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A Retrospective Study on Dairy Cattle Mortality Patterns in Two Farms of South-eastern Botswana

Diphetogo Mosalagae[1], Kabo Mogotsi[2]*, Innocent Moagisi Ithuteng[1], Onkemetse Basinyi[1], and Davies Mubika Pfukenyi[3]

[1]*Animal Production and Range Research Division, Department of Agricultural Research, Ministry of Agriculture, Private Bag 0033, Gaborone, Botswana*
[2]*Animal Production and Range Research Division, Department of Agricultural Research, Ministry of Agriculture, P.O. Box 10275, Francistown, Botswana*
[3]*Department of Veterinary Sciences, Faculty of Animal and Veterinary Sciences, Botswana University of Agriculture and Natural Resources, Private Bag 0027, Gaborone, Botswana*

*Corresponding author's Email: kbmogotsi@yahoo.com

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ABSTRACT

Generally, high mortalities of dairy cattle due to infectious and non-infectious diseases cause huge economic losses, unprofitability, and low productivity in the dairy industry. The present study aimed at determining the mortality rates, their causes, and risk factors among 1779 cattle at two dairy farms belonging to the Department of Agricultural Research, Botswana. An 8-year retrospective study was conducted using farm records during 2005-2012. Monthly and annual records of the farms were examined regarding the total dairy cattle population, sex, breed, age, cattle deaths, and causes of death. Mortality was calculated from the total cattle population and expressed as a percentage, and it was analyzed with respect to farm, breed, age, sex, year, season, and mortality causes. The overall mortality rate was 8.5%. The semi-intensively managed Farm II, as well as young stock (<12 months old), and males recorded significantly higher mortalities than their counterparts. Dairy crosses of pure exotic and indigenous Tswana cattle had higher mortalities than the Friesians and Jerseys, and the wet season accounted for over 70% of the total deaths. Only two years (2010 and 2012) out of the 8-year study period had a mortality rate < 5%. Notably, 28.1 % of mortalities with a known cause were due to heartwater disease (n = 57), but most deaths (62.3%) were due to unknown causes. In conclusion, to improve farm herd health and husbandry practices, more efforts should be devoted to preventing heartwater and mortalities in young stock and male animals, particularly during the hot-wet season.

Keywords: Dairy cattle, Heartwater, Mortality, Risk factor

INTRODUCTION

In Botswana, cattle are the main source of milk production for human consumption. Indigenous Tswana cattle and other local beef breeds dominate the traditional dairy subsector in rural communities despite their low potential for milk production (APRRD, 2001). Commercial milk production developed recently in Botswana and is dominated by exotic Friesians, Jersey, Brown Swiss, and dairy crosses (Mosielele, 2005). Dairy goat milk is an alternative livestock enterprise suitable for small-scale livestock operations (Norris et al., 2011), although it is not a significant source of milk in the country. National milk demand is about 65 million liters annually, while local production accounts for only 11% of the demand, indicating that 89% of milk is imported (DAP, 2009). The reliance on milk importation has a negative impact on local production and has caused the average Motswana (citizen) to be unable to afford the high cost of milk.

The dairy sector experiences challenges regarding fodder and feed production, breeding, and dairy cattle management, leading to low productivity. One contributor to low milk production in the dairy sector of Botswana is the mortality of high-quality dairy animals. The losses of dairy animals occur during the different stages of their growth and is attributable to many factors (Jousan et al., 2005; Yitagesu et al., 2022). Dairy animal mortality results in huge financial losses through decreased production, high treatment and heifer replacement costs, and general loss of livestock (Raboisson et al., 2011). High mortality rates indicate sub-optimal health and welfare.

A recent study in Botswana showed high mortalities of dairy cattle (LEA, 2011). The reported main causes were pasteurellosis, heartwater, mastitis, brucellosis, anthrax, dystocia, milk fever, botulism, bloating, and unknown diseases (LEA, 2011). Other causes included inappropriate feeding, starvation due to droughts and road-traffic accidents (LEA, 2011). High mortalities of dairy calves aged 0-6 months (26.3%) and those aged between 6-12 months (32.6%) have been reported in Botswana (Mahabile and de Waal, 2011). Internal and external parasites were also noted as a problem in lactating cows (Jousan et al., 2005; Aldomy et al., 2009). Other potential causes of mortality are the physiological changes associated with high milk production, improper management, and feeding, especially in dairy calves (Lopez-Gatius et al., 2002; Silke et al., 2002). Unfavorable environmental and poor housing conditions may also contribute to

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high dairy cattle mortality, especially in Botswana, where ambient temperatures are high, with summer temperatures of 30-35^{o}C. These temperatures are high for exotic dairy cattle breeds developed and bred to produce in cooler environments and may cause lethal heat stress (Burhans et al., 2022).

