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Incidence of morbidity and mortality in calves from birth to six months of age and associated risk factors on dairy farms in Hawassa city, southern Ethiopia

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ABSTRACT

Calf morbidity and mortality are major causes of economic losses on dairy farms worldwide, with a far greater impact in developing countries such as Ethiopia. A prospective longitudinal study on dairy farms in the city of Hawassa was conducted between August 2018 and July 2019, to estimate the cumulative incidence of calf morbidity and mortality and to identify the associated risk factors. For this purpose, 221 calves from 20 farms were examined every 15 days from birth to the age of six months. We used the Kaplan Meier (K-M) method, log rank test, and Cox proportional hazards regression to analyze the data. Of the calves examined, 48.4% (n = 107) had various clinically visible health problems, while 19.5% (n = 43) died from various causes. Using the K-M method, the cumulative incidence of all-cause morbidity at the end of the sixth month of life was 50.12% (95% CI: 43.58%–57.05%), while the cumulative incidence of all-cause mortality was 20.04% (95% CI: 12.56%–26.06%). The most commonly diagnosed disease syndrome was diarrhea (64.5%), followed by pneumonia (15%), septicemia (6.5%), joint disease (4.7%), conjunctivitis (3.7%), umbilical infections (2, 8%) and other unknown causes (11.2%). Diarrhea was also the leading cause of death (46.5%). The other causes of calf mortality were pneumonia (16.3%), septicemia (7%), and unknown diseases (30.2%). In the K-M hazard analysis, the greatest risk of calf morbidity and mortality was observed during the first month of life and then the risk decreased significantly as the calves grew. Of the 21 potential risk factors studied, the multivariable Cox proportional hazards regression model showed that time calves ingested their first colostrum, calving difficulty, and calving season were the three predictors that were significantly associated with a higher risk of morbidity and mortality. A higher risk of morbidity was observed in calves that had ingested their first colostrum six hours after birth (HR = 1.9; P = 0.003), had calving difficulties (HR = 2.96; P < 0.001) and were born in the rainy season (HR = 1.64; P = 0.017) compared to calves that had consumed colostrum immediately after birth, had no difficulties at birth and were born in the dry season. The same three factors have been identified to influence calf mortality. The mortality risk was 2.73 (P = 0.002), 4.62 (P < 0.001) and 2.74 (P = 0.002) times higher in calves that had difficulty calving, ingested their first colostrum meal six hours after birth and were born in the rainy season, respectively. In general, the calf morbidity and mortality rates identified in this study were beyond economically justifiable limits and calls for educating farmers to raise awareness of some easy-to-fix issues such as colostrum feeding.

1. Introduction

Ethiopia has given priority to the development of small-scale dairy products in order to stimulate milk production. As a result, the dairy industry in the country is growing rapidly due to increasing urbanization and higher demand for milk and dairy products, especially in urban and peri-urban areas (Tesfaye, 2019). Peri-urban and urban dairy farms practice semi-intensive or intensive production systems and keep exotic or crossbred cows with relatively improved management practices (Goshu and Singh, 2013). Although the dairy sector has shown considerable development in recent years, the sector has reportedly suffered from reproductive inefficiency, poor calf survival, high calf morbidity

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and mortality, and high incidence of mastitis, lameness, pneumonia and ketosis (Eneyew et al., 2000).

Calf morbidity and mortality are a constant problem for milk producers around the world (Radostits et al., 2007), especially in the tropics, where high temperatures and humidity promote the multiplication and transmission of infectious agents (Moran, 2011). Calf diseases are the result of a complex interplay of management practices, environmental conditions, infectious agents and risk factors at calf level (Radostits et al., 2007). Various diseases have been considered as causes of calf morbidity and mortality; however, neonatal diarrhea and pneumonia in older calves are responsible for most of the morbidity and mortality in the calf hood (Svensson et al., 2006). In addition, several risk factors for calf morbidity and mortality have been identified, such as insufficient or no colostral immunity, overcrowding and poor hygiene, naive immune system in neonates and stress factors such as cold ambient temperature and frequent mixing of animals, and calf nutrition status (Quinn et al., 2011).

