Scientific African 12 (2021) e00805

Contents lists available at ScienceDirect

Scientific African

journal homepage: www.elsevier.com/locate/sciaf

Farmers' perception of calf housing and factors influencing its adoption on dairy cattle farms in Uganda

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ARTICLE INFO

Article history:
Received 4 May 2020
Revised 20 May 2021
Accepted 27 May 2021

Editor: DR B Gyampoh

Keywords:
Calf housing
Dairy cattle
Technology adoption
Uganda

ABSTRACT

Calf housing is a significant challenge affecting calf performance. Despite its importance in ensuring optimal calf performance, inadequate housing facilities cause morbidity and mortalities on many dairy farms. This study explores farmer perception of calf housing and factors influencing its adoption on dairy cattle farms in Uganda. A cross-sectional survey was conducted to collect data across four regions of Uganda. Data analysis was through descriptive and inferential statistics (chi-square), and a binary logit model was estimated. Results revealed that 70.8% of farmers provided housing for their calves. Of these, 59.2% constructed permanent while 40.8% constructed temporary structures. Of the farmers who provided calf housing, 54.6% were dissatisfied with the structures' appropriateness in protecting the calves on their farms. Among the variables included in the model, education level, region, and cattle breeding method positively influenced calf housing adoption. On the other side, the number of cattle owned, cattle grazing system, and land tenure system negatively influenced calf housing adoption. Subsequently, increasing literacy levels, possession of a small cattle herd, and private ownership of land with a title deed increase the likelihood of adopting calf housing. In light of these results, we recommend that the promotion of calf housing needs to be sensitive to farmers' demographic and socio-economic characteristics and farm characteristics. Additionally, the provision of farmer education and training should be enhanced to ensure the adoption of calf housing on dairy farms across the country.

1. Introduction

Dairy production in Uganda continues to receive considerable investment support from private and public sectors due to its high potential as a driver to lift the populace from poverty and improve farming households' livelihoods in Uganda. At the farm level, dairy producers face several production and infrastructure challenges, which reduce dairy herds' productivity and result in low enterprise profitability. In commercial dairy production, achieving one calf per year per cow is an essential

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https://doi.org/10.1016/j.sciaf.2021.e00805

measure of its productivity and profitability. However, Mugisha et al. [27] reported that the average calving interval for dairy cows in Uganda is about 14 months. This interval implies that some farmers cannot get a calf per cow per year, which in turn affects the total lactation yield from the cows. Where a dairy farmer achieves a calf, the calf's performance is constrained by several factors, including the lack of proper housing facilities on the farms. However, despite the importance of proper calf housing in ensuring calf performance and survival, inadequate and inappropriate calf housing facilities remain a significant problem undermining calf performance and survival in Uganda. Nalubwama et al. [29] reported that less than forty percent sampled smallholder dairy farmers in Kayunga and Luwero districts provided housing to their cattle.

Moreover, poor calf housing is associated with abnormal calf behavior, health complications, and calf mortalities in worst-case scenarios. In Uganda, calves are often housed in open shelters close to the main cattle shed, which exposes them to unfavorable microclimatic conditions and predisposes them to infections at an early stage. Also, calves are kept in makeshift mud structures, often having dusty floors during the dry seasons or damp floors during the rainy season. Such facilities pre-expose calves to health complications such as pneumonia and several bacterial infections. However, most calves do not survive such infections leading to high calf mortalities and eventually significant losses to dairy farmers aiming to attain a calf per year.

Moreover, the few calves that survive infections often perform poorly [21]**.** This author further noted that pneumonia infections in calves reduce pre-and post-weaning calf growth rates by 18%. As such, the surviving calves take long to achieve the required weight for conception. Also, milk production is delayed and lowered by 5% in cows poorly housed during calf hood, representing considerable losses to dairy farmers [25].

In Uganda, investment in livestock structures, especially proper housing, is still meager on most dairy farms. Like many other agricultural technologies, the adoption of calf housing is still low. Agricultural technology adoption in Uganda is influenced by several factors at different levels of production. Socio-demographic factors like age and education level of household head, size of land owned by household, access to extension services, and credit are critical in decision making [11, 35]. Farm-level factors like ownership of improved dairy cattle breed with higher milk productivity significantly improved the adoption of improved forage technologies among dairy cattle farmers in Uganda's Soroti district [36]. Many factors influence the decision of smallholder dairy cattle farmers to adopt agricultural technologies in Uganda. Ekepe and Tirivanhu [11] reported a positive influence of access to extension service on the adoption of legume-based multiple cropping systems and a negative influence of family size on adopting the same system. However, there is a paucity of literature on the factors that influence smallholder dairy farmers' decision to adopt calf housing. Therefore, the objectives of this article were to explores perceptions of farmers on calf housing and to assess the demographic and socio-economic factors that influence the adoption of calf housing on dairy cattle farms in Uganda. The findings from this study are critical in informing policy regarding essential infrastructure development on dairy farms in Uganda and informing agricultural extension both the public and private sector involved in promoting dairy production on how to promote and improve the welfare of calves on dairy farms. The study will also provide evidence-based data that can inform marketing strategies to be used by sector players while disseminating and promoting different products and services to livestock farming households.