High mortalities of dairy cattle cause huge economic losses leading to unprofitability and low productivity of the sub-sector in Botswana. Despite previous reports of high dairy cattle mortality in the Department of Agricultural Research (DAR) farms in Botswana (Mpapho, 2011), the mortality causes have not been fully studied and documented. For the DAR to find a solid remedy for the current high dairy cattle mortalities, there is a need to carry out a study to determine the mortality rates, their causes, and risk factors. This will also assist dairy farmers currently encountering losses due to livestock mortality in the country and similar environments elsewhere. Reduced mortalities could enable further opportunities to sustainably increase the national dairy herd, thus increasing milk yields and subsequently improving household food nutrition and security. Therefore, the aim of the study was to determine the level of mortality among the dairy cattle population on two dairy farms and to establish the causes of such mortality.

MATERIALS AND METHODS

Ethical approval

The study followed the Management Guide for Dairy Production in Botswana (DAR, 2002).

Study sites

The study was carried out at two farms belonging to the DAR. Farm I is located 10km north of Gaborone in the south-eastern part of Botswana; latitude 24^{o} 33' S, longitude 25^{o}57' E, and altitude 994 m. The mean rainfall for the area is 550 mm with a monthly average minimum and maximum temperature of 4.1^{o}C and 34.4^{o}C, respectively. The farm is almost flat with gently undulating plains, kopjes or small hills, and associated pediments. It is characterized by granite soils. The pasture availability is affected by season, being plentiful in the months of December-May and inadequate in June-November. The vegetation is a mixture of *Acacia savanna* with *Combretum apiculatum* and *Burkea africana*. The herbaceous layer consists of *Eragrostis rigidior* (*E. rigidior*) and other grasses including *Panicum maximum* (*P. maximum*), *Digitaria milanjiana* (*D. milanjiana*), *Urochloa mosambicensis* and *Urochloa trichopus*.

Farm II is located approximately 45 km south of Gaborone, latitude 25^{o} 06' S and longitude 25^{o} 44' E. The area receives erratic rainfall between October and May that averages 517 mm and is characterized by soils that are eutric regosols skeletic (pH of 6.2, Organic Carbon (OC) 0.2%, available Phosphorus (P) 3ppm, and Calcium (Ca) 2.7, Magnesium (Mg) 0.5, Potassium (K) 0.7 and Cation Exchange Capacity CEC 5.1 meq/100g) (APRRD, 2001). The vegetation can be described as Tree Savanna – semi-sweet mixed bushveld. The dominating tree species are *Peltoforum africanum, Acacia tortilis*, *Terminalia sericea,* and *Combretum imberbe*. The shrub layer is characterized by *Ziziphus mucronata*, *Acacia karoo, Acacia mellifera*, and *Grewia bicolor*. The species can provide desirable fodder to browsers during the dry season. Grass species, such as *E. rigidior*, Aristida congesta, and Schmidtia pappophoroides dominate the lower layer. The grasses have intermediate to good nutritional value as livestock feed except for *A. congesta,* which has poor nutritional value.

Farm I had 765 exotic *taurus* Friesian and Jersey breeds while Farm II hosted 1014 dairy cattle crossbreds; dairy *taurus* breed bulls sired with indigenous *indicus* Tswana cows and comprised of Friesian (FxT), Jersey (JxT) and Brown Swiss (BSxT) crosses. Animals at Farm I were intensively managed at zero-grazing and were fed locally made concentrates (3 types that include calf starter, grower, and production diets, Table 1) with grass-hay, maize stover, or maize silage as roughage. The Farm II animals were semi-intensively managed and were allowed to graze natural pastures comprising *E. rigidior, P. maximum, D. milanjiana,* and *Urochloa* grass species and had minimal supplementation with concentrate diets. Supplementation was done mainly during the dry season. Calves were allowed to suckle for 3 weeks before being offered calf starter and grower meals and allowed to graze. The nipple bottle and bucket feeding methods were used, where calves were fed 4 liters of whole milk per day (2 liters each in the morning and afternoon) for 3 months. The feeding was gradually reduced to 2 liters in the morning only in the last month. The weaning age was 3 months. At both farms, portable water was given ad libitum. Cows were bred through artificial insemination, and calves were housed in conventional calf pens for up to 3 months. The animal health management guide for DAR cattle was followed and used in the two farms. A veterinarian attended to any animal showing signs of disease appropriately, and treatment sheets were recorded by the farm manager.

