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Impact of calf housing improvement and farmer training on finances, management and animal welfare perceptions of Kenyan smallholder dairy farmers

Kimeli Peter[1,2*], VanLeeuwen John[1], Gitau George[2], Heider Luke[1], McKenna Shawn[1] and Greenwood Spencer[3]

[1]Department of Health Management, Atlantic Veterinary College, University of Prince Edward Island, Canada.
[2]Department of Clinical Studies, Faculty of Veterinary Medicine, University of Nairobi, Kenya.
[3]Department of Biomedical Sciences, Atlantic Veterinary College, University of Prince Edward Island, Canada.

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This study estimated the changes in economics and farmer perceptions towards calf welfare as a result of implementing low-cost calf housing enhancements and changes in calf management on Kenyan smallholder dairy farms. The trial involved 187 heifer calves from 150 farms allocated to either an intervention or control group. The interventions were improvements on the floor and roof of the calf housing, and training for the farmers on calf care. Animal- and farm-level characteristics were collected every two months over a 16-month period. Data gathered from questionnaires on the first and sixth visits were used to determine changes in calf management and farmer perceptions on calf welfare pre- and post-intervention. Partial budgeting was used to assess the additional costs and benefits associated with the intervention for heifer calves from birth to 15 months old. The net financial return of undertaking the housing and management improvements was positive at Ksh 6,594 (USD 65.94) per heifer, based on having a larger heifer at 15 months, reduced bedding and medical care costs, and lower risk of death. It is thus concluded that calf housing improvements and on-farm training on calf care are cost-effective and improve management and calf welfare perceptions of farmers.

Key words: Heifer, partial budget analysis, zero-grazing.

INTRODUCTION

Smallholder zero-grazing dairy farming varies considerably in housing design and management practices across Kenya (Nguhiu-Mwangi et al., 2013). Sub-optimal performance in Kenyan smallholder dairy herds is mainly attributed to infectious diseases as well as poor nutrition and housing (Aleri et al., 2012).

*Corresponding author. E-mail: pkimeli@upei.ca. Tel: 902-566-0457. Fax: 902-620-5053.

Zero-grazed cattle, especially youngstock, require suitability in housing design, construction, and management because the animals are housed 24 h a day. Additionally, proper housing management enhances sanitation, prevents roof leakage and run-offs, provides comfort to animals, as well as preventing injuries and diseases (Nguhiu-Mwangi et al., 2013).

How farmers support and care for heifer calves significantly influences their growth (Makau et al., 2019a), health (Gitau et al., 1994), and welfare (Kathambi et al., 2018). Kimeli et al. (2021a) revealed that calf housing and management improvements increased daily weight gain by 5.6% in the post-weaning period. Improved animal comfort reduces the stress level in calves, enhances immune function and subsequently increases weight gain (De Paula et al., 2010). Housing improvements, therefore, have a positive impact on calf growth performance.

In developing countries, studies on the effectiveness of training farmers have shown that few programs achieve success because of the tendency toward excessively concentrating on a particular technology transfer (for example via mobile phones), rather than a broader spectrum of farmer training and empowerment methods, including on-farm knowledge dissemination (Oreszczyn et al., 2010). Improving the knowledge of farmers through on-farm training has been reported to be more valuable than the provision of financial support, because it raises both productivity and income (Murshed-E-Jahan and Pemsl, 2011). While different approaches to farmer training have been studied, including the use of mobile phones (Makau et al., 2018), Kathambi et al. (2019) reported that identifying specific on-farm inadequacies and providing a participatory role in management modification led to good acceptance, implementation, and overall animal comfort. Therefore, on-farm farmer training targeted at specific management or facility changes can be a sustainable way of knowledge transfer, attitude change, and enhanced practices.

While building on five freedom provisions of animal welfare, Mellor (2017) has advanced a five-domain model for assessing animal welfare. The model has incorporated four predominantly physical/functional domains of “nutrition”, “environment”, “health” and “behaviour”, and a fifth “mental” domain. The mental domain refers to specific subjective experiences (affects or affective states) related to how an animal feels, and can be negative or positive (Webb et al., 2019). Such affects may include anxiety, fear, panic, frustration, anger, helplessness, loneliness, boredom, and depression (Mellor, 2016). Little research has been conducted on smallholder dairy farmers’ perceptions of these affective experiences, and how they relate to housing design and management. However, one would expect that farmers would provide comfortable housing if they believe that animals can feel pain and other affective states similar to people.

Though significant research has been done to demonstrate increased milk yield and improved comfort with enhanced management in cows on smallholder dairy farms (Makau et al., 2019b; Kathambi et al., 2019), little is known about the economic effects of improved calf care. The housing environment is second to nutrition when it comes to achieving improved growth, health and welfare (Costa et al., 2019). Knowing that smallholder farmers suffer scarcity of resources, demonstrating economic benefits of management changes through partial budgeting to care for animals better through improved housing can be very effective. There were no published estimates of the economic effects of improved calf housing for calves and heifers on smallholder dairy farms in the tropics.

This study was designed to firstly estimate the economic effect of implementing low-cost housing enhancements and change in management when raising a 15-month heifer (the desired age at first breeding if large enough); and secondly to determine farmer perceptions towards affective welfare on Kenyan smallholder dairy farms. Understanding the magnitude of changes in farmers’ perceptions and practice changes over the study would be a useful adjunct to financial implications of housing improvements in planning future farmer training to improve overall calf/heifer care (Wambui et al., 2018).