2. Materials and methods

2.1. Sampling procedure and data collection

A multi-stage stratified random sampling strategy was adopted to ensure that a representative sample of dairy cattle farmers was obtained across the country. Four dairy clusters were identified in the first stage, namely the eastern, western, northern, and central clusters based on regional location. From each cluster, three districts were selected with guidance from Heifer project international field technical manager. With the district local government officials' help, three sub-counties with the dairy cattle farmers were purposively selected. A list of dairy cattle farmers collaborating with Heifer International Uganda constituted the sampling frame from each of the three villages sampled per sub-county. Five households were then randomly selected from the list to make a total of 45 respondents per district. Overall, 360 respondents were interviewed. Primary data related to the farm household socio-demographic and economic characteristics were collected using pre-tested questionnaires during face to face interviews in a household survey. A total of 10 trained field research assistants were recruited and trained on administering the study questionnaire. Several quantitative questions were developed to collect primary data from the selected households. The tool was pre-tested in an exploratory survey with a total of 20 dairy farmers in Mukono district. After the pre-test, the tool was refined to ensure accurate data collection.

2.2. Theoretical framework

The adoption of agricultural technologies is a complex process that is influenced by a host of factors. We assume that dairy cattle farmers are risk-averse and will only invest when they expect to maximize returns or utility. Therefore, the farmer is faced with the choice of making optimal investment decisions due to uncertainty about the cost and the performance of the new technology [33]. This study's theoretical framework is based on the expected utility theory (EUT) that assume technology adoption to be based on utility maximization [1]. A dairy farming household will adopt calf housing if the expected benefit (utility) from its construction outweighs the utility of not using it. The expected utility theory allows for the capture of the concept of risk aversion [26], which a key consideration for smallholder dairy producers in the context of this study.

Furthermore, the EUT provides a basis for studying the effect of farm size, risk attitudes, credit constraints, and fixed costs of adoption [23]. As suggested by Kelebe et al. [17], the farmer's choice to adopt calf housing can be represented by y, where y= j if the household is willing to choose the j technology and y = k otherwise. The utility function is given by;

$U_{ij} = U_i$ (y = j), the utility obtained by I household from adopting j technology; $U_{ik} = U_i$ (y=k), the utility obtained by I household from adopting k technology. Therefore, a utility-maximizing household will only adopt the new calf housing technology if the utility from the technology j outweighs that of k; expressed by the function

$$U_i(y = j) > U_i(y = k)$$

2.3. Empirical modeling of calf housing adoption

The decision to adopt a technology or not is a binary decision. As such, a household's technology adoption behavior can be assessed using different econometric techniques depending on the type of outcome and explanatory variables. The commonest of which is the linear probit or logit models. The logit model was used in this study since the dependent variable is a dichotomy, and the independent variables are of any category [16, 37]. Also, the logit model was chosen because it can be applied to non-normally distributed data besides the inverse linear transformation of the logit model can be directly interpreted as a logarithm of the probability. In contrast, the probit's inverse transformation cannot easily be interpreted [19]. The dependent variable took on the value 1 (adopters) or the value 0 (for non-adopters). In this study, Adopters were defined as farmers who provide housing to their dairy calves, while non-adopters were farmers who did not provide housing for the calves. The parameters of the model were estimated using the maximum-likelihood method [14].

The dependent variable is a logit, which is the natural log of the odds. The relationship between the logit and the probability is:

$$logit \ = In\left(\frac{P}{1-P}\right) = \ \alpha \ + \ \beta X \tag{1}$$

Extracting P from this equation, it comes out that

$$P = \frac{exp\ (\alpha \ + \ \beta X)}{1 \ + \ exp\ (\alpha \ + \ \beta X)} \tag{2}$$

Where P is the probability of the event occurring, X are the independent variables, exp is the base of the natural logarithm, and α and β are the parameters to be estimated by the model. The empirical form of the model used in the study is as follow;

$$PrY = \frac{1}{1 \ + \ exp \ --(\alpha \ + \ \beta X)} \tag{3}$$

Where Y is the logit for the dependent variable. The logistic prediction equation for the present study was;

$$\begin{aligned} Y = In(odds(event)) = In(prob(event)/prob(nonevent)) \ = In(prob(event)/[1-prob(event)] \\ = \ \beta_0 \ + \beta_1 \ X_1 + \ \beta_2 \ X_2 + \ .... + \ \beta_n X_n \end{aligned} \tag{4}$$

Where β_0 is a constant term, X_1, X_2, ……, X_n are independent variables likely to affect the probability of adopting calf housing, and β_1, β_2, ……, β_n are the coefficients to be estimated. The dependent variable was modeled as Y = adoption of calf housing = P(Y) = {1, where the farmer provides calf housing, and 0 otherwise}.