Manual animal records at both farms included data on birth dates and weights, monthly weights, milk yields, feed types and intakes, animal breeds, reproduction parameters, pasture assessments, deaths, and causes. With respect to cases of animal diseases and deaths, the farms engaged the Department of Veterinary Services for advice on diagnoses, treatments, control and prevention. Samples from sick and dead animals were submitted to the Botswana National Veterinary Laboratory for diagnosis to confirm the cause of sickness or death.

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Table 1. Ingredients and composition of starter, grower, and production meals for dairy cattle during the study in Botswana.

Ingredient \ Diet	Calf starter (Percentage of Dry Matter)	Calf grower (Percentage of Dry Matter)	Production meal (Percentage of Dry Matter)
Ground maize	47.5	39.5	73.0
Maize stover	-	20.0	-
Sunflower-seed cake	34.0	-	15.0
Soyabean meal	-	22.0	-
Feed grade urea	-	-	1.5
Limestone	-	-	2.0
Dicalcium Phosphate (DCP)	0.5	0.5	0.5
Bran (wheat)	10.0	10.0	-
Molasses liquid	7.0	7.0	7.0
Salt	0.5	0.5	0.5
Vitamin and mineral premix*	0.5	0.5	0.5
Total	100	100	100

*Vitamin A 45000 IU. Vitamin D3 20000 IU, Vitamin E 125 mg, Vitamin B1 25 mg, Chromium 2 mg, Cobalt 18 mg, Copper 200 mg, Iodine 12 mg, Manganese 325 mg, Magnesium 25 mg, Selenium 4 mg, Sulphur 250 mg, Zinc 700 mg and Antioxidant 160 mg

Data collection and analysis

A retrospective study covering 8 years (2005-2012) was conducted using farm records of the two farms to determine dairy cattle mortality, causes, and risk factors. The study population included all dairy cattle at the two farms during the 8-year study period. Monthly and annual records of the two farms were examined regarding total dairy cattle population, sex, breed, age, cattle deaths, and causes of death. Data were captured into Microsoft Excel 2016 spreadsheet. Crude mortality rate (Number of deaths/Total number of animals x 100) was calculated from the total dairy cattle population and expressed as a percentage. The crude mortality rate was examined in relation to location, breed, sex, age, year, season, and causes of death. Categories were generated as follows: two for location (Farms I and II), five for the breed (Friesian, Jersey, FxT, JxT, and BSxT crosses), two for sex (male and female), three for age (< 12 months, 12-24 months and > 24 months), two for the season (wet and dry) and 8 for years (2005-2012). Comparisons were made for the different categories and a statistical package, EpiCalc 2000 (version 2) was used to measure the percentage differences between categories, and p values (analyzed by the Chi-square test for proportions) less than 0.05 were considered as significant. Associations between crude mortality rate and different categories of studied variables were assessed by calculating the odds ratio (OR) using the EpiCalc 2000 (version 2) statistical package.

RESULTS

The crude mortality according to different categories is presented in Table 2. A total of 1779 dairy cattle were studied, and the overall mortality rate was 8.5%, with Farm II recording a significantly higher mortality rate than Farm I ($p < 0.05$). Farm II was found to have a significantly higher odds ratio (OR = 2.2) of crude mortality than the other farm.

A significantly higher crude mortality rate was recorded for male (11.5%) compared to female (7.3%) dairy cattle ($p < 0.05$). The odds of mortality rate were approximately twice in males (OR = 1.7), compared to females. Regarding age, the crude mortality rate differed significantly among the groups ($p < 0.05$), with young dairy cattle (< 12 months) recording the highest (29.9%) and adults the lowest (2.4%). Young cattle (less than 12 months) were significantly associated with higher odds of crude mortality compared to the 12-24 months old (OR = 2.4) and older than 24 months old (OR = 17.2) age groups.