There are some studies on calf morbidity and mortality and the associated risk factors in Ethiopia (Asmare and Kiros, 2016; Fentie et al., 2020; Mohammed et al., 2020). The studies reported a wide range of calf morbidity (22%–62%) and mortality (5%–30%) figures from different parts of the country. Most studies, however, are cross-sectional and only provide a snapshot of the morbidity or mortality data and associated risk factors at a single point in time. The very important limiting factor for this design in epidemiological studies is that it cannot help to determine cause-effect links between the outcome and exposure variables and not appropriate for establishing risk factors for mortality. Although there is a prospective longitudinal study in the current study area (Megersa et al., 2009), there is no clear mention of the age at which the calves entered the study and the follow-up ended. In addition, the time of the event and how long calves were observed without event occurring were not considered. Furthermore, the association of potential risk factors with morbidity or mortality was analysed using the traditional logistic regression method, which is not suitable for time-to-event analysis. In prospective studies, the result is not only of interest whether an event has occurred or not, but also when this event has occurred. Thus special statistical methods, which include a time-to-event analysis, are used to analyze the data. In the present prospective observational study, we followed-up calves from birth to 6 months of age with appropriate recording of the timing of morbidity and mortality events and censoring, and we examined more than 21 possible risk factors for calf morbidity and mortality using survival analysis. It is worth mentioning that increasing information about risk factors related to calf morbidity and mortality will support the growth of evidence-based management recommendations and could have a significant impact on improving milk production efficiency. The objective of the present investigation was to estimate the cumulative incidence of morbidity and mortality and the associated risk factors in calves from birth to six months of age.

2. Materials and methods

2.1. Study area

This study was carried out between August 1, 2018, and July 30, 2019 on selected dairy farms in the city of Hawassa in southern Ethiopia. Hawassa is located 273 km south of Addis Ababa at a latitude 7°3′ North and longitude 38°28′ East. The city has an altitude of 1708 m above sea level, an average annual rainfall of 800–1000 mm, and an average annual temperature of 20.1 °C – 25 °C (CSA, 2013). Increasing urbanization makes Hawassa one of the greatest potential for milk production in southern Ethiopia.

2.2. Study population

There are at least 109 dairy farms in the city of Hawassa with herd sizes of only three to 130 cattle. All farms selected for the present study raise exotic or crossbred cattle which, in contrast to the extensive production system prevailing in Ethiopia, were kept under relatively improved management practices and a zero-pasture system. The target population was all calves under six months old found on dairy farms in Hawassa City. In this study, calves were defined as cattle less than 6 months old (Boden, 2005). The majority of the calves were crossbred types (Holstein-Friesian local zebu breed) while some were Jersey breeds. Artificial insemination was the common breeding method, while all farms also used bull service as an alternative if fertilization failed after insemination or the insemination technician could not arrive on time.

2.3. Study design and sampling method

A prospective longitudinal study was used to estimate the cumulative incidence of morbidity and mortality and to identify the associated risk factors. Records were available for 109 dairy farms in Hawassa City of which 22 had 10 or more cows. Since calf births are not synchronized with a specific time of year, we specifically selected 20 farms with at least 10 cows with the intention to increase the likelihood of finding more than one calf for follow-up. The selected farms represent 18.4% of the dairy farms in the city. In addition to the herd size, the willingness of the owner to participate in the study was another factor that was taken into account when selecting the farm. All calves with few birthdays at the start of the study and calves born in the following seven months were recruited for the study. At the beginning there were only 18 suitable calves in the selected farms, 203 calves were born later and a total of 221 calves were checked regularly every 15 days up to the age of six months. A questionnaire survey was also conducted during the study period to collect data at the herd and calf level.

2.4. Data collection

2.4.1. Questionnaire survey

A semi-structured questionnaire was developed to collect information on the potential factors associated with the risk of calf morbidity and mortality in the farms studied. The questionnaire was tested in advance and administered to the farmer, if available, or to a staff most responsible for managing the animals, through a face-to-face interview. The data collected includes variables at the calf and herd level and other farm management practices. All examined variables are shown below under 2.5.