The coefficients in this model are tested by the Wald statistics, which has a Chi-square distribution and t statistics. The positive or negative sign of the coefficient β indicates the direction of the relationship between a given independent variable (X) and the dependent variable. In contrast, the odds ratio gives the magnitude of the change in the odds of having the dependent variable event for a one-unit change in the given independent variable.

2.4. Explanatory variables for the adoption of calf housing in Uganda

In this study, we defined adoption as housing provision to dairy calves until the calves were weaned. Agricultural technology adoption studies carried by several authors have shown that demographic and socio-economic characteristics of households have a significant influence on technology adoption in Uganda [35, 37]. While selecting variables to be included in the logit model, an attempt was made to include the most critical factors influencing adoption decisions among dairy cattle farmers in Uganda. From literature review, the factors that affect livestock technology adoption with demographic, socio-economic, and farm specific (Gebremedhin et al., 2003; Lwiza et al., 2017; Mekonnen et al. The full list of determinants of calf housing and their definitions are presented in Table 1.

GENDER: This is represented by a dummy variable that takes on 1 of the household head is male and 0 if female. We hypothesized that gender could have either a positive or negative effect on the adoption of calf housing. In Uganda, labor for dairy production is mostly dominated by women [30], and therefore female household heads would be more willing to adopt calf housing to protect the calves. Meanwhile, males traditionally have a more significant say in the expenditure of

Table 1
Description of explanatory variables for calf housing used in the binomial logit regression model.

Variable	Description	Unit of measure	Variable type	Expected sign
Dependent variable Housing of dairy calves on the farm	Farmer houses dairy calves or not	1=houses dairy calves, 0=does not house dairy calves		
GENDER	Gender of respondent	1= Male, 0=Female	Dummy	+/-
AGE	Age of the respondents	Number of years	Continuous	-
EDUC	Highest education level attained by the household head	1= No formal education, 0= otherwise	Dummy	-
		1= Primary, 0= otherwise	Dummy	+
		1= Secondary, 0= otherwise	Dummy	+
		1= Tertiary, 0= otherwise	Dummy	+
HERDSIZE	Number of cattle kept by the farmer	Number of cattle	Continuous	-
DAIRYEXP	Number of year of keeping dairy cattle	Number of years	Continuous	+
BREED	Breed of dairy cattle kept	1= Local, 0= otherwise	Dummy	-
		1= Exotic, 0= otherwise	Dummy	+
		1= Crossbreed, 0= otherwise	Dummy	+
BREEDMETHOD	Method of breeding used by the dairy farmer on the farm	1= Controlled use of bull, 0= otherwise	Dummy	+
		1= Uncontrolled use of bull, 0= otherwise	Dummy	-
		1 =Artificial insemination, 0= otherwise	Dummy	+
GRAZESYTM	Cattle grazing system practiced by the farmer	1=Free range, 0= otherwise	Dummy	+
		1= Herding, 0= otherwise	Dummy	-
		1= Zero grazing, 0= otherwise	Dummy	+
		1= Tethering, 0= otherwise	Dummy	-
		1= Others, 0= otherwise	Dummy	-
REGION	Region where farm is located	1= Central, 0= otherwise	Dummy	+/-
		1= Eastern, 0= otherwise	Dummy	+/-
		1= Western, 0= otherwise	Dummy	+/-
		1=Northern, 0= otherwise	Dummy	+/-
LANDTEN	Land tenure system	1= Individual with tittle, 0= otherwise	Dummy	+/-
		1= Individual with no title, 0= otherwise	Dummy	+/-
		1= communal with tittle, 0= otherwise	Dummy	+/-
		1= communal with no title, 0= otherwise	Dummy	+/-
		1= others, 0= otherwise	Dummy	+/-
VETSERV	Access to veterinary extension services	1= Veterinary service, 0= No veterinary service	Dummy	+
EXTSERV	Access to extension services	1= Extension service 0= No extension service	Dummy	+
CREDIT	Access to credit	1= Credit access, 0= No credit access	Dummy	+

proceeds from dairy production systems and readily accept calf housing. AGE is presented as a continuous variable in the number of years of the household head. We hypothesize that the farmers' age will negatively influence the adoption of calf housing as older farmers are less likely to take on new technologies than younger dairy farmers [8, 15]. The number of cattle owned (HERDSIZE) is captured as a continuous variable. As the herd size increases, this should positively influence calf housing adoption since the farmers can better invest in managing the replacement stock [12, 13, 15]. Dairy experience (DAIRYEXP) is captured as a continuous variable measured in years. Experience in dairy production is hypothesized to positively influence calf housing adoption [8, 34].