MATERIALS AND METHODS

Ethical approval

This study was approved by the Research Ethics Board and the Animal Care Committee of the University of Prince Edward Island (REB Ref # 6007717). The study was fully explained orally to all participants, and signatures for informed consent were obtained from all participants.

Description of the study area

The study was carried out in 150 farms between July 2018 and February 2019 from two neighboring counties in central Kenya: Kiambu (75 farms) and Murang’a (75 farms) (Figure 1). The two counties were purposely selected due to the immense growth in dairy farming and their proximity to our partner research institution. These counties experience an average annual environmental temperature of about 18-20°C, and a mean average rainfall of 962-1195 mm. Murang'a has an estimated human population of 1,056,640 (KNBS, 2019) and an area of 2,558.8 km², with an altitude of between 914 and 3,353 m above sea level, while Kiambu has an estimated population of 2,417,735 (KNBS, 2019) with an area of 2,543.5 km² and an altitude of 1200 to 2550 m above sea level. The region has experienced considerable development in dairying due to its ready access to a large urban market (particularly Nairobi city) and the existence of local milk processing facilities.

Study population and data collection

Inclusion criteria for 150 study farms included: 1) being in the target county; 2) having at least one newborn heifer calf aged less than six weeks; 3) practicing zero-grazing; and 4) having less than ten milking cows (cut-off for smallholder dairy farms). The smallholder dairy farms were recruited for a controlled trial, in which housing improvements for calves and heifers were implemented at the start of the trial on intervention farms in Kiambu County, and at the end of the trial on control farms in Murang'a County. At the first visit, 117 farms had one calf while 29 and 4 farms had 2 and 3 calves, respectively. Also, the 75 farms in Murang'a and Kiambu had 89 and 98 animals, respectively. The number of study farms and candidate calves decreased in subsequent visits, such that only 91 farms were visited six times during this study, primarily because recruitment took longer than expected, leading to 40 farmers not starting soon enough to allow six visits two months apart. Other minor reasons for lost visits included farmer relocation (n=4), voluntary withdrawal from the study (n=5), animal death (n=16), and sale of the trial animal (n=22).

Housing structural improvements administered to intervention farms by the researchers included: 1) filling floor holes if the calf was on the ground or repairing broken wooden slats if the calf was on an elevated floor; 2) the introduction of rubber mats on the lying area; 3) ensuring a floor gradient for drainage, and 4) patching leaking roofs. For the 75 intervention farms, all were provided with the rubber mat for the enrolled calf, and all required levelling of the floor gradient, although only 59% of farms required holes or slats to be fixed. One third of farms required roof repairs. Also, farmers were trained on general care of heifer calves targeted at nutrition, disease control, and affective experiences (how an animal feels). Recommendations on the use of bedding (for example sawdust), were given to intervention farms to maintain flooring dryness only because of the rubber mats (2 kg/day/animal); this was approximately half of the amount recommended (anecdotal evidence from local farmers using mats) for both dryness and softness (4-5 kg/day/animal).

Each study animal was routinely monitored every two months for up to 6 farm visits from July 2018 to October 2019. Data on animal and farm characteristics pre-intervention were collected using a face-to-face questionnaire to determine that the two study groups were similar at the start of the trial (Tables 1 and 2). On each farm visit, study animals underwent clinical examinations, and data were collected on farm management practices, health, and veterinary interventions. Bodyweight (kg) via girth measurements (cm) was recorded at recruitment and during all visits using a girth measuring tape.

Data on farm specific management practices for calves and heifers for this study were also acquired using a face-to-face questionnaire (with the principal farmer) on all enrolled farms before the invention started (visit 1), and on all farms that completed the sixth planned visit of the intervention. The questionnaire themes included: age at concentrate introduction, concentrate amount per day at weaning, age and frequency of anthelmintic and acaricide application, frequency of manure removal from the pen, and amount of colostrum fed in the first 6 h (Tables 3 and 4). Also captured were Likert scale data on farmers' perceptions of animals' affective experiences, such as pain, loneliness, boredom, fear, anger, happiness, and animals' right to live in a clean and comfortable environment (Table 5).

Data management and statistical analysis

Data were entered into MS Excel 2010 (Microsoft, Sacramento, California, USA), cleaned and coded. Descriptive statistical analysis (summarizing means, and standard deviation) was done for continuous variables. Categorical variables were also summarized using percentages. Analysis for statistically significant ($P \leq 0.05$) differences in means between the intervention and control groups, and between pre- and post-intervention data within groups, was performed using Student's t-tests and paired t-tests, respectively, while chi-squared tests were used for differences in percentages. Significant differences among Likert responses were determined using the test of proportion (z statistic). All statistical analyses were conducted in in STATA (version 15.1, Stata Corp., College Station, TX).

Partial budget analysis was used to estimate the benefits (additional revenues and costs no longer incurred) and costs (additional costs and revenues foregone) of implementing the intervention over the first 15-month period of a calf's life. The analysis was done at the animal level based on Rushton et al. (1999). All financial calculations are presented in Kenyan shillings and US dollars (conversion rate USD 1= Ksh 100), using market prices at the time of the study. Where a benefit or cost has a subjective element, an expert panel was utilized to assist in the subjective estimate. The expert panel comprised of 1) an experienced smallholder dairy farmer; 2) a cattle dealer involved in buying and selling cattle; and 3) an experienced area veterinarian.

