recommendations by the farmers, which subsequently results in a higher implementation rate as was observed in various earlier studies (Ivenleyer, 2008; Main et al., 2012; Whay and Main, 2015).

The likelihood that implementing farmers would share the knowledge gained on cow comfort with other farmers may be expected to be high, especially with the farmers playing a participatory role in the research project. This sharing would possibly lead to improved cow welfare in more farms than researchers can reach at any given time. In this region of Kenya, the smallholder dairy farms are in close proximity due to the limited land space available in these high altitude areas (Global Forum On Agricultural Research, 2016). Furthermore, the farmers in the study are in a close knit community, and are members of the Naari Dairy Farmers Co-operative Society, which further enhances their interactions within the community, and in turn the ease of knowledge transfer between the farmers. During the study, this "contamination" could have led to reduced statistically significant differences between groups, but in terms of farming community in this region, this knowledge transfer is clearly a good outcome of the study.

In regards to costs incurred by any governmental or non-profit organizations aiming to improve welfare of cows in farms, giving farm-specific recommendations to farmers and training them on the importance of making cow comfort changes may be more cost-effective than making the changes for the farmers, and it may allow inclusion of more farmers than when making the changes for the farmers. Our compliance results would indicate that when recommendations are given clearly, using the local language, both orally and written format, a large majority of the recommendations are implemented correctly. The feasibility and long-term sustainability of a cow comfort project may be improved using this clear recommendation approach because farmers may have a better understanding of cow comfort when they implement the changes themselves, and then advise other farms after the project is completed.

APPENDICES

Appendix A: Sample title page

CALF COMFORT PILOT STUDY AND COMPLIANCE AND EFFECTS OF COW COMFORT RECOMMENDATIONS IN SMALLHOLDER DAIRY FARMS IN KENYA

A Thesis

Submitted to the Graduate Faculty

in Partial Fulfilment of the Requirements

for the Degree of

Masters in Science

in the Department of Health Management

Faculty of Veterinary Medicine

University of Prince Edward Island

Emily Kathambi Kiugu

Charlottetown, P. E. I.

18/05/2018

© 2018, Emily Kathambi

Appendix B: Thesis non-exclusive License

THESIS/DISSERTATION NON-EXCLUSIVE LICENSE

Family Name: Kiugu	Given Name, Middle Name (if applicable): Emily Kathambi
Full Name of University: University of Prince Edward Island	
Faculty, Department, School: , Faculty of Veterinary Medicine	
Degree for which thesis/dissertation was presented: MSc	Date Degree Awarded:
Thesis/dissertation Title: CALF COMFORT PILOT STUDY, AND COMPLIANCE AND EFFECTS OF COW COMFORT RECOMMENDATIONS IN SMALLHOLDER DAIRY FARMS IN KENYA	
Date of Birth. It is **optional** to supply your date of birth. If you choose to do so please note that the information will be included in thebibliographic record for your thesis/dissertation. 13/01/1992	

In consideration of my University making my thesis/dissertation available to interested persons, I,

Emily Kathambi Kiugu

Hereby grant a non-exclusive, for the full term of copyright protection, license to my University,

The University of Prince Edward Island:

(a) to archive, preserve, produce, reproduce, publish, communicate, convert into any format, and to make available in print or online by telecommunication to the public for non-commercial purposes;

(b) to sub-license to Library and Archives Canada any of the acts mentioned in paragraph (a).

I undertake to submit my thesis/dissertation, through my University, to Library and Archives Canada. Any abstract submitted with the thesis/dissertation will be considered to form part of the thesis/dissertation.

I represent that my thesis/dissertation is my original work, does not infringe any rights of others, including privacy rights, and that I have the right to make the grant conferred by this non-exclusive license.

If third party copyrighted material was included in my thesis/dissertation for which, under the terms of the *Copyright Act*, written permission from the copyright owners is required I have obtained such permission from the copyright owners to do the acts mentioned in paragraph (a) above for the full term of copyright protection

I retain copyright ownership and moral rights in my thesis/dissertation, and may deal with the copyright in my thesis/dissertation, in any way consistent with rights granted by me to my University in this non-exclusive license.