Dairy cattle breed (BREED) is expected to influence the management level needed to maximize breed performance. The coefficients of the different breed were hypothesized to either positively or negatively influence calf housing adoption. The cattle breeding method (BREEDMETHOD) practiced by the dairy farmers can influence investment in improved livestock technologies. The coefficients of different cattle breeding methods were hypothesized to either negatively or positively influence calf housing adoption. The grazing system (GRAZESYTM) reflects the level of investment in livestock management on any farm. Farmers who practice intensive production systems like zero-grazing are more willing to adopt new technologies that maximize utility from the space available on the farm. On the other hand, low input grazing systems can result in low technology adoption because farmers usually have small capital investments in animal production. The coefficients of different grazing systems were hypothesized to either negatively or positively influence calf housing adoption. Region (RE-

GION) variables control the regional effects with their coefficients hypothesized to either negatively or positively influence calf housing adoption. The coefficients of different tenure systems were hypothesized to either negatively or positively influence the adoption of calf housing [35]. Land tenure system (LANDTEN) variables control the land tenure system's influence on adopting calf housing. Secure land tenure systems are hypothesized to positively influence adoption, while non-secure tenure systems are expected to influence adoption negatively (Ayuk, 1997).

Education of household head (EDUC) variables control for the effects of education with their effects hypothesized to influence calf housing adoption among households positively. Previously, education has been shown to positively facilitate agricultural technologies' adoption [35]. Access to veterinary advisory services (VETSERV) is a dummy variable taking on the value of 1 if the farmer has access to veterinary advisory service and 0 if the farmer has no access to the service. Access to veterinary services is hypothesized to positively influence calf housing adoption because the farmer has access to information in improved dairy farms' management [10]. Access to extension service (EXTSERV) is a dummy variable representing whether or not the farmer receives general extension advisory service on their farm. Access to extension service is denoted by a value of 1 and 0 otherwise. It is hypothesized that access to extension services is positively related to adopting calf housing on dairy cattle farms. Access to credit (CREDIT) is a dummy variable with 1 denoting credit availability and 0 denoting no access to credit service. Access to credit is hypothesized to positively influence adoption of calf housing on dairy farms as farmers can gain access to capital to invest in housing infrastructure [5, 10].

2.5. Statistical data analysis

Data editing and coding were carried out before entering the data into the SPSS program for later analysis and export to STATA. After data cleaning, 336 were used for subsequent data analysis. Data were analyzed using several statistical techniques, including descriptive statistics, cross-tabulation, means, t-test, and logistic regression with STATA13.0. The significant association of between adopter and non-adopters and selected demographic, socio-economic, and farm characteristics was examined using the Pearson's chi-square (χ^2) since the variables were either nominal or ordinal while the categories of farmers were either adopters or non-adopters [28]. Also, STATA was used to generate the maximum likelihood coefficients, standard errors, marginal effects, and probability values for the logit model used to fit the data.

3. Results

3.1. Demographic and socio-economic characteristics of surveyed farm households

Cross-tabulation analysis revealed significant relationships between adopters and non-adopter of calf housing with gender, regional, educational level of the household heads, grazing system, and experience in dairy production (Table 2). More females (51.7%) reported housing their dairy calves than male-headed households (37.6%). Northern Uganda had the highest percentage of respondents who reported housing their dairy calves than other regions. On the other hand, the eastern regions had the highest percentage of farmers who did not provide housing to their dairy calves. Data depicts a significant association between education level and calf housing adoption among the surveyed smallholder dairy households. Generally, surveyed farmers' education level was good, with a small percentage (average of 3.6%) who reported not to have acquired any formal education across the two categories of adopters and non-adopters of calf housing. The majority of the farmers (34.5%) who had attained higher levels were adopters of calf housing than only 16.5 % who were non-adopters. Grazing systems practiced by dairy cattle farmers who reported providing housing for their calves were different. The majority of the farmers who provided calves with housing (57.3%) practiced zero-grazing compared to 33.7% of zero grazers who did not provide housing.

More dairy cattle farmers with dairying experience of fewer than 11 years were adopters of calf housing (59.7%), compared to 43.8% of non-adopters. However, farmers with dairying experience of more than 16 years were more non-adopter (43.7%) compared to 28.6% of farmers who had adopted calf housing.