The average mortality cost savings per farm were derived from the difference between the number of dead calves for the intervention and control groups (11-5=6) multiplied by the possible sale price of heifers at 5 months (6 calves * Ksh 20000 (USD 200.00) = 120, 000 (USD 1200.00)), divided by the 75 farms (Ksh 120,000 (USD 1200.00)/75= Ksh 1600 (USD 16.00)/farm). The mean concentrate intake during the 3.4 weeks was 1.15 kg/d ((0.5 + 1.8) / 2) multiplied by 3.4 wk * 7 d), costing Ksh 876.8 (USD 87.48) (27.4 kg * Ksh 32 (USD 0.32) / kg). The total benefits (Ksh 11,450 or USD 114.50) of the intervention were calculated as the sum of the additional revenue and costs no longer incurred. The total costs (Ksh 4,856 or USD 48.56) were the sum of the foregone revenues and additional costs. The net benefit of the intervention was calculated as the difference between the total benefits and total costs.

RESULTS

Animal and farm characteristics

There was no baseline difference between intervention and control groups in the number of adults per household, age of principal farmer, years of experience in dairy farming, overall proportion of income from dairy farming, floor area of the calf pen, average weaning age, calf age at enrolment, gender/marital status of the principal farmer, previous attendance at dairy training, calf breed and dam parity number (Tables 1 and 2). Only the gross income from milk sales and herd size were significantly different between the two groups (Table 1).

Effects of the intervention on farm practices and farmer perceptions

The calf management characteristics that were the focus

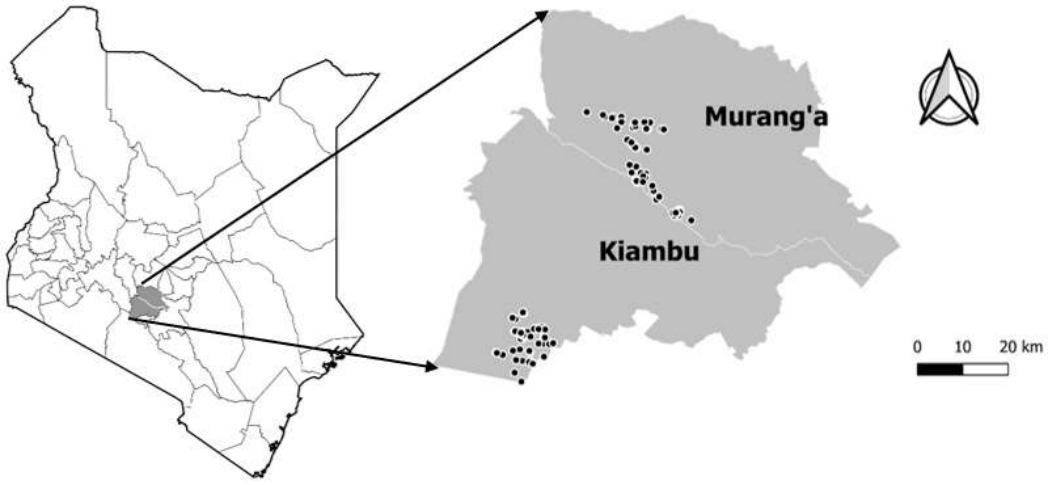

Figure 1. Map of Kenya showing households that were visited in Kiambu and Murang'a Counties in our study on 150 smallholder dairy farms.

of attention during the intervention program demonstrated statistically significant improvements in the intervention group compared with the control group (Table 3). Of the intervention farms, the frequency of daily manure removal from the calf-pen increased from 43 to 98%, while giving calves more than 3 liters of colostrum in the first 6 hours increased from 50 to 59%, and both were statistically significant (Table 4). Furthermore, intervention farmers were advised on other calf management practices during the study, and as a result, there was a significant reduction in age at the first introduction of concentrate, an increase in the amount of concentrate offered to calves at weaning, and an increase in the age of calves at first anthelmintic and acaricide application on the intervention farms (Table 3).

Overall, most of the farmers strongly agreed with statements regarding perceptions towards animal affective experiences in both the control and intervention farms at pre- and post-intervention (Table 5). While the responses from the control group stayed the same from start to finish of the trial, the intervention group demonstrated a statistically significant increase over time in the proportion of farmers strongly agreeing with the statements regarding calves and heifers feeling pain, loneliness, boredom, fear and anger.

Financial analysis

Results showed that the birth weight averaged 43.7 kg (estimates based on the weight of Friesian calves that were less than three days old) with preweaning (≤90 days) and post-weaning growth rates of 0.32 and 0.51 kg per day, respectively. It also showed that the intervention increased daily weight gain post-weaning by 5.6% compared to the control group, leading to 15-month heifers weighing 266.4 and 256.1 kg for intervention and control calves, respectively. To be ready for first breeding, heifers should be 15 months of age and achieve 60% (270 kg) of the mature body weight (which averaged 450 kg and ranged between 400 and 500 kg). The expert panel consensus indicated that a farmer could be able to sell the 15-month intervention heifer at 266 kg for Ksh 5000 (USD 50.00) more than the 15-month control heifer at 256 kg (additional revenue) (Table 6).

Costs no longer incurred (Table 6) are represented by costs incurred on the control farms but avoided when the intervention was introduced. Such costs in our study included: 1) lower volume of bedding materials (sawdust/ wood shavings); 2) lower veterinary medicine costs; and 3) lower mortality risk compared to control farms, as explained below.