I further promise to inform any person to whom I may hereafter assign or license my copyright in my thesis/dissertation of the rights granted by me to my University in this non-exclusive license.

Signature	**Date**

Appendix C: Certification of thesis work

University of Prince Edward Island

Faculty of Veterinary Medicine

Charlottetown

<u>CERTIFICATION OF THESIS WORK</u>

We, the undersigned, certify that Emily Kathambi Kiugu, candidate for the degree of

Masters of Science has presented his/her thesis with the following title

CALF COMFORT PILOT STUDY AND COMPLIANCE AND EFFECTS OF COW COMFORT RECOMMENDATIONS IN SMALLHOLDER DAIRY FARMS IN KENYA

that the thesis is acceptable in form and content, and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate through an oral examination held on June 18^{th} 2018.

Examiners

Dr. Bronwyn Crane

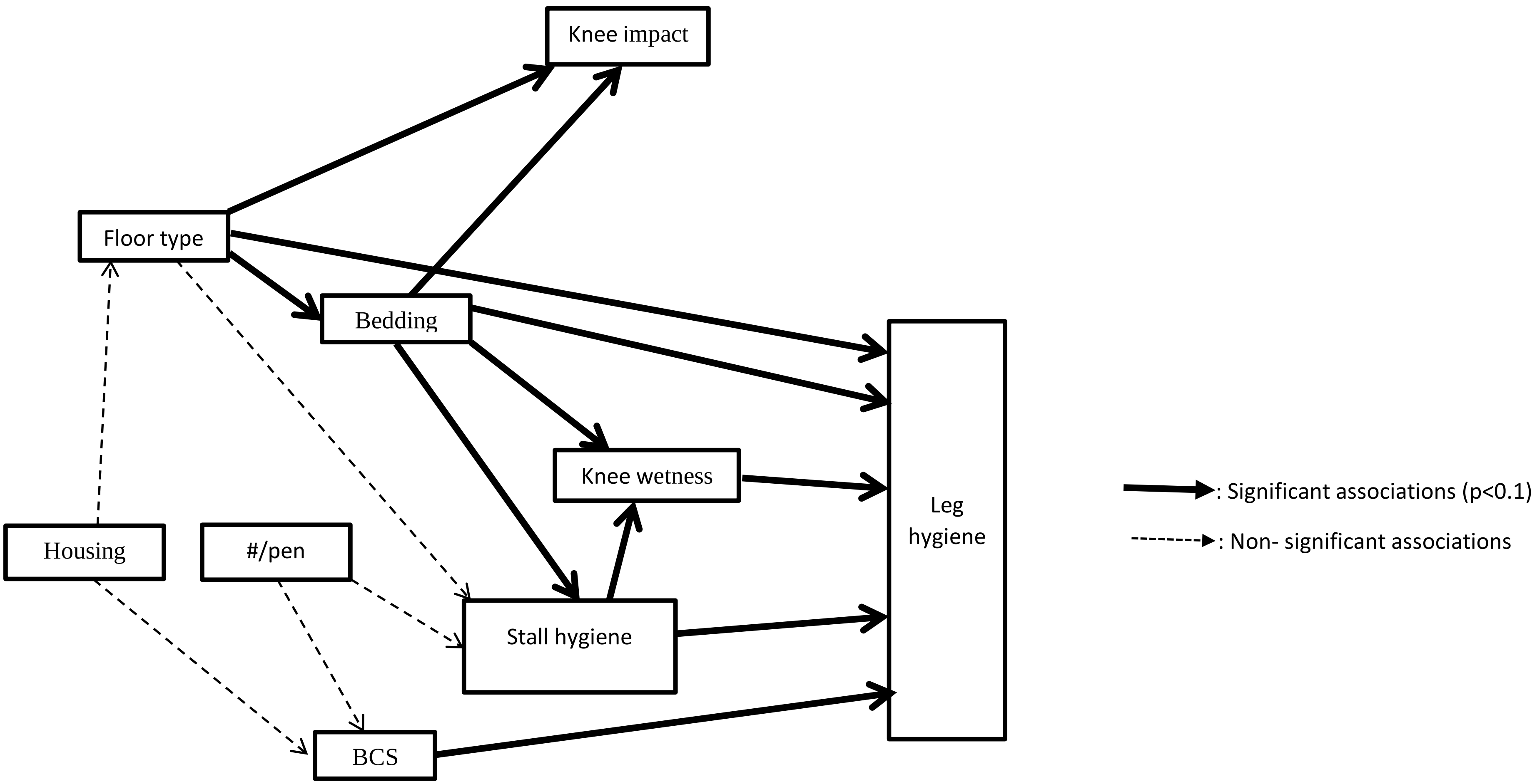
Dr. Luke Heider

Dr. John VanLeeuwen

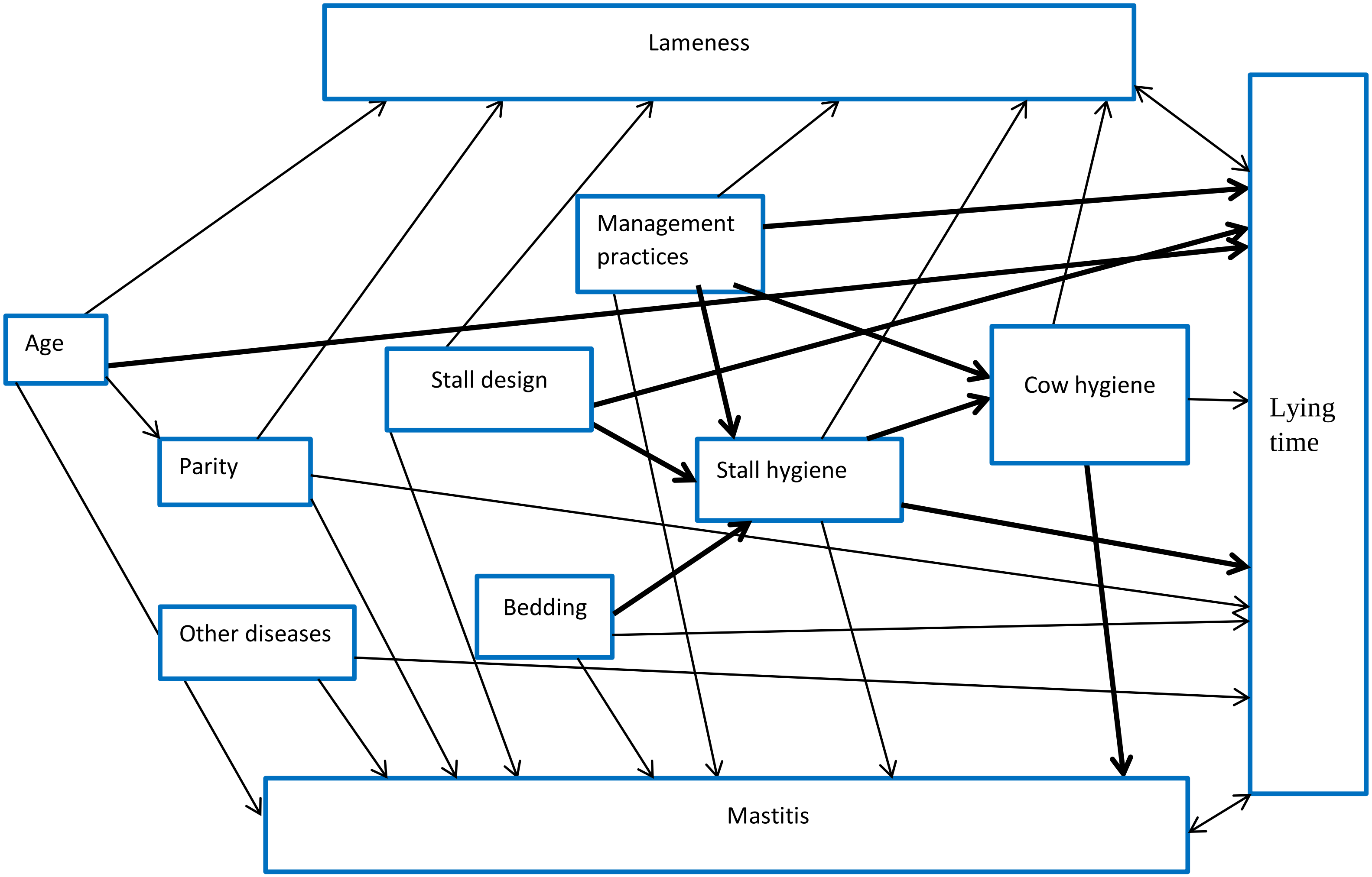
Dr. Shawn McKenna

Dr. Collins Kamunde

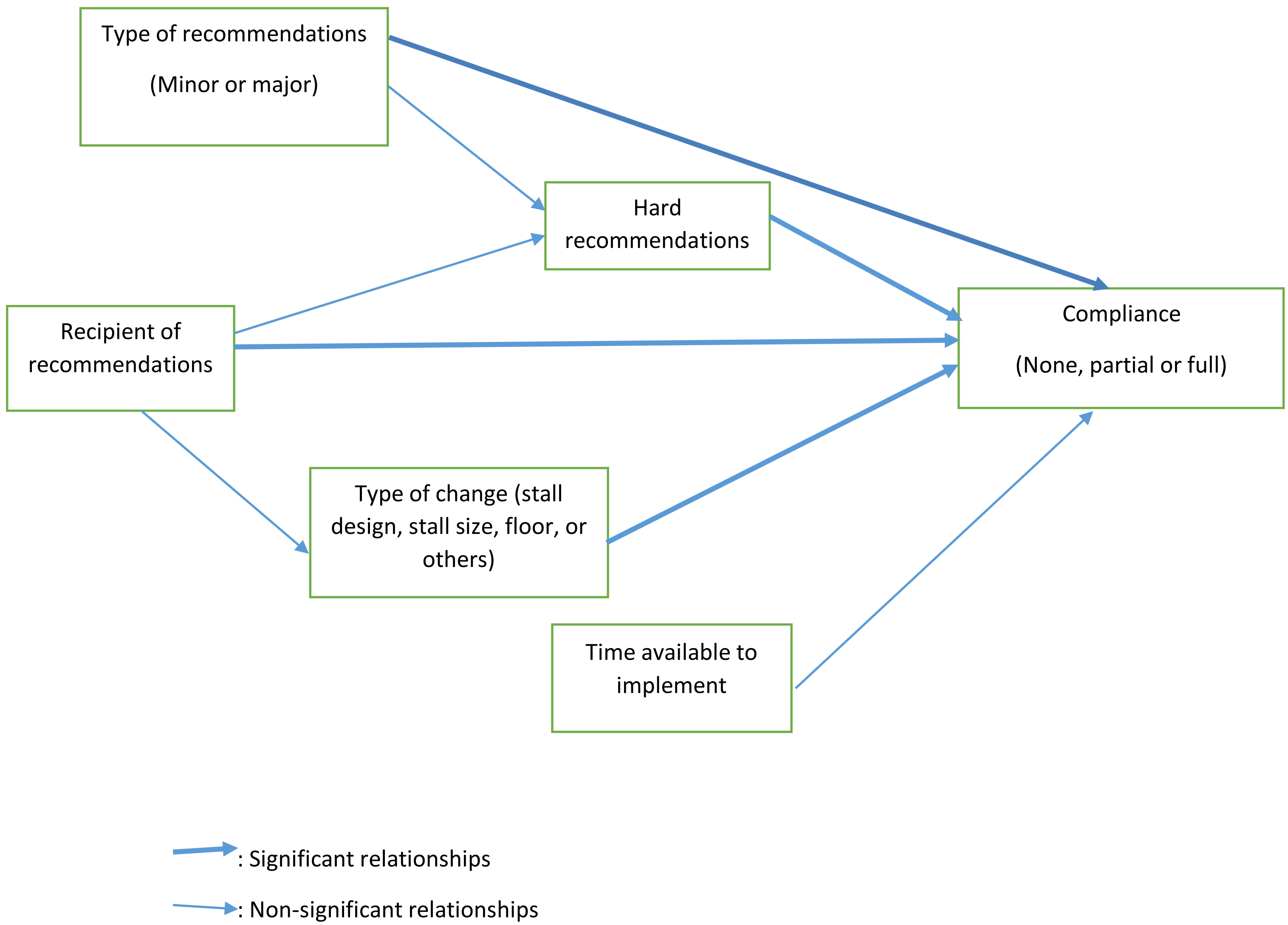
Appendix D: Causal diagram of calf leg cleanliness