There was an insignificant difference in crude mortality rate between Friesians and Jerseys ($p > 0.05$), and similarly, the mortality rates of dairy crosses were not significantly different ($p > 0.05$). However, dairy crosses recorded higher mortality rates compared to pure breeds, with the JxT crosses (12.3%) recording a significantly ($p < 0.05$) higher mortality rate than the Friesians (5.2%) and Jerseys (5.9%).

The wet season accounted for over 70% (73.5%, n = 111) of the total deaths. The crude mortality rate varied annually, with the year 2011 (16%) recording the highest and 2012 (0.4%) the lowest. Out of the 8-year study period, only two years (2010 and 2012) recorded less than 5% crude mortality rates. The causes of death are shown in Table 3. Most of the deaths (62.3%, n = 94) had unknown causes, and for death with known causes, most (28.1%) were due to heartwater, followed by predation (12.3%) and coccidiosis (10.5%).

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Table 2. Summary of crude mortality in Farms I and II of Friesian, Jersey, and crossbred dairy cattle in Botswana from 2005 to 2012

Variable	Level/Category	Number of animals	Number of deaths	Crude mortality (95% CI)	Odds ratio (95% CI)	* p-value
	All animals	1779	151	8.5 (7.3-9.9)	-	-
Location	Farm I	765	41	5.4[a] (3.9-7.3)	-	-
	Farm II	1014	110	10.9[b] (9.0-13.0)	2.2 (1.5-3.1)	0.0001
Sex	Female	1276	93	7.3[a] (6.0-8.9)	-	
	Male	503	58	11.5[b] (8.8-14.7)	1.7 (1.2-2.3)	0.003
Breed	Friesian	544	28	5.2[a] (3.5-7.4)	-	-
	Jersey	221	13	5.9[a] (3.3-10.1)	1.2 (0.6-2.3)	0.82
	#FxT cross	312	31	9.9[ab] (7.0-13.9)	2.0 (1.2-3.5)	0.012
	#BSxT cross	353	36	10.2[ab] (7.3-14.0)	2.1 (1.4-3.5)	0.006
	#JxT cross	349	43	12.3[b] (9.2-16.3)	2.6 (1.6-4.3)	0.0002
Age	> 24 months	1034	25	2.4[a] (1.6-3.6)	-	-
	12-24 months	397	22	5.5[b] (3.6-8.4)	2.4 (1.3-4.3)	0.005
	< 12 months	348	104	29.9[c] (25.2-35.0)	17.2 (10.9-27.2)	0.00001
Years	2005	245	32	13.1[a] (9.2-18.1)	-	-
	2006	251	32	12.8[a] (9.0-17,7)	35.3 (4.8-260.6)	0.00001
	2007	277	16	5.8[b] (3.5-9.4)	34.3 (4.7-353.4)	0.00001
	2008	184	10	5.4[b] (2.8-10.1)	14.4 (1.9-109.5)	0.002
	2009	238	26	10.9[a] (7.4-15.8)	13.5 (1.7-106.5)	0.004
	2010	173	6	3.5[b] (1.4-7.7)	28.8 (3.9-214.3)	0.00001
	2011	175	28	16.0[a] (11.1-22.5)	8.4 (1.0-70.8)	0.05
	2012	236	1	0.4[c] (0.02-2-7)	44.8 (6.0-332.5)	0.00001
Season	Dry	882	40	4.5[a] (3.3-6.2)	-	-
	Wet	897	111	12.4[b] (10.3-14.8)	3.0 (2.0-4.3)	0.00001

[abc] Different superscript letters in a column mean significant differences ($p < 0.05$), CI: Confidence interval #FxT: Friesian x Tswana cross, #BSxT: Brown Swiss x Tswana cross and #JxT: Jersey x Tswana cross, *p-values are for the odds ratios and calculated for categories

Table 3. Summary of the causes of deaths in Farms I and II of Friesian, Jersey, and crossbred dairy cattle in Botswana from 2005 to 2012

Causes	Numbers	Percentage
Unknown	94	62.25
Heartwater	16	10.60
Predation	7	4.64
Coccidiosis	6	3.97
Dystocia	4	2.65
Pasteurellosis	4	2.65
Accidents	3	1.99
Bloat	3	1.99
Endoparasites	3	1.99
Rabies	3	1.99
Abscessation (liver)	2	1.32
Botulism	2	1.32
Uterine prolapse	2	1.32
Starvation	2	1.32
Total	151	100