On average, farmers in the control group reported using 70 kg of sawdust/wood shavings per calf per month, which costs Ksh 600 (USD 6.00) per month. With the introduction of a rubber mat, the use of sawdust/wood shavings was reduced by half on most intervention farms, costing the farmer Ksh 300 (USD 3.00) per month. Some farmers completely stopped the use of bedding when the mat was introduced, leading to a lying area that was mostly wet (Table 6).

Regarding veterinary costs, Table 3 shows the significantly delayed first deworming and acaricide application associated with the reduced risk on intervention farms. The education part of our intervention led to an increased age at first deworming by 7.3 weeks,

Table 1. Summary of continuous variables of animal and farm characteristics pre-intervention for 187 calves on 150 Kenyan smallholder dairy farms.

Continuous variable	Intervention Group			Control Group			
	No.	Mean	SD	No.	Mean	SD	*P*-value
Number of adults per household	75	2.6	1.4	75	2.9	1.1	0.204
Age of principal farmer (year)	75	53.1	12.7	75	49.9	12.5	0.131
Experience in dairy farming (yr)	75	19.5	13.7	75	15.5	10.6	0.052
Overall proportion of income from dairy farming (%)	75	47.4	20.8	75	51.4	27.3	0.322
Gross income from milk sales (USD) per month	75	213.8	331.6	75	403.3	403.3	0.003
Floor area of the calf pen (m^2)	75	3.8	6.0	75	4.3	4.6	0.633
Average weaning age (week)	75	13.5	4.9	75	13.2	3.1	0.647
Herd size	75	4.5	3.5	75	6.9	5.3	0.001
Calf age at enrolment (d)	89	26.5	15.7	98	24.8	19.5	0.508

Table 2. Summary of categorical variables of animal and farm characteristics pre-intervention for 187 calves on 150 Kenyan smallholder dairy farms.

Categorical variable	Category	Intervention group % (n/N)	Control group % (n/N)	*P*-value
Gender of the principal farmer	Male	49.3 (37/75)	50.7 (38/75)	0.870
	Female	50.7 (38/75)	49.3 (37/75)	
Marital status of the principal farmer	Married	85.3 (64/75)	88.0 (66/75)	0.571
	Single	8.0 (6/75)	4.0 (3/75)	
	Widowed	6.67 (5/75)	8.0 (6/75)	
Attended any dairy farmers training previously	No	41.3 (31/75)	42.7 (32/75)	0.869
	Yes	58.7 (44/75)	57. 3 (43/75)	
Calf breed	Friesian	94.4 (84/89)	86.7 (85/98)	0.110
	Ayrshire and Jersey	5.6 (5/89)	12.4 (12/98)	
Dam parity number	1	30.3 (27/89)	23.5 (23/98)	0.544
	2	28.1 (25/89)	27.6 (27/98)	
	≥ 3	41.6 (37/89)	49.0 (48/98)	

indicating one less deworming, costing about Ksh 250 (USD 2.50). Also, the age at first acaricide application increased by 7.8 weeks in the intervention group, meaning one less acaricide application, costing about Ksh 100 (USD 1). The cost saved on acaricides and anthelmintics was therefore estimated at Ksh 350 (USD 3.5) per animal for the intervention farms (Table 6).

Regarding mortality risk, our study showed that 12.4% (11/89) of heifer calves died in the control group compared to 5.1% (5/98) in the intervention group. While other factors may have contributed to some of the difference in mortality risk, with the similarities in farm characteristics (Tables 1 and 2), it was assumed that the mortality risk was reduced by 6 calves to our intervention group of 75 farms. The average age at mortality was 20 weeks, and the expert panel suggested that the value of a 20-week-old calf was Ksh 20,000 (USD 200.00).

Additional costs represented those costs of implementing the intervention (Table 6). The project provided the rubber mats and some repair materials where purchases were needed. Much of the repair materials (that is roofing iron sheets, timber, nails) were available on the farm (confirming that the improvements were practical). Both the researchers and farmers provided the repair labor. However, for this financial analysis, we assumed the farmer paid all of these costs. The 3' by 5' rubber mat cost was Ksh 1800 (USD 18.00) (retail market value), and based on our study, the

Table 3. Means (+SD) and differences in calf management characteristics of 91 (Control= 47; Intervention= 44) smallholder dairy farms at pre- and post-intervention visits.

Description	Category	Pre-intervention	Post- intervention	*P*-value
Age at first concentrate feeding (week)	Control	7.3±8.1	7.1±8.1[a]	0.889
	Intervention	5.4±3.9	2.0±1.3[b]	<0.001*
Amount of concentrate given at weaning (kg/d)	Control	0.6±0.8	0.7±0.8[a]	0.711
	Intervention	0.5±0.4	1.8±0.8[b]	<0.001*
Age at first anthelmintic application (week)	Control	15.8±7.5	20.3±27.8	0.286
	Intervention	16.6±11.6	23.9±8.9	0.001*
Interval between anthelmintic application (week)	Control	12.5±7.0	12.9±7.2	0.816
	Intervention	11.2±6.4	12.1±2.2	0.403
Age at first acaricide application (week)	Control	20.2±11.2	20.4±11.1[a]	0.912
	Intervention	20.7±13.4	28.5±11.0[b]	0.004*
Interval between acaricide applications (week)	Control	9.2±5.4[a]	9.6±5.7[a]	0.766
	Intervention	12.8±9.6[b]	15.0±10.1[b]	0.278
Age at weaning (week)	Control	12.3±1.0[a]	12.6±1.6	0.359
	Intervention	13.6±3.8[b]	12.5±1.8	0.103

[a,b] Represent intervention and control groups that are significantly different at either the pre-intervention or post-intervention stage.
*Represent p- value <0.05

Table 4. Proportions and difference in manure and colostrum management of calves in 91 (Control= 47; Intervention= 44) smallholder dairy farms at pre- and post-intervention visits.