3.2. Calf housing methods among smallholder dairy cattle farmers in Uganda

Among the households which reported providing housing to dairy calves, three major housing systems were identified during the survey, the classification of which is based on the nature and type of construction materials used in making the roof, walls, and the floor of the calf houses. The description of different housing systems and the frequency of their occurrence in the study sites are presented in Table 3. The majority of the farmers reported housing their calves in structures constructed using timber to make the walls and the slated floor.

3.3. Perception of smallholder farmers on the influence of housing on dairy calf performance

There were significant relationships between farmer perceptions on calf housing's influence on calf performance on their farms (Table 4). The majority of adopters (61.5%) and non-adopters (73.4%) tended to agree that calf housing facilities are a challenge that continues to undermine calf performance on their farms. Likewise, most farmers indicated that they were not satisfied with the calf housing facilities on their farms. However, 34.8% of the farmers providing calf housing reported

Table 2
Comparison (χ^2) of demographic and socio-economic characteristics of adopters and non-adopter of calf housing in the study group.

	Dairy calf housing			
	Adopters (N)	Non-adopters (*N*)	χ^2	**P-value (2-sided)**
1. Gender			**4.940**	**0.026**
a) Male	48.3	62.4		
b) Female	51.7	37.6		
2. Age (categories)			**4.720**	**0.317**
a) <30	7.4	11.0		
b) 30-39	25.3	20.5		
c) 40-49	20.3	27.4		
d) 50-59	21.7	24.7		
e) >60	25.3	16.4		
3. Region			**10.636**	**0.014**
a) Central	11.7	12.8		
b) Eastern	26.3	37.2		
c) Western	23.3	30.2		
d) Northern	38.7	19.8		
4. Education level of household head			**10.158**	**0.017**
a) No education	2.5	4.7		
b) Primary	31.9	41.2		
c) Secondary	31.1	37.6		
d) Tertiary	34.5	16.5		
5. Grazing system			**30.293**	**0.001**
a) Free range	28.5	24.4		
b) Herding	6.7	22.1		
c) Zero grazing	57.3	33.7		
d) Tethering	5.9	14.0		
e) Others	1.6	5.8		
6. Experience in dairy production (yrs.)			**13.603**	**0.009**
a) 1-5	29.2	16.3		
b) 6-10	30.5	27.5		
c) 11-15	11.6	12.5		
d) 16-20	8.6	22.5		
e) >20	20.1	21.2		
7. No. of cattle kept[†]	12.2 (1.72)	13.9 (2.94)		**0.6165**
8. No. of goats[†]	11.1 (2.08)	9.8 (1.85)		**0.6690**
9. No. of sheep[†]	4.4 (1.630	6.5 (1.63)		**0.3989**
10. No. of pigs[†]	9.1 (1.48)	6.4 (2.35)		**0.3713**
11. Total land size[†]	12.7 (2.31)	14.7 (2.93)		**0.6396**

N indicates the % of the farm households in each category (with or without calf housing) in a given socio-economic characteristics.
Significant at P<0.05 (two sided).
† Figures in brackets are standard errors of the means

that they were satisfied with the calf housing system and infrastructure. Eighty-four percent of farmers reported housing calves very close to the main cowshed. The opinions of dairy cattle farmers on the importance of a select number of factors on calf growth rate are presented in Table 5. Cross tabulation revealed no difference in opinion in the factors that affect calf growth rates on farms for adopters and non-adopter.

3.4. Determinants of calf housing among smallholder dairy in Uganda

The logit regression model showed that only five variables significantly influenced the household's decision to house calves. The marginal effects of the changes in the independent variable on the probability of calf housing adoption are presented in Table 6. Results indicated that the total number of cattle, region where the farmer was located, education level of the household head, cattle grazing system, and the land tenure system significantly influenced housing (P<0.01). Though not statistically significant, the gender of the household had a positive influence on the adoption of calf housing. Female-headed houses were more likely to provide housing for dairy calves than male-headed households in this study. The household head's age had a positive but non-significant effect on the adoption of calf housing among smallholder dairy cattle farmers.

Generally, the number and breed of cattle kept by a farmer negatively influenced calf housing adoption. The number of cattle (HERDSIZE) and breed of dairy cattle (BREED) kept on farms were significant and negatively associated with the probability of calf housing adoption. Method of cattle breeding (BREEDMETHOD), especially artificial insemination, was significant and positively associated with calf housing adoption. Our findings show that holding other factors constant, artificial insemination increases the probability of calf housing adoption by 13.0% of the marginal effect. The grazing system (GRAZESYTM)

Table 3
Calf housing methods for dairy calves in surveyed smallholder dairy farms in Uganda