2.4.2. Monitoring of calves

In the selected farms, the calves recruited for the study were identified individually by their ear tags, if available, or by their mother's identification number. The selected farms were regularly visited every 15 days and at each visit all incidents of calf illness and deaths were recorded in a special data recording format that was created separately for each farm. Whenever health problems arose, the affected calf was clinically examined to determine the cause, and in the case of diarrheal diseases, faecal samples were taken for laboratory testing for bacterial and parasitic pathogens. In this study, morbidity was defined as any disease with identifiable clinical signs that manifests itself in calves and can ultimately lead to death or warrant therapeutic intervention during follow-up; whereas mortality was defined as any death event in calves after 24 h after birth, regardless of the cause. Calves were excluded from follow-up when they were six months old. In this way, each calf was monitored a maximum of 12 times, unless losses to follow up occurred because of sales or for other reasons. If calves lost to follow-up, the date and reason were recorded. Farm managers were informed to list and describe any health problems and deaths that occurred between visits. In addition to regular visits, emergency visits were made in response to calls from farm owners about calf health problems. Calves that lost follow-up or remained without the outcome event (morbidity/mortality) at the end of the study were censored.

2.4.3. Laboratory examination of fecal samples

If diarrhea calves appeared, two faecal samples were taken aseptically, one for parasitological and the other for bacteriological examination. Approximately 15 g of feces were collected directly from the rectum of affected calves using a sterile latex surgical glove and placed in a separate sterile universal bottle with a screw cap. Each sample was clearly labelled, stored in ice box, and shipped to the Hawassa University Veterinary Faculty laboratory. The samples were processed in the laboratory as soon as possible after they were taken. Initially, the samples were collected for screening of rotavirus, bovine coronavirus, *Escherichia coli* strain K99, *Salmonella* and *Cryptosporidium* spp. Due to the lack of diagnostic possibilities, the laboratory tests were limited to *E. coli*, *Salmonella* spp. and *Cryptosporidium* spp., which were identified using standard methods (Goldman and Green, 2009; Quinn et al., 2011; Markey et al., 2013). *Cryptosporidium* spp. was detected by means of faecal flotation with sucrose solution, followed by staining of the oocysts with modified Ziehl-Neelsen, as described by Kaufmann (1996). The research was approved by the Research Ethics Review Committee of Hawassa University.

2.5. Description of the variables

Outcome variable: The outcome (dependent or response) variable for this study is the morbidity or mortality of calves from 24 h after birth to the age of six months. Since the variables are dichotomous (yes or no), they were designated with 1 if the event of interest occurred, or with 0 if it did not occur during the observation period of the study.

Independent variables: the potential independent variables or predictors of calf morbidity and mortality considered in the current study are sex, breed, calving season, weaning age, herd size, calving difficulty, dam's parity number, maternity pen (yes/no), calf housing, mix of calves of different ages, mix of calves and cows in barn, farmers' knowledge of the advantage of colostrum feeding for calves, time calves ingested their first colostrum meal, method of colostrum feeding, ventilation, hygiene, educational status of the farmers, whether or not dairying is the primary source of income for the farmer, vaccination, and chemoprophylaxis. Calving season refers to the month in which the study calves were born. Thus, months that do receive short to heavy rain (April–August) are categorized as "wet season" while those months that do not experience rain (September–March) are designated as "dry season."

2.6. Statistical analysis

Morbidity and mortality data were saved, filtered and encoded using the Microsoft Excel 2007 spreadsheet, and transferred to Stata version 14.2 (Stata Corp. TX USA, 2006) for statistical analysis. Morbidity/mortality rates were estimated as true incidence rate, which was defined as the number of new cases of diseased cases/mortality that occurred during the follow-up period over the number of calf-months-at risk (Dohoo et al., 2009). For morbidity rate, the time at risk was measured from the onset of the study until the calf develops a clinical sign of any illness. Moreover, a calf that suffered from a particular illness was considered at risk for another. The risk time for mortality was estimated from the time a calf is enrolled in the study (24 h after birth) until the death occurs from any cause. Also, a calf affected with a disease condition was considered to be at risk of dying. Calves dropped out (lost to follow up) from the study before the study ends or remain event-free (morbidity or mortality) at the end of the observation period were censored and this is called right censoring.