Appendix E: Causal diagram of cow lying time, stall and cow cleanliness



Appendix F: Causal diagram of farmers' compliance



Appendix G: Accelerometer data sheet

Farm	Cow ID	Mins lying	Mins standing	No of bouts	Bout length	Mins lying	Mins standing	No of bouts	Bout length

Appendix H: Accelerometer use on farms

Visit	Cow #	Launcher #	HOBO#	Attached			Removed		
	Farm#-Cow#	(1,2,3)	(10505079)	Date	Time	Orientation (if not normal)	Date	Time	Orientation (if not normal)

Orientation options: Normal, Black top up (BU), Black top down (BD), slightly angled (*)

Appendix I: Pre-intervention questionnaire

Farmer Name: Farm Number: Phone #:

Survey Visit date: Interviewer Initials:

Questionnaire for Cow comfort and mastitis prevention practices on Small holder dairy farms in Naari.

Part 1: Cow comfort

1a: For Examination and observation:

	Cow #1 ID_______	Cow #2 ID_________	Cow #3 ID_________ _	Cow #4 ID_________ _
a. Breed				
b. Age				
c. Weight				
d. Height				
e. Body condition score				
f. TPR/physical exam Normal / Abnormal? (manure, feet, skin, lymph nodes, eyes, rumen)	N / A	N / A	N / A	N / A
g. Udder hygiene score (1-5)				

h. Leg hygiene score (1-5)				
i. Stall hygiene score (1-5)				
j. Lameness (absent, mild or severe)				
k. Mastitis (absent, mild or severe				
l. Subclinical mastitis (P/A)				
m. Milk production (Kg/day)				
n. Milk production the previous day (kg/day)				

1b: Stall dimensions: For Measurement

Stall	**a. Width (cm)**	**b. Total Length (cm)**	**c. Neck Rail Height (cm**	**d. Forward Lunge space (P/A)**	**e. F-Lunge space (cm)**	**f. Side Rail Height Lowest Board (cm)**	**g. Side Rail Mid Board (cm)**	**h. Side Rail High Board (cm)**
#1								
#2								
#3								
#4								

For observation:

1. What is the type of the floor where the milking cows lie down?

1) concrete 2) dirt 3) other (please specify: ________________)

2. Is the floor (observe - check all that apply):

1) lumpy (have to lie on sticks, rocks, dirt chunks , etc.) Yes __ No __
2) hard (fails Knee impact test) Yes __ No __
3) wet in the udder area (fails the Knee wetness test) Yes __ No __

3. What kind of bedding is used where the milking cows lie down?

a) grass/hay b) straw c) sawdust d) crop waste e) soil f) none g) other (specify _________)

4. How is the drainage of the stall? (Slope of the floor surface, pooling of urine & water)

a. Poor b. fair c. good d. very good

5. Is water/urine/feces able to flow (by gravity) under udder where milking cows lie down? Y _N _

6. Are there any sharp objects in the cow shed that may risk injuring the cattle (eg nails)? Yes __ No __

7. Is the roof appropriate (observe – no holes, extends to cover udder area)? Yes __No _

1c: Stall management

8. How often do you **remove manure** from where the **milking cows** lie down?

a) more than once a day
b) once a day
c) every other day
d) twice a week
e) once a week
f) less than once a week