Calf housing type	Description	Deficiencies of the housing system	Photo
Brick walled with concrete floor (permanent housing = 97)	• Calves are housed in a well-built shade • However, this housing system has several variations from those which are entirely enclosed to those where the upper part of the structure is open to improve ventilation. • Calves are either housed individually or in a group.	• The system is costly to construct. • The concrete floor does not allow urine to filtrate through. Hence calves usually have to rest and sleep on wet bedding materials. • Due to the wet bedding materials, calves may experience respiratory complications because of the accumulated ammonia in pens.	
Raised with a slatted floor (temporary housing= 135)	• In this type of housing, the pen for a single calf or group of calves is made from timber and other wood materials. • The floor of the pen is raised and made from wooden slates of timber offcuts. • In some instances, the floor is made of grass bedding, although the majority don't have the beddings. The roof is usually made of iron sheets or thatch. • The pen is either constructed as a standalone or constructed with a connection to the main cattle shade.	• Calves are predisposed to diseases. • Calves spend much energy that would otherwise have been used for growth in standing since the floors are usually wet and filthy. • It is, in most cases challenging to clean out the urine and fecal the dropping of the calves from underneath the pen. This results in the accumulation of fecal materials, which encourages the volatilization of urine producing ammonia, which may cause respiratory complications for the calves. • This type of pen provides little protection of the calf from extreme cold weather, especially during the rainy season when temperatures in the night drop to close to 15°C.	 Group calf pen with a slated floor  Individual calf pens with slatted floor

Table 4
Perception of smallholder dairy cattle farmers on the influence of housing on calf performance.

	Perception of farmers on calf housing				
	Undecided	Disagree	Agree	χ^2	P-value
Calf housing facilities on my farm remain a major challenge undermining calf performance	9.5	29.0	61.5	4.778	0.091
I am satisfied with current calf housing on my farm	10.6	54.6	34.8	14.306	0.001
Poor calf housing is associated with abnormal calf behavior and health implications	6.3	9.5	84.2	0.736	0.692
Calves on my farm are often housed in a shelter close to the main animal kraal	7.7	25.2	67.1	8.678	0.013
I need to consistently monitor the bodyweight of my calves to enhance their future productivity	8.4	4.9	86.7	2.342	0.310

Table 5
Opinion of farmers on the factors that affect calf growth among dairy cattle farmers.

		Dairy calf housing			
		Adopters	Non-adopters	χ^2	P-value
Cleaning of the calf premises	Most important	26.4	17.8	3.1063	0.212
	Less important	40.5	38.4		
	Not important	33.1	43.8		
Health management of the calf	Most important	37.9	34.2	2.3906	0.303
	Less important	33.7	27.6		
	Not important	28.4	38.2		
Proper feeding of the calf	Most important	48.2	44.7	0.3246	0.850
	Less important	35.7	36.8		
	Not important	16.1	18.5		
Proper feeding of the nursing cow	Most important	48.8	47.4	0.4396	0.803
	Less important	23.8	27.6		
	Not important	27.4	25.0		
Adequate housing of the calf	Most important	31.1	23.7	1.6548	0.437
	Less important	35.3	42.1		
	Not important	33.6	34.3		

was found to be significant and negatively influencing calf housing adoption. Herding and tethering reduce the probability of calf housing adoption by 30.3 and 53.6 percent, respectively. The region (REGION) where the farm was located was positive and significantly associated with calf housing adoption. Location of a dairy farm in northern Uganda increased the probability of calf housing adoption by 28.6 percent. The land tenure system (LANDTEN) had a significantly negative association with calf housing adoption. The household head's education level (EDUC) was a key determinant of calf housing adoption. Education was positive and significantly associated with calf housing adoption. On average, possession of formal education increases the probability of calf housing adoption by 41.5 percent.

4. Discussion

4.1. Demographic and socio-economic characteristics of surveyed farm households

Our study revealed significant differences between farmers that provide calf housing (adopters) and farmers that did not provide housing (non-adopters) regarding their gender, region, education, grazing systems used for cattle production, and farmers' experience in dairy production. Female-headed households had higher chances of adopting calf housing, possibly because many livestock households, care, and calf management is usually the responsibility of women and girls. Women and girls are usually responsible for calf health and the welfare of calves.

Education is usually associated with higher odds of technology adoption among smallholder farming households. This is because the educated household head can easily follow and comprehend instruction from extension staff or facilitators, enhancing their new technology adoption chances. Since most farmers who did not provide to the calves had also attained formal education and therefore read and write, this implies enormous opportunities for improved adoption of calf housing even among respondents who had not adopted. This implies that the provision of extension services and trainings can

Table 6
Logit regression of socio-economic factors influencing adoption of calf housing among smallholder dairy cattle farmers in Uganda.