Description	Category	Control (n= 47)		Intervention (n=44)	
		Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
Amount of colostrum given in the first 6 h (L)	<2 L (25.3%)	12.8	14.9	38.6	11.4
	2-3L (9.9%)	8.5	17.0	11.4	29.6
	>3 L (64.8%)	78.7	68.1	50.0	59.1
	P-value	0.764		<0.001	
Frequency of manure removal from the calf pen	Every day (27.5%)	12.8	14.9	43.2	97.7
	Thrice a week or less (47.2%)	59.6	63.8	34.1	2.3
	Twice a month or less (25.3%)	27.7	21.3	22.7	0.0
	P-value	0.412		0.005	

average cost associated with the pen repairs was Ksh 500 (USD 5.00) (additional costs (Table 6). There was no cost associated with the management recommendations because that was strictly the researcher's time, and it was assumed that the intervention farmers could access this information from local extension officers, dairy training sessions and/or manuals found online. Based on the calf management training, the intervention farmers reported starting calves on concentrate 3.4 weeks earlier than their pre-intervention timing and 5.1 weeks earlier than the control group farmers post-intervention. Furthermore, the amount of concentrate reported being fed at weaning post-intervention was significantly higher in the intervention group by 1.3 kg/day at 3 months of age. Since there was no difference in these amounts in the control group over time, or between the control and intervention groups per-intervention, the difference over time in the intervention group was utilized for calculations. Using the retail cost of Ksh 32 (USD 0.32) per kg of commercial concentrate for calves, it was

Table 5. Differences in farmer perceptions towards affective welfare in 91 smallholder dairy farms pre- and post-intervention, by intervention and control groups.

Description	Category	Control (n=47)		Intervention (n=44)	
		Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
Calves & heifers can feel physical pain the same as humans	Strongly disagree	0.0	0.0	0.0	0.0
	Disagree	2.1	2.1	0.0	0.0
	Unsure	0.0	0.0	0.0	0.0
	Agree	2.1	2.1	9.1	0.0
	Strongly agree	95.7	95.7	90.9	100.0[a]
Calves and heifers can feel loneliness the same as humans	Strongly disagree	0.0	0.0	0.0	0.0
	Disagree	0.0	0.0	0.0	0.0
	Unsure	8.5	10.6	4.6	0.0
	Agree	2.1	2.1	15.9	2.3
	Strongly agree	89.4	87.2	79.4	97.7[a]
Calves and heifers can feel boredom the same as humans	Strongly disagree	4.3	4.3	0.0	0.0
	Disagree	2.1	2.1	4.6	0.0
	Unsure	4.3	8.5	9.1	0.0
	Agree	6.4	4.3	25.0	6.8
	Strongly agree	83.0	80.9	61.4	93.2[a]
Calves and heifers can feel fearful the same as humans	Strongly disagree	0.0	2.1	0.0	0.0
	Disagree	6.4	0.0	0.0	0.0
	Unsure	2.1	6.4	0.0	0.0
	Agree	2.1	2.1	15.9	0.0
	Strongly agree	89.4	89.4	84.1	100.0[a]
Calves and heifers can feel anger the same as humans	Strongly disagree	0.0	2.1	4.6	0.0
	Disagree	4.3	2.1	6.8	0.0
	Unsure	12.8	12.8	13.6	4.6
	Agree	4.3	4.3	13.6	6.8
	Strongly agree	78.7	78.7	61.4	88.6[a]
Calves and heifers can feel happy the same as humans	Strongly disagree	0.0	0.0	0.0	0.0
	Disagree	0.0	0.0	0.0	0.0
	Unsure	0.0	2.1	0.0	0.0
	Agree	0.0	0.0	0.0	0.0
	Strongly agree	100.0	97.9	100.0	100.0
Calves and heifers have the right to live in an environment that is clean and comfortable	Strongly disagree	0.0	0.0	0.0	0.0
	Disagree	0.0	0.0	0.0	0.0
	Unsure	0.0	0.0	0.0	0.0
	Agree	0.0	0.0	0.0	0.0
	Strongly agree	100.0	100.0	100.0	100.0

[a]Represent pre- and post-intervention proportions of farmers that strongly agreed and are significantly different ($P<0.05$).

estimated that a calf would consume 27.4 kg more over the additional 3.4 weeks (assuming the 1.3 kg increase in concentrate from 0.5 to 1.8 kg/d over the 3.4 weeks would occur gradually.

Foregone revenues represented the revenue available to the control group that was lost in the intervention group

Table 6. Partial budget analysis (in Kenya Shillings as of May 2020) and overall financial returns per animal unit for the first 15 months of life due to housing improvement.