9. How often do you **add new bedding** to where **milking** cows lie down?

a) every day
b) every other day
c) twice a week
d) once a week
e) less than once a week

10. How often do you trim your cows feet?

a) every 3 months
b) every 6 months
c) every 12 months
d) less often or never

11. Do your cows do any of the following behaviours (circle all that apply – observe to confirm)?

a) perching (standing partly in the stall and partly out of the stall for more than a few minutes)
b) standing backwards in stall
c) idle standing in the stall (standing fully in the stall for more than a few minutes)
d) dog-sitting in the stall (sitting on hind legs but standing on front legs)
e) kneeling in the stall (standing on hind legs but kneeling on front legs)
f) lying restless in the stall (shifting position in the stall every 15 minutes or less)
g) nose-pressing against a post or board while standing or sitting in the stall
h) lying somewhere other than in the stall
i) Other behaviours you wonder about (please specify _________)

12a. Do cows hit any of the body parts when lying down or getting up? Yes __No __

12b.If yes, what body parts? ____

Part 2: Calf comfort

13a.Do you have a pen for preweaned calves ? Y__N__

13b. If yes, type of flooring? _____________________ 13c. Adequate roof?_ Y__N__

13d. Type of bedding?

14a.Do you have a pen for weaned calves ? Y__N__

14b. If yes, type of flooring? ______________________ 14c. Adequate roof?_ Y__N__

14d. Type of bedding?

2a. for Examination and observation:

	Calf #1 ID_______	Calf #2 ID________	Calf #3 ID________ _	Calf #4 ID________ _
a. Breed				
b. Age				
c. Sex				
d. Weight				
e. Height				
f. Body condition score				
g. TPR/physical exam Normal / Abnormal? (manure, feet, skin, lymph nodes, eyes, rumen)	N / A	N / A	N / A	N / A
h. Leg hygiene score (1-5)				
i. Stall hygiene score (1-5)				
j. Lameness (absent, mild or severe)				

2c. Stall management

15.How often do you **remove manure** from where the **calves** lie down?

a) more than once a day
b) once a day
c) every other day
d) twice a week
e) once a week
f) less than once a week

16. How often do you **add new bedding** to where calves lie down?

a) every day
b) every other day
c) twice a week
d) once a week
e) less than once a week

Appendix J: Post-intervention questionnaire

Farmer Name: Farm Number: Phone #:

Survey Visit date: Interviewer Initials:

Post –intervention questionnaire for assessment of cow comfort recommendations made on Small holder dairy farms in Naari.

	Cow #1.1 ID_______	Cow #1.2 ID________	Cow #1.3 ID_______	Cow #1.4 ID_______
o. Body condition score				
p. TPR/physical exam Normal /Abnormal? Pathological? (manure, feet, skin, lymph nodes, eyes, rumen)	N / A	N / A	N / A	N / A
q. Udder hygiene score (1-5)				
r. Leg hygiene score (1-5)				
s. Stall hygiene score (1-5)				
t. Lameness (absent, mild or severe)				
u. Neck injuries score (1-3)				
v. Carpal injuries score (1-3)				
w. Hock injuries score (1-3)				
x. Mastitis (absent, mild or severe)				
y. Subclinical mastitis (CMT)	*LF__RF__* *LB__RB__*	*LF__RF__* *LB__RB__*	*LF__RF__* *LB__RB__*	*LF__RF__* *LB__RB__*
z. Milk production yesterday (kg/day)				

aa. Yesterday was typical day for milk?				

2a. How many of the given recommendations did you complete?

a. none b. some d. most e. all

2b. If none, why not?...

3. How well do you feel you completed the given recommendations?

a. fair b. good c. very good d. excellent

4a. Were there any recommendations that were harder to complete than others?

Yes…… No……

4b. If yes, which ones?............................

5. When did you start making the recommended changes made? Within…

a. 1 day b. 1 week c. 1 month

6. How long did it take to make all the changes to the milking cow stalls?

a. a few hours b. 1 day c. a few days d. 1 week 3. More than a week

7. What are the challenges you encountered in making the changes?

____

8a. Were there financial costs to make these changes? Yes…… No……

8b. If yes, how much?..