Variable	Coef.	Std. Err.	Marginal effects	RobustStd. Err.	P>z	VIF	Tolerance
GENDER							
Female	0.39	0.512	0.054	0.57	0.451	1.27	0.79
AGE	-0.01	0.023	-0.001	0.03	0.724	1.63	0.62
HERDSIZE	-0.05	0.022	-0.007	0.02	0.027**	1.98	0.51
DAIRYEXP	0.04	0.028	0.005	0.03	0.173	1.67	0.60
BREED							
Crossbreed	-1.53	0.845	-0.190	0.99	0.07*	2.84	0.35
Exotic	-0.39	1.026	-0.060	1.12	0.701	2.84	0.35
BREEDMETHOD							
Bull (uncontrolled)	-0.69	0.674	-0.110	0.70	0.307	1.59	0.63
Artificial insemination	0.96	0.546	0.130	0.52	0.08*	1.53	0.65
GRAZESYTM							
Herding	-1.58	0.872	-0.303	0.84	0.07*	1.86	0.54
Zero grazing	-0.61	0.706	-0.084	0.66	0.389	2.30	0.43
Tethering	-2.55	1.072	-0.536	0.85	0.018**	1.81	0.55
Other	5.19	3.314	0.183	2.78	0.117	2.00	0.50
REGION							
Eastern	0.71	0.782	0.097	0.85	0.365	3.02	0.33
Western	-0.16	1.156	-0.023	1.29	0.891	2.75	0.36
Northern	2.98	1.101	0.286	0.91	0.007***	2.81	0.36
LANDTEN							
Individual owned without title deed	-1.61	0.765	-0.192	0.81	0.036**	1.70	0.59
Communal with title deed	-4.33	1.814	-0.777	1.95	0.017**	1.26	0.80
Communal without title deed	-4.44	1.441	-0.791	1.24	0.002***	1.46	0.70
EDUC							
Primary	3.65	1.594	0.405	1.60	0.022**	9.42	0.11
Secondary	3.42	1.616	0.364	1.62	0.034**	9.14	0.11
Higher	5.25	1.752	0.476	1.63	0.003***	8.47	0.12
EXTSERVE							
Yes	0.29	0.730	0.043	0.70	0.688	1.54	0.65
VETSERV							
Yes	-0.77	0.823	-0.088	0.74	0.351	1.48	0.68
CREDIT							
Yes	0.13	0.604	0.018	0.69	0.828	1.23	0.81
Constant	0.03	2.038		2.27	0.989		

Number of observations = 253.
LR chi2(24) = 51.92.
Wald chi2 =
Prob > chi2 = 0.0005.
Psuedo R2 = 0.343.
* Significant at 10% (0.05<P<0.10).
** Significant at 5% (0.01<P<0.05).
*** Significant at 1% (P<0.01).

sway more non-adopters of calf housing to adopt the technology. Furthermore, educated farmers have higher chances of appreciating the rationale behind proposed agricultural technologies. The proportion of adopters of calf housing was highest among the zero-grazing farmers, possibly because such farmers live in urban and peri-urban centers where land is a limited resource, and the incidence of animal theft is higher. Therefore, the provision of housing ensures calf safety and optimizes space utilization on the farms. Farmers with less than ten years of experience were more adopters than those with greater dairying experience. This suggests that farmers with fewer years in dairying are more receptive to new technologies than farmers with many years of experience who are more rigid and are less likely to adopt new technologies.

4.2. Perception of farmers on Calf housing

The opinion of farmers on calf housing infrastructure on dairy calf performance is critical in understanding and designing interventions that can be applied to improve any production system's productivity. Although some dairy cattle farmers indicated providing calf housing for their calves, most of them were not satisfied with calf performance on their farms, possibly because they had poorly managed calf housing facilities. The performance and welfare of dairy calves were highly influenced by the housing system [9, 24]. In Uganda, there is a growing tendency towards dairy intensification to improve dairy herds' productivity. However, the realization of this is hampered by the lack of proper infrastructure, undermining calf performance.

On many farms, farmers kept their calves very close to the main cattle shade, which predisposes them to disease and contamination from pathogenic microbes. It is not uncommon to find many cattle sheds poorly maintained with cattle dunging in the same area where they are supposed to rest. Affected calves may experience delays in meeting performance targets like delay in attainments of weaning weights, a longer period to first conception and calving, and mortalities in some cases [21, 38]. Nonetheless, keeping the calf close to the main shed due to lack of adequate space to construct a separate housing of the calf provides better security for the calf at night and helps avoid restlessness of the dam during the time of milking of the lactating cow.

The type of materials used in the construction of the calf pens varied from one farm to another. However, the type of material used may be influenced by the farmer's financial status [22]. Farmers with better financial resources invested in constructing permanent brick-walled, iron sheet roofed structures and a concrete floor, while poor farmers only constructed makeshift structures made from mud and wattle and with a mud floor. However, the majority used timber as the primary construction material, possibly because timber is readily available and can be afforded by many farmers.