Non-parametric and semi-parametric approaches were used to analyzing the time to event data. We used the Kaplan–Meier (K-M) life-table analysis, which is a popular non-parametric approach, to compute and describe the cumulative survival probability and cumulative incidence of calf morbidity and mortality from birth to six months of age in tabular forms. Moreover, the K-M curves were used to plot the cumulative survival data with respect to age groups and the exposure factors studied. With the K-M approach, the survival probability was computed using the formula in Eq. (1)

$$S_{t+1} = S_t^*((N_{t+1} - D_{t+1})/N_{t+1}) \quad (1)$$

where S_t is survival probability past interval t; N_t is number at risk during interval t; and D_t is the number of disease events or deaths during interval t. The cumulative incidence, or cumulative failure probability, was computed easily from the K-M approach as 1-St. It was assumed that censoring is independent of the likelihood of developing the outcome event and that survival probabilities are comparable in participants who are recruited early and later into the study (non-informative censoring). Log-rank test was used to statistically test the hypothesis that there is no difference in the survival curves between the groups of categorical predictors studied and to explore whether or not to include the predictor in the final model. A P value cut off of 0.2 from the log-rank test was used as criterion to select a variable for the multivariable model.

A multivariable Cox proportional hazards regression model, a semi-parametric approach, was used for the analysis of risk factors associated with calf morbidity and mortality. The Cox proportional hazards regression model used can be written as in Eq. (2)

$$h(t) = h(t) = h_0(t)\,\mathbf{exp}(\beta_1 X_1 + \beta_2 X_2 + _{\dots}\, \beta_p X_p) \quad (2)$$

where h(t) is the expected hazard at time t, $h_0(t)$ is the baseline hazard, X_1, X_2, X_p are the predictors (or independent variables), and $\beta_1 + \beta_2 +_{\dots}$ β_p are the coefficients for each independent variable. The baseline hazard represents the hazard when all of the independent variables are equal to zero. The Cox model allows the time to event to be analyzed with respect to many factors simultaneously, and provides estimates of the strength of the effect (hazard ratio, HR) for each constituent factor (Sullivan, 2016). The final model was built by stepwise backward elimination of variables not significant at the 5% level. At every step during model building, control of potential confounders was made. A variable was considered a confounder if coefficients of the remaining variables were altered by ≥ 20%, and these were retained in the model even if not significant. The assumption taken into account in the Cox proportional hazard model was that the hazards are proportional, which means that the relative hazard remains constant over time with different predictor or covariate levels (Sullivan, 2016). We tested the proportionality assumption by using the Schoenfeld and the scaled Schoenfeld residuals. We also checked the proportionality by visualizing the KM curves of the predictors for the crossing. *P* values less than 0.05 were considered to be statistically significant.

3. Results

3.1. Description of the study farms

The herd size of the farms varied from 16 to 108 with a mean value of 36. All farm owners were educated and their level of education ranged from elementary school (20%) to secondary school (60%) to college (20%) level. Dairying was the most important livelihood for 80% of the farm owners. Most of the farmers (80%) had more than six years of experience in dairy industry. Thirty five percent of the farm owners were women. The study found that 65% of dairy farmers knew about the benefits of feeding calves with colostrum and thus fed colostrum within the first six hours after birth. In contrast, seven (35%) dairy farmers lacked sufficient knowledge that they discarded the first milk and only fed the calves six hours after birth. In 65% of dairy farms, colostrum was hand-fed to the calves, while others (35%) let the calves suckle their dams. In five farms (20%) calves were allowed to stay with their dams for 2–15 days. Most farmers (65%) kept calves in the cowshed, while others (35%) housed calves separately away from adult animals. Milking was carried out twice a day (morning and evening) on all farms. The residual suckling of calves was practiced by six farms (30%), with either a hind-quarter being unmilked or partially milked for suckling. Only four farms