9a. Do you think you are well versed with the cow comfort requirements now? Yes… No…

9b. If yes, have you advised anyone else? Yes……. No……….

9c. If no, why not?...

Detailed assessment:

Type of Change Recommended	a. Recommendation made 0. None 1. Minor 2. Major	b. Recommendation compliance 0. Not done 1. Done partly 2. Done well	c. Score (equals a. times b.)
10.Roof water			
11.Surface Water			
12.Floor soft/dry			
13.Floor flat			
14.Total width			
15.Total length			
16. Leg space			
17.Lunge space			
18.Neck rail			
19.Brisket board			
20.Alley clean			
20.Sharps fix			

Appendix K: Contributions provided to the Queen Elizabeth II Diamond Jubilee Scholarships (QES) project led by the University of Prince Edward Island (UPEI), and contributed by the QES partners:

This appendix provides details of the contributions of the five main partners associated with the QES project led by UPEI and located in Kenya. The UPEI contributions were partially supported by QES funding ($499,842). Canadian Queen Elizabeth II Diamond Jubilee Scholarships are managed through a unique partnership of Universities Canada, the Rideau Hall Foundation (RHF), Community Foundations of Canada (CFC) and Canadian universities. This program is made possible with financial support from the Government of Canada, provincial governments and the private sector.

A. University of Prince Edward Island (UPEI) resources provided to the QES project

UPEI is a small but growing university in the province of Prince Edward Island in eastern Canada with a reasonably broad array of tertiary education programs, including programs in the Department of Health Management at the Atlantic Veterinary College, and in the Department of Applied Human Sciences in the Faculty of Science. From 2015 to 2018, UPEI provided the following resources to the QES project. These resources, in conjunction with other resources from other QES project partners, helped to achieve the QES project objectives.

Resources to Naari Dairy Farmers Cooperative Society Ltd. and members

- Training on cattle health management, in general, and in dairy cattle nutrition, reproduction and cow comfort specifically
- Training on cattle health management, medicine and surgery with Naari Dairy veterinary technician
- Arranged for interactions between QES interns and Scholars in Naari and Veterinarians without Borders veterinarians and interns from various locations including Wakulima Dairy
- Motorcycle for Naari Dairy veterinary technician, cost-shared with Naari Dairy
- Veterinary medicine and equipment and bonus for the Naari Dairy veterinary technician
- Leguminous shrub seedlings for augmenting cattle nutrition to Naari Dairy farmers
- Semen and semen storage equipment for Naari Dairy, cost-shared with Naari Dairy
- One silage chopper, cost-shared with Naari Dairy, and silage materials
- Dairy Health Management Handbooks (content)

Resources to Two Naari Women's Groups

- Face-to-face training on family nutrition
- Trained peer-nutrition trainers called "Champs"
- Provided nutrition training resources
- Cell phone text messaging on family nutrition
- Honoraria (maize, beans, cooking oil, cattle dewormer) for members participating in research projects
- Solar lights (with capacity to charge cell phones) to 24 members of a Naari women's group
- Funding for a tree seedling greenhouse and resources to grow leguminous shrub seedlings for augmenting cattle nutrition to Naari Dairy farmers

Resources to nine Naari area schools

- Nutritional quality assessment of school meals
- Reports for schools regarding the nutritional quality assessment of school meals, and recommendations and goal setting for nutritional enhancement of the school meals
- Nutrition education seminars for parents

In addition to these specific funds for the Naari Dairy, two Naari women's groups, and 9 Naari schools, UPEI also funded, either through QES funding or UPEI funding, general project costs.

- Selection of QES Scholars
- Training of QES Scholars and Interns
- Orientation and supervision of QES Scholars and Interns
- Management of the QES project
- Transportation costs to and from Kenya, and in Kenya for QES Scholars, Interns and supervisors
- Accommodation and food costs in Kenya for QES Interns and supervisors
- Living stipend costs in Canada and in Kenya for QES Scholars
- Tuition and other registration fees for QES Scholars

B. Farmers Helping Farmers (FHF) resources provided as part of the QES project

FHF is a Canadian based non-profit organization based in Prince Edward Island with a longstanding presence working with Kenyan farmer groups. From 2015 to 2018, FHF provided the following resources to the QES project. These resources, in conjunction with other resources from other QES project partners, helped to achieve the QES project objectives.