4.3. Determinants of calf housing

The number of cattle kept was used as a proxy variable to represent the dairy production system's scale and the farm household's wealth status. Our results suggest that keeping more than five heads of cattle reduces the likelihood of providing calf housing. This observation is in convergence with findings by [7], who reported a reduction in record keeping with an increase in herd size. As the number of animals kept increases, the capital investment in dairy infrastructure increases, yet most farms lack the resources to invest in infrastructure development. Secondly, many smallholders who keep a small number of dairy cattle own improved crossbred cattle, which require intensive management to optimize the herd productivity right from the calf stage through the cow's productive life. Where land is limited, farmers face several competing land-uses and tend to tether their animals as a coping strategy. Farmers who practice tethering are usually resource-constrained and therefore lack the capital to invest in capital infrastructure investments like calf housing. Also, such farmers have limited land for the construction of animal housing facilities on their small farms. The influence of artificial insemination on calf housing adoption is consistent with results by Chagunda et al. [7], who also observed a positive influence of artificial insemination on willingness to adopt performance record-keeping on dairy farms in Malawi. Farmers who use artificial insemination are usually in close contact with veterinarians and therefore have opportunities to learn about the importance of calf housing than farmers who depend on bulls for mating.

Farmers in northern Uganda were more likely to provide calf housing to their dairy calves than farmers from other regions. This was probably because dairy farmers in this region have continued to receive support from both government and non-governmental organizations (NGOs like Send a cow Uganda and Heifer International Uganda) to boost the dairy enterprise as a post-conflict rehabilitation strategy [4, 6]. Therefore, part of this support has been in setting up animal housing infrastructure to minimize mortalities. Land tenure systems where farmers do not own land title deeds and therefore no guaranteed access rights to land were found to discourage investment in long-term infrastructure developments like calf housing. This result agrees with Ogada et al. [31] findings, who reported that farmers with secure land tenure in Kenya were more likely to adopt improved maize varieties than their counterparts who had less secure tenure systems. On the other hand, farmers who have title deeds were more likely to invest in long-term infrastructure developments since the landowners decide which enterprise can be sited on which part of the farm.

The household head's education level increased the probability of adoption of calf housing among dairy cattle farmers. The increase in calf housing adoption with education could be because educated heads have great access to information to decide whether to adopt any agricultural technology. Also, educated household heads have a positive attitude and are more willing to try new technologies than their non-educated counterparts. This finding agrees with other adoption studies [2, 3, 18, 20, 31]. However, this result is contrary to findings by Walekhwa et al. [37] and Sserunkuma [35], who reported a reduction in the probability of adopting biogas technology and animal manure with an increase in the education level of the household head in Uganda. Nonetheless, other studies have reported no significant influence of education on technology adoption [32].

5. Conclusion and policy recommendations

Calf housing infrastructure is critical in influencing the performance, productivity, and profitability of any dairy cattle farm. However, our results have shown that most dairy cattle farmers perceived calf housing as a major challenge undermining calf performance. Most of the farmers cognizant of the need to improve their farms' calf housing facilities. The study identifies several factors that affect calf housing adoption. Ownership of a small number of cattle, possession of a secure land tenure system with title deed, and higher education levels positively improved the adoption of calf housing among dairy cattle farmers. Deliberate efforts should be devoted to continued training of dairy cattle farmers through regular access to extension services or farmers' engagement in farmer field days or farmer field schools. This is because education is critical in breaking traditional perceptions, beliefs, and misconceptions held by farmers in rural areas about embracing new agricultural technologies. Likewise, there is a need to promote commercial dairy production to educated persons who are more receptive to technology adoption and can actors as early adopters to influence the less educated farmers who are usually late adopters of new technologies. Security on land ownership is critical in the promotion of adoption of agricultural technologies

Declaration of Competing Interest

None.

Acknowledgments

This work was supported by the Government of Uganda and the World Bank through the ATAAS project. We appreciate the support of the district veterinary officers in the participating districts and Heifer International Uganda staff. Special thanks go to Mr. Anecho Stephen for his invaluable input in the survey tool's design and to Mr. Ssenkumba Ahmed for the support of data analysis. Finally, the invaluable support from Dr. Nanyeenya William in proofreading the manuscript is much appreciated.

Author contribution

Swidiq Mugerwa, Muhammad Kiggundu, and Hussein Kato conceptualized and designed the study. Muhammad Kiggundu, Kigozi Abasi, and Hussein Kato contributed to and participated in design and field data collection. Swidiq Mugerwa and Muhammad Kiggundu participated in the data analysis. Muhammad Kiggundu and Swidiq produced the first draft while the other authors participated in the manuscript's review and final approval.

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