(20%) had provided separate places available for pregnant cows. All calves received whole milk from the dam and, in 80% of the farms, calves also received roughage such as wheat bran, hay, fresh grass, molasses, and straw from the age of two months. None of the dairy farms included in the current study provided pasteurized milk or milk replacer for calves. Weaning age on the farms ranged from 3 - 6 months. In 55% of the farms, cattle were regularly vaccinated against blackleg, anthrax, lumpy skin disease, and bovine pasteurellosis, which are endemic diseases in the study areas. In addition, vaccinations against foot and mouth disease were carried out in two farms. Thirteen farms (65%) had given prophylactic antibiotic treatment with a combination of penicillin and streptomycin or oxytetracycline intramuscularly, and the calves had been dewormed at three months of age.

3.2. Descriptive epidemiology of morbidity and mortality

Of the 221 calves that were monitored from birth to 6 months of age, 55.2% (N = 122) were female and 44.8% (N = 99) were male. All the calves included in the study are cross-breeds of which 71% (n = 157) had Holstein Friesian blood-line while 29% (n = 64) had Jersey blood. All the study calves were born in the farms. Calf births were recorded in each month of follow-up, with relatively higher births in November (18.6%) followed by October (14.9%). A total of 33 calves were lost due to sales for follow-up examination and the survival data of these calves had been censored. Of the total calves lost, 54.55% (n = 18) were male and 45.45% (n = 15) were females.

Of the 221 calves examined, 48.4% (n = 107) had manifested one or more clinically visible health problems and 19.5% (n = 43) died from various causes. The estimated total risk time for morbidity outcome was 775.04 calf-months, while it was 1044.83 calf-months for mortality. The overall incidence rate of morbidity was 13.81 (95% CI: 11.42–16.68) cases per 100 calf-months. Based on sex, it was 12.02 (95% CI: 8.85–16.33) for males and 15.21 (95% CI: 11.95–19.36) for females per 100 calf-months. When mortality is used as the endpoint, all-cause mortality rate was estimated at 4.12 (95% CI: 3.05–5.55) deaths per 100 calf-months. In terms of sex, it was 4.76 (95% CI: 3.11–7.31) for male and 3.64 (95% CI: 2.40–5.53) for female calves. The confidence intervals for both morbidity and mortality rate values for male and female calves overlap and show the absence of significant differences between the sexes (Table 1).

3.3. Causes of morbidity and mortality

The diagnosis of sick and dead calves was made solely on the basis of the animals' clinical signs. Diarrhea was the leading cause of morbidity and accounted for 64.5% of all the morbidities. The other causes of morbidity were pneumonia (15%), septicemia (6.5%), joint disease (4.7%), conjunctivitis (3.7%), naval infection (2.8%), and other unknown causes (11.2%). Seven calves were affected by two or more diseases at different times during the follow-up period. Ectoparasites and congenital diseases such as loss of sight, loss of tail, deformed lumbar vertebrae, triple navel flap, and limb deformities were also observed in 8.1% (18/221) and 2.7% (6/221) calves monitored. As with morbidity, diarrhea, pneumonia, and septicemia were the top three causes of mortality, accounting for 46.5%, 16.3% and 7% of all deaths, respectively. In addition, sudden death of unknown cause occurred in 30.2% of the monitored calves (Table 2).

Table 1. Morbidity and mortality rates in calves under six months of age on 20 dairy farms in Hawassa city.

Outcome	No. calves at risk	No. cases	Time at risk	Incidence rate/ 100 calf-month	95% CI for IR
Morbidity					
Male	99	41	314.07	12.02	8.85–16.33
Female	122	66	434.0	15.21	11.95–19.36
Overall	221	107	775.04	13.81	11.42–16.68
Mortality					
Male	99	21	440.73	4.76	3.11–7.31
Female	122	22	604.1	3.64	2.40–5.53
Overall	221	43	1044.83	4.12	3.05–5.55

Table 2. Causes of morbidity and mortality in calves under six months of age on 20 dairy farms in Hawassa city.