Benefit	Quantity	Ksh/ Unit	Total	Costs	Quantity	Ksh/ unit	Total
Additional revenues				**Additional costs**			
Extra income from mature healthy heifer at 15 months	1 heifer[a]	5000/ heifer	5000	Rubber mat (5 by 3 feet)	1 mat	1800	1800
				Housing repair materials and labour	1 unit[c]	500	500
				Extra calf meal	33 kg	32	1056
Costs no longer incurred				**Revenues foregone**			
Beddings saved per month, such as sawdust, wood shavings	15 months	300	4500	Reduction in saleable manure per month	15 Months	100	1500
Purchase of acaricides and anthelmintics	1 calf	350	350				
Mortalities avoided	1 calf[b]	1600	1600				
Total benefit			11450	Total cost			4856
Net benefit (cost)			6594				

[a]Represents the added value from one heifer. [b]Represents the portion of a dead calf avoided per farm, on average. [c]Represents the average additional costs per farm.

when the intervention is implemented. In our case, the reduced use of bedding materials, such as sawdust/wood shavings, on the intervention farms meant that the quantity of bedding/manure mix was reduced by half. Therefore, the income from the sale of the bedding/manure mix would be reduced by half. The expert team estimated that an animal from birth to 15 months would produce manure that can be sold at Ksh 3000 (USD 30.00) in total; thus, half of it would be Ksh 1500 (USD 15.00) (Table 6).

Overall, a net profit of approximately Ksh 6594 (USD 65.94) per heifer was accrued because of undertaking the specific housing improvements and farmer training on the smallholder dairy farms (Table 6).

DISCUSSION

Effects of the intervention on farm practices and farmer perceptions

The observed changes towards early introduction of concentrate (for example calf starter with at least 18% protein) to heifer calves, and increased quantity of concentrate eating at weaning, are positive changes towards improving calf nutrition and growth. In a related study, it was reported that the early introduction of commercial concentrate supplements significantly improved daily weight gain (Kimeli et al., 2021a). This improved weight gain is explained by hastening rumen papillae development, which accelerates nutrient absorption to enhance growth (Reddy et al., 2017). The increased amount of concentrate at weaning provided a supplemental protein source at the time when milk feeding was being withdrawn.

The delay in anthelmintic and acaricide treatments to calves is a strategic decision towards minimizing unnecessary costs. In a related study (Kimeli et al., 2020), it was reported that helminths and tick infestations were not a threat to the zero-grazed heifer calves at less than one-year-old. It is believed that the prudent reduction in anthelmintic and acaricide use was observed in the intervention group of this study and would lower the costs of the farm operation. The conservative estimates utilized in the partial budget for these lower costs were based on the average delays as reported in Table 3, but there could be even higher cost savings (higher net benefit) if delays to 1 year of age in zero-grazed calves was included.

The increase in both the amount of colostrum fed to calves in the first 6 hours and the frequency of manure removal from the calf-pens suggests a deliberate decision to strengthen calf immunity and improve hygiene. A study on gastrointestinal parasites (Kimeli et al., 2020) reported an association between coccidia infection and hygiene status of the calf housing, which implies that poor sanitation in the calf housing areas increases calf exposure to coccidia oocysts. Adequate and timely ingestion of high-quality colostrum is the most critical factor affecting both short- and long-term performance of calves, as it significantly impacts the passive transfer of immunity and calf ability to overcome

early infections (Williams et al., 2014).

Most (> 61 %) farmers strongly agreed with statements relating to affective experience in calves and heifers (Table 5). However, intervention farms showed a consistent increase in proportions strongly agreeing post-invention compared to pre-intervention, implying that farmers' views on animal affective experience improved during the course of the intervention. These changed perceptions could partly explain the positive impacts of how the farmers cared for their calves and heifers (Tables 3 and 4). For instance, frequency of manure removal was significantly ($p<0.05$) associated with farmer perception of calves and heifers feeling pain and hunger. Farmer perceptions have been shown to affect how farmers treat their animals and the environment they provide their animals, which can impact productivity (Kauppinen et al., 2013).

Future research should explore whether these perceptions are long-lasting, and if so, whether the improved care is also long-lasting.

Financial analysis

The financial analysis (Table 6) comparing the presence or absence of intervention effects on calf performance showed a net benefit, which indicated that the implementation of housing improvements and specific calf management from the time a calf is born has financial benefits to the farmer. The higher daily weight gain, reduced use of other bedding materials, reduced cost of veterinary service and medicines, and decrease in mortality in the intervention group implies that housing improvements for newborn heifers have economic benefits. The most substantial savings were due to a decrease in requirements of bedding materials such as sawdust or wood shavings. Elsewhere, improved hygiene in calf pens as a result of housing upgrades had far-reaching effects in optimizing growth and reducing disease and deaths (Fentie et al., 2020). Gitau et al. (2010) identified gastrointestinal and respiratory conditions as a leading cause of calf mortality in the Nairobi peri-urban area, and suggested suitable housing as a possible remedy. It is, therefore, clear that improved management approaches have a significant benefit on the overall performance of heifer calves (Santos and Bittar, 2015).

Building a modern dairy unit is not a suitable option for smallholder dairy farmers as they struggle with a scarcity of resources and underperformance (low milk yield) (Kilungo, 1999). Therefore, low-cost and uncomplicated housing improvements should be considered, coupled with better management. Many study farmers reared their calves in either a makeshift or old dilapidated pens with a damaged roofs and uncomfortable flooring. Rubber mats have the benefit of increasing the softness of flooring and reducing the adverse effects of hard flooring (Norring et al., 2010). Additionally, good quality rubber mats can last for years and provide useful benefits to calves, while reducing bedding and wooden floor repair costs. The need to combine bedding, such as wood shavings, to the rubber mats to reduce wetness was observed; dryness should be emphasized for maximum welfare benefits when using rubber mats.