DISCUSSION

The findings of this study should be viewed in light of its limitations. Due to missing data on the exact date of death for most animals, the animal time at risk was not calculated. Animal time at risk is an important parameter for calculating a more accurate mortality rate. Nevertheless, the available data showed some important mortality trends worth noting. Management practices could possibly explain the observed significant difference between the studied farms. Farm I, with intensive management with zero-grazing, had a lower mortality rate than Farm II, with semi-intensive management and pasture grazing. Individual animal attention is likely reduced on semi-intensively animals grazing on pasture, leading to a higher mortality risk. In addition, grazing is associated with an increase in mortality rate (Thomsen et al., 2006).

Breed has been previously reported to have a strong relation to mortality in dairy cattle (Alvasen et al., 2014; Pannwitz, 2015). For example, the high-producing Friesian breed is associated with increased mortality rates compared

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to other exotic dairy breeds (Thomsen et al., 2006; Raboisson et al., 2011; Alvasen et al., 2012, 2014; Pannwitz, 2015). However, the current study found no differences in mortality between Jersey and the Friesian breeds. Unexpectedly, the crossbreds recorded higher mortality rates than the exotic Friesian and Jersey breeds. This might be due to different management practices; exotic breeds were under an intensive system with zero-grazin,g while the crossbreds were under a semi-intensive system with pasture grazing and limited supplementation. In Farm II, animals can freely graze the natural pastures, leading to stress and exposure to harsh climatic conditions like excessive summer heat and cold winter temperatures. In addition to inadequate grazing, ingestion of poisonous plants like *Dichapetalum cymosum* and *Pavetta harborii* and possible malnutrition could also likely have contributed to the observed higher mortality at Farm II. While out freely grazing, some unattended crossbred animals at Farm II were killed by predators, such as jackals and hyenas. In Botswana, livestock depredation has been reported as a challenge by livestock farmers, especially during the spring calving season or drought when the predators' natural prey numbers are limited (Schiess-Meier et al., 2007; Mosalagae and Mogotsi, 2013).

The high mortality rate observed in male more than female animals agrees with previous findings (Swai et al., 2010; Pannwitz, 2015; Reimus et al., 2017). This probably reflects biological features (Raboisson et al., 2013; Pannwitz, 2015), such as heavier weights at birth leading to dystocia and higher mortality (Linden et al., 2009; Johanson et al., 2011). The relatively higher economic value of female animals as future replacements or animals for sale (Swai et al., 2010; Pannwitz, 2015) may also contribute to higher mortality of male animals since more management attention is shifted towards female animals, which are the mainstay of the dairy enterprise. The high economic cost of feeding male calves with milk in the dairy farming industry could also not be ruled out (Gitau et al., 1994; French et al., 2001), thus contributing to suboptimal management practices, with repercussions for mortality. Hossain et al. (2014) noted a higher mortality rate in females, possibly due to their higher proportion at the studied farm. According to Moran (2011), 20-25% of cows are generally anticipated to be replaced yearly in dairy farms. Therefore, since the mortality of female animals was 7.3 % in the current study, there is a possibility of raising enough replacement animals, and therefore the herd can be expanded.

The young age group (< 12 months old) had a higher mortality rate than the older animals. This is in agreement with earlier findings in Botswana (Mahabile and de Waal, 2011), other African countries (Gitau et al., 1994; French et al., 2001; Swai et al., 2010; Fentie et al., 2020) and elsewhere (Prasad et al.,2004; Hossain et al., 2014; Reimus et al., 2017). The observed pattern is likely attributable to poor management practices, including bucket feeding of calves and poor hygiene conditions that could lead to outbreaks like diarrhea or coccidiosis (Duguma et al., 2012). Calves also have an increased susceptibility to diseases and environmental stress than adults. It could be because some calves had compromised immune systems due to inadequate colostrum intake shortly after birth and subsequently experienced poor nutrition. However, this reason is also not expected to be too widespread since calves in the study area were allowed access to their mother's colostrum during the first few hours of birth for up to 3 weeks. Well-managed dairy farms in the USA have shown that mortality in young stock does not exceed 5% (Speicer and Hepp, 1973). The high young animal and annual mortality rates (only two years had a mortality rate < 5%) might be due to poor management practices on the studied farms, such as inadequate colostrum feeding, inadequate tick control programs, inadequate use of heat stress prevention methods (for example using shades on the farms) among others. The higher rate of unknown causes of death reported in this study (>60%) supports the need to improve farm husbandry practices, such as complete investigations of animal carcasses, recording accurate and complete individual animal records, and adopting electronic capturing of farm data.