Causes	Morbidity (N = 107)		Mortality (N = 43)	
	Frequency	Proportion (%)	Frequency	Proportion (%)
Diarrhea	69	64.5	20	46.5
Pneumonia	16	15	7	16.3
Septicemia	7	6.5	3	7
Joint disease	5	4.7	–	–
Conjunctivitis	4	3.7	–	–
Naval infection	3	2.8	–	–
Unknown	12	11.2	13	30.2

3.4. Kaplan-Meier survival analysis

The cumulative survival probability of calves to all-cause morbidity and mortality by age are shown in Figures 1 and 2, respectively. To better visualize the cumulative survival probability or incidence of morbidity or mortality from birth to six months of life, the same data were also presented using the K-M life table (Table 3). The study showed that the cumulative incidence of all-cause morbidity, or the likelihood of a calf having a disease event at the end of the sixth month, was 50.12% (95% CI: 43.58%–57.05%) while the cumulative death rate, or the probability that a calf will die, was 20.04% (95% CI: 12.56%–26.06%). The current study further showed that the cumulative incidence of calf morbidity on individual farms varied widely between 17.2 and 80% while the cumulative mortality ranged between 0 and 50%. The K-M survival curves show a steady decrease in the survival probability of calves with increasing age. Disease events were recorded in all age groups, but deaths only up to the fifth month of life.

Using the Kaplan-Meier method, we also calculated the hazard of morbidity and mortality at the end of each month until the calves were six months old. Accordingly, the greatest risk of morbidity and mortality was observed during the first month of life and then the risk decreased significantly as the calves grew up. Compared to the first month, the risk of morbidity at the end of the second, third, fourth, fifth and sixth months of life was reduced by 50%, 43%, 51%, 88%, and 96%, respectively. Similarly, the risk of mortality at the end of the second, third, fourth, and fifth months was reduced by 78%, 81%, 85% and 69% compared to the first month. No mortalities were recorded in the 6th month (Table 4).

3.5. Log-rank test for equality of survival function

In this study we collected data on 21 host and management related variables listed in 2.5 above that were believed to be potential risk factors (predictors) for calf morbidity and mortality. All variables are categorical and are therefore checked by the Kaplan-Meier curve and the log-rank test to select candidate predictors for the final multivariable analysis. Based on the result of the Log-rank test, 12 variables evaluated with all-cause morbidity had a *P* value of 0.20 and were thus selected for the multivariable Cox proportional hazard regression model. On the other hand, seven of the variables analyzed using all-cause mortality had a *P*-value of 0.20 and were thus selected as candidates for the multivariable model (Table 5).

3.6. Multivariable Cox proportional hazards regression analysis

Based on the result of the log-rank test, a multivariable Cox proportional hazards regression model for all-cause morbidity was fitted with

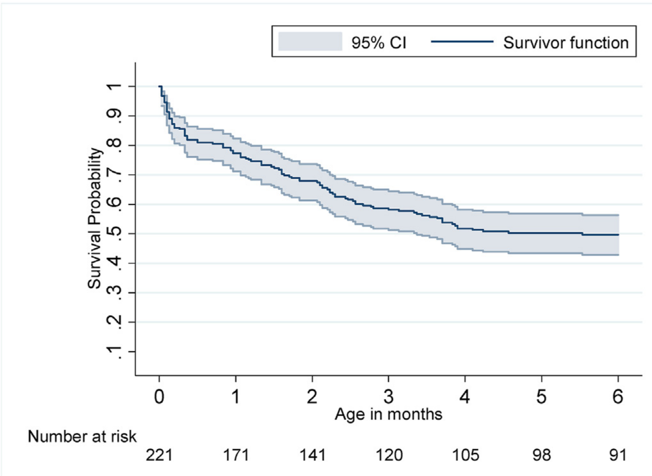

Figure 1. Kaplan-Meier survival curve of all-cause morbidity in calves from birth to 6 months of age.