The intervention started with improvements for the newborn heifer calf to ensure steady growth pre- and post-weaning, to hopefully achieve target live weights at first insemination and first calving. Additional benefits from the intervention would likely be improved lifetime productivity of the cow, and long-term returns from the intervention investment. Undersized heifers can lead to low first-service conception rates and increased calving difficulties, and reduced life-time milk production (Wathes et al., 2014). Furthermore, small heifers may even be culled for poor performance post-calving, and all of these productivity concerns could potentially be costs no longer incurred with a successful intervention. As a result, it is likely that the net benefit in our study is an underestimation. Quantifying additional revenue due to improved early conception and milk yield at calving would be an opportunity for future research.

This partial budget focused on the financial costs and benefits of the intervention, but clearly, there were also non-financial benefits of the intervention. Based on the changed perceptions toward affective welfare of the calves among the intervention farmers, there would be some welfare improvements from the intervention. Some of these welfare benefits, such as increased lying time, improved floor cleanliness and better animal hygiene scores, have been documented by Kimeli et al. (2021b).

As a limitation to our study, there were losses to follow-up both in the intervention and control groups, reducing the final sample size and power of this study. The reasons for farmers not completing the study were farmer relocation, voluntary withdrawal from the study, animal death, sale of animal, and late enrolment. However, none of these reasons was deemed to have biased the study results because the lost animals and farms were unrelated to the factors and outcomes examined. Nonetheless, the reduction of the sample size might have had an impact on the power of the study, but it is believed that there was adequate statistical power.

Regarding another possible limitation, the respondents may have agreed to perception issues because they thought the responses were what they were supposed to answer, leading to a possible social desirability bias. However, the improvements in perceptions in the intervention group would not likely be related to this bias.

CONCLUSIONS AND RECOMMENDATIONS

The benefits clearly outweighed the intervention costs of

the housing improvement and calf care recommendations during the first fifteen months of a heifer calf's life on the smallholder dairy farms in Kenya. The perceptions of the farmers towards animal affective experiences also improved during the intervention, and this should continue to lead to better management, growth, and improved incomes to the farmers. The intervention should be considered by farmers, veterinarians and extension service providers. Further research to quantify the long-term effects of the improved housing, farmer training and affective perceptions on reproduction indices and lactation performance is recommended.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Aleri JW, Nguhiu-Mwangi J, Mogoa EM, Mulei CM (2012). Welfare of dairy cattle in the smallholder (zero-grazing) production systems in Nairobi and its environs. Livestock Research for Rural Development 24:159. http://www.lrrd.org/lrrd24/9/aler24159.htm

Costa JHC, Cantor MC, Adderley NA, Neave HW (2019). Key animal welfare issues in commercially raised dairy calves: social environment, nutrition, and painful procedures. Canadian Journal of Animal Science 99(4):649-660. https://doi.org/10.1139/cjas-2019-0031

De Paula VA, Von Keyserlingk MAG, Weary DM (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(7):3079-3085. https://doi.org/10.3168/jds.2009-2516

Fentie T, Guta S, Mekonen G, Temesgen W, Melaku A, Asefa G, Tesfaye S, Niguse A, Abera B, Kflewahd FZ, Hailu B, Begna F, Worku Z (2020). Assessment of major causes of calf mortality in urban and peri-urban dairy production system of Ethiopia. Veterinary Medicine International 3075429. https://doi.org/10.1155/2020/3075429

Gitau GK, Aleri JW, Mbuthia PG, Mulei CM (2010). Causes of calf mortality in the peri-urban area of Nairobi, Kenya. Tropical Animal Health and Production 42(8):1643-1647. https://doi.org/10.1007/s11250-010-9614-2

Gitau GK, McDermott JJ, Waltner-Toews D, Lissemore KD, Osumo JM, Muriuki D (1994). Factors influencing calf morbidity and mortality in smallholder dairy farms in Kiambu district of Kenya. Preventive Veterinary Medicine 21(2):167-177. https://doi.org/10.1016/0167-5877(94)90005-1.

Kathambi EK, VanLeeuwen J, Gitau GK, McKenna SL (2018). A cross-sectional study of the welfare of calves raised in smallholder dairy farms in Meru, Kenya. Veterinary World 11(8):1094-1101. https://doi.org/10.14202/vetworld.2018.1094-1101

Kathambi EK, VanLeeuwen JA, Gitau GK, Revie CW (2019). Assessment of farmers' compliance in implementing recommended cow comfort changes and their effects on lying time, stall and cow cleanliness within smallholder dairy farms in Kenya. Preventive Veterinary Medicine 172:104784. https://doi.org/10.1016/j.prevetmed.2019.104784

Kauppinen T, Valros A, Vesala KM (2013). Attitudes of dairy farmers toward cow welfare in relation to housing, management, and productivity. Anthrozoos 26(3):405-420. https://doi.org/10.2752/175303713X13697429463718

Kilungo JK (1999). An economic analysis of smallholder dairy production in Kiambu district, Kenya. Ph.D. thesis, University of Nairobi, Kenya. http://erepository.uonbi.ac.ke/handle/11295/24377.