The season was a factor that influenced the mortality, with the hot-wet season accounting for over 70% of the cases. Similar observations have been reported elsewhere (Reimus et al., 2017; Armengol and Fraile, 2018). The hot-wet season in Botswana is characterized by extreme weather conditions that include high ambient temperatures and erratic but heavy rainfalls exacerbated by climate change. High temperatures predispose livestock to heat stress, the effects of which may be influenced by lactation stage, breed, and age (Crescio et al., 2010), as well as a management approach. This may increase heat-related dairy cattle mortality (Crescio et al., 2010; Alvasen et al., 2012; Bishop-Williams et al., 2015; Cox et al., 2016; Reimus et al., 2017; Armengol and Fraile, 2018). Wet weather also increases the risk of infection with various pathogenic microorganisms. The study shows the importance of putting more emphasis on devising and implementing preventive measures during the hot-wet season. Strategies to mitigate heat stress at the studied farms need to be considered, and the farms should adapt their production systems to changing climate conditions.

The observed higher percentage of unknown causes of death reported in this study is similar to earlier findings in the region. Phiri et al. (2010) showed that many mortalities reported on smallholder dairy farms in Eastern and Southern Africa had undiagnosed causes. Except for drowning (0.01%) and snakebite (1%), the cause of death for most dairy cows (n = 1774) on dairy farms in the Eastern Cape Province of South Africa was not given (Diniso and Jaja, 2021). In contrast, lower proportions of unknown causes of death in dairy farms (4-20%) are reported from developed countries (Thomsen et al., 2004; Pinedo et al., 2010; Fusi et al., 2017; Armengol and Fraile, 2018). During the present study, some cases of sudden deaths occurred outside of normal staff working hours, and cases were decomposed, and no cause of

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death was reported. Farmers' knowledge of mortality causes would enable them to prioritize their resources on preventing the predisposing factors associated with morbidity and mortality (Reimus et al., 2017). Therefore, the two farms in the current study should prioritize herd health improvement plans.

Heartwater, a tick-borne disease, was the most important of the known causes of death in dairy cows. Tick-borne diseases are reported to be the major causes of mortality on smallholder dairy farms in eastern and southern Africa (Phiri et al., 2010). The culling of dairy cows in the Eastern Cape province of South Africa was due to Redwater and heartwater (Diniso and Jaja, 2021). In Botswana, heartwater and gall sickness are the two main tick-borne diseases of economic importance, and young calves may be especially vulnerable during their first grazing season after weaning as they encounter heavy parasitic loads for the first time (Batisani et al., 2012; Ramabu et al., 2018; Raboloko et al., 2020). Our observation is an indication of the need to revise the tick control strategies at the studied farms.

CONCLUSION

The study results showed that farm management practices, sex, and age of the animal as well as the season, influenced mortality. Males, young stock (<12 months old), and the hot-wet season were found to be associated with higher mortalities. Only two years (2010 and 2012) of the 8-year study period had a mortality rate of less than 5%. The percentage of unknown causes of death was very high (> 60%). Of the known causes of death, heartwater was the most important disease. Adequate colostrum feeding is recommended to reduce calfhood diseases due to malnutrition and immune deficiency. Following the recommended dipping regime for tick control is paramount to reducing heartwater cases. The provision of shades (none of the farms had shades) and automated cooling systems is recommended to mitigate heat stress. Electronic, accurate, and complete data recording is also an important activity that the studied farms need to consider.

DECLARATIONS

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Authors' contributions

Diphetogo Mosalagae contributed to the study conceptualization, data analysis, and manuscript writing. Kabo Mogotsi, Innocent Ithuteng, Onkemetse Basinyi, and Davies Pfukenyi contributed to data cleaning, data analysis, and manuscript writing. All authors read and approved the final manuscript and agreed to submit the manuscript to the current journal.

Competing interests

All the authors declare that there are no competing interests regarding this work.

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Ethical considerations

Before submission of the manuscript, all authors checked for ethical issues, including plagiarism, data fabrication, duplicate publishing, or submission.

Availability of data and materials

The authors declare that they will prepare all the necessary data upon reasonable request.

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