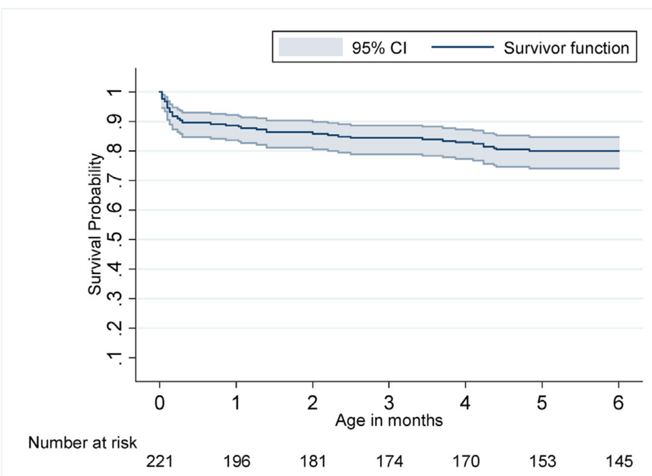

Figure 2. Kaplan-Meier survival curve of all-cause mortality in calves from birth to 6 months of age.

sex, calving difficulty, calving season, weaning age, ventilation, herd size, knowledge of dairy farmers about the benefit of colostrum, time calves ingested their first colostrum, mixing calves of different ages, mixing of cows and calves in stalls, calf housing and whether or not dairying is a major source of income for the farmer. For the mortality analysis, the variables were calving difficulty, calving season, weaning age, knowledge of the benefits of colostrum, time calves ingested their first colostrum, mixing of calves and cows, and chemoprophylaxis as they had a *P* value below 0.2, were adapted to the multivariable model.

The final multivariable Cox proportional hazards regression model identified three variables that are significantly associated with the risk of both morbidity and mortality ($P < 0.05$). These were: time calves ingested their first colostrum, calving difficulty, and the calving season. It was found that calves that ingested their first colostrum six hours after birth had a 1.9-fold risk of morbidity compared to calves that received colostrum earlier, while all other variables were held constant. The risk of morbidity in calves with dystocia was almost three times (HR = 2.96) higher than in normal-born calves. When other variables are held constant, calves born in the rainy season are 1.64 times more likely to experience morbidity for some reason than calves born in the dry season. At any point during the follow-up time, calves that ingested their first colostrum six hours after birth had a 2.73 times greater chance of dying compared to calves that ingested colostrum immediately after birth, while the effect of other variables were held constant. Given the constant effects of time calves ingested colostrum and the calving season, the risk of death in calves with dystocia was 4.62 times higher than in calves born without difficulty. In addition, calves born in the rainy season had a 2.74 times higher risk of death than calves born in the dry season (Table 6). In addition to the multivariable analysis, the K-M plots (Figures 3, 4, 5, 6, 7, 8) clearly show that calves which suffered dystocia, received colostrum six hours after birth and were born in the rainy season had poor survival probability. We tested the final models for the proportional hazards assumption and found that the PH assumption was effective for both morbidity (Chisq = 5.41, df = 3, P = 0.1439) and mortality (Chisq = 3.32, df = 3, P = 0.3455) is not violated. In addition, the K-M survival curves of the predictors did not cross, which is further evidence that the PH assumption is not violated. Therefore, we came to the conclusion that the proportionality assumption is fulfilled and the hazard ratio between two groups of the predictors or covariates in the final model remained constant over survival time.

3.7. Incidence of diarrhea in calves and isolation of causative agents

Diarrhea was the leading cause of calf morbidity and mortality. During the study period, a total of 69 cases of morbidity and 20 cases of mortality due to diarrhea were registered. It was diagnosed in all age groups of calves but a higher proportion (50.7%) was observed in the first month of life followed by the second (21.7%) and third (15.9%) months.

Table 3. Age-specific cumulative survival and