Resources to Naari Dairy Farmers Cooperative Society Ltd. and members

- Regular training on milk quality and milk production by FHF staff : Stephen Chandi and Leah Kariuki
- Training on bookkeeping with Dairy directors and groups
- Arranged for guidance from Wakulima Dairy on setting up a Savings and Credit Cooperative (SACCO)
- Two silage choppers, cost-shared with Naari Dairy
- Computers and printer to prepare monthly income statements for members of Naari Dairy
- Funds for a revolving cow loan program to lend money for a cow to needy youth and women
- Dairy Health Management Handbooks (content and printing)

Resources to Two Naari Women's Groups

- Horticultural extension support including:
  - Training on how to install and manage drip irrigation
  - Training in composting and soil tillage
  - Training in the use of recommended inputs, including establishing a small nursery to grow seedlings
  - Training in disease and insect control, etc. in gardens
- Training in book-keeping and provided book-keeping booklets
- Dairy production extension support from Leah Karioki and Stephen Chandi, including agronomy and milk quality
- Water tanks, drip irrigation and inputs for a vegetable garden for 45 women's farms
- Solar lights (with capacity to charge cell phones) for 35 members of a women's group in the Naari area

Resources to seven Naari area schools

FHF has established healthy school lunch programs at each of the following schools. School vegetable gardens and water tanks were funded and installed by FHF. Horticultural supports were provided by FHF staff in Kenya. With maize and beans from parents with children attending the school, and food from the school garden, lunches were prepared in a new cookhouse. The cookhouse and a gardener were funded by the Souris Village Feast in PEI.

In addition to these specific funds for the Naari Dairy, two Naari women's groups, and 7 Naari schools, FHF also assisted in:

- Selection of QES Scholars and Interns
- Training of QES Scholars and Interns
- Orientation and supervision of QES Scholars and Interns
- Management of the QES project
- Transportation costs in Kenya for QES Scholars, Interns and supervisors

C. Naari Dairy Farmers Cooperative Society (NDFCS) resources provided for the QES project

NDFCS is a cooperative located in Naari within Meru County of Kenya. It purchases milk from cooperative members, and sells the milk either retail or to a processor, either chilled or not chilled. From 2015 to 2018, NDFCS provided the following resources to the QES project. These resources, in conjunction with other resources from other QES project partners, helped to achieve the QES project objectives.

- Orientation and supervision of QES Scholars and Interns
- Providing board members to help locate farms
- Training of QES Interns
- Management of the QES project
- Training of farmer members on cattle health management, medicine and surgery, through the veterinary technician
- Cost-sharing of the motorcycle for the veterinary technician
- Cost-sharing of semen and semen storage equipment and silage choppers

D. University of Nairobi (UoN) resources provided for the QES project

UoN is a large university in Nairobi, Kenya, with a broad array of tertiary education programs, including veterinary medicine in the Faculty of Veterinary Medicine. From 2015 to 2018, UoN provided the following resources to the QES project. These resources, in conjunction with other resources from other QES project partners, helped to achieve the QES project objectives.

- Selection of QES Scholars

- Training of QES Scholars and Interns
- Orientation and supervision of QES Scholars and Interns
- Management of the QES project

E. Kenyatta University (KU) resources provided for the QES project

KU is a large university in Nairobi, Kenya, with a broad array of tertiary education programs, including programs in the Department of Community Resource Management and in the Department of Foods and Nutrition, both in the School of Applied Human Sciences. From 2016 to 2018, KU provided the following resources to the QES project. These resources, in conjunction with other resources from other QES project partners, helped to achieve the QES project objectives.

- Selection of QES Scholars
- Training of QES Scholars and Interns
- Orientation and supervision of QES Scholars and Interns
- Management of the QES project