Kimeli P, VanLeeuwen J, Gitau GK, Heider LC, McKenna SL, Greenwood SJ, Richards S (2021b). Evaluation of environmental and comfort improvements on affective welfare in heifer calves on smallholder dairy farms. Preventive Veterinary Medicine 189:105296. https://doi.org/10.1016/j.prevetmed.2021.105296

Kimeli P, VanLeeuwen J, Gitau GK, Heider LC, McKenna SL, Greenwood SJ (2020). Management factors associated with time-to-onset and fecal egg/oocyst counts of gastrointestinal parasites in heifer calves on Kenyan smallholder farms. Veterinary Parasitology 283:109174. https://doi.org/10.1016/j.vetpar.2020.109174

Kimeli P, VanLeeuwen J, Gitau GK, Heider LC, McKenna SL, Greenwood SJ (2021a). Effect of housing improvements on the growth of heifer calves on Kenyan smallholder farms. Tropical Animal Health and Production 53:120. https://doi.org/10.1007/s11250-020-02548-4.

KNBS (2019). Volume I: Population by county and sub county. Kenya population and housing census. https://www.knbs.or.ke/?wpdmpro=2019-kenya-population-and-housing-census-volume-i-population-by-county-and-sub-county#

Makau DN, VanLeeuwen JA, Gitau GK, McKenna SL, Walton C, Muraya J, Wichtel JJ (2019a). Effects of calliandra and sesbania supplementation on weight gain in dairy calves on smallholder farms in Kenya. Preventive Veterinary Medicine 172:104787. https://doi.org/10.1016/j.prevetmed.2019.104787

Makau D, VanLeeuwen JA, Gitau GK, McKenna SL, Walton C, Muraya J, Wichtel JJ (2019b). Livelihood impacts of Calliandra calothyrsus and Sesbania sesban: Supplementary feed in smallholder dairy farms in Kenya. Journal of Development and Agricultural Economics 11(10):234-246. https://doi.org/10.5897/JDAE2019.1079

Makau DN, VanLeeuwen JA, Gitau GK, Muraya J, McKenna SL, Walton C, Wichtel JJ (2018). Effectiveness of using cellphone technology as a dairy management training tool for smallholder dairy farms in Kenya. Livestock Research for Rural Development 30: 195. http://www.lrrd.org/lrrd30/11/dennm30195.html

Mellor JD (2016). Updating animal welfare thinking: Moving beyond the "five freedoms" towards "a life worth living". Animals 6(3):21. https://doi.org/10.3390/ani6030021

Mellor JD (2017). Operational details of the five domains model and its key applications to the assessment and management of animal welfare. Animals 7(8):60. https://doi.org/10.3390/ani7080060

Murshed-E-Jahan K, Pemsl DE (2011). The impact of integrated aquaculture-agriculture on small-scale farm sustainability and farmers' livelihoods: Experience from Bangladesh. Agricultural Systems 104(5):392-402. https://doi.org/10.1016/j.agsy.2011.01.003

Nguhiu-Mwangi J, Aleri JW, Mogoa EGM, Mbithi PMF (2013). Indicators of poor welfare in dairy cows within smallholder zero-grazing units in the peri-urban areas of Nairobi, Kenya. In: Insights from Veterinary Medicine. InTech. https://www.intechopen.com/books/insights-from-veterinary-medicine/indicators-of-poor-welfare-in-dairy-cows-within-smallholder-zero-grazing-units-in-the-peri-urban-are

Norring M, Manninen E, Passillé AM, Rushen J, Saloniemi H (2010). Preferences of dairy cows for three-stall surface materials with small amounts of bedding. Journal of Dairy Science 93(1):70-4. https://doi.org/10.3168/jds.2009-2164

Oreszczyn S, Lane A, Carr S (2010). The role of networks of practice and webs of influencers on farmers 'engagement with and learning about agricultural innovations. Journal of Rural Studies 26(4):404-417. https://doi.org/10.1016/j.jrurstud.2010.03.003

Reddy KE, Jeong J, Baek YC, Oh YK, Kim M, So KM, Lee HJ (2017). Early weaning of calves after different dietary regimens affects later rumen development, growth, and carcass traits in Hanwoo cattle. Asian-Australas. Journal of Animal Science 30(10):1425-1434. https://doi.org/10.5713/ajas.17.0315

Rushton J, Thornton PK, Otte MJ (1999). Methods of economic impact assessment. Revue scientifique et technique 18(2):315-42. https://doi.org/10.20506/rst.18.2.1172

Santos GD, Bittar CMM (2015). A survey of dairy calf management practices in some producing regions in Brazil. Sociedade Brasileira

de Zootecnia 44(10):361-370. https://doi.org/10.1590/S180692902015001000004
Wambui JM, Lamuka P, Karuri EG, Matofari JW (2018). Animal welfare knowledge, attitudes, and practices of stockpersons in Kenya. Anthrozoos 31(4):397-410. https://doi.org/10.1080/08927936.2018.1482111
Wathes DC, Pollott GE, Johnson KF, Richardson H, Cooke JS (2014). Heifer fertility and carry over consequences for lifetime production in dairy and beef cattle. Animal 1:91-104. https://doi.org/10.1017/S1751731114000755
Webb LE, Veenhoven R, Harfeld JL, Jensen MB (2019). What is animal happiness? Annals of the New York Academy of Sciences 1438(1):62-76. https://doi.org/10.1111/nyas.13983
Williams DR, Pithua P, Garcia A, Champagne J, Haines DM, Aly SS (2014). Effect of three colostrum diets on passive transfer of immunity and preweaning health in calves on a California dairy following colostrum management training. Veterinary Medicine International 698741. https://doi.org/10.1155/2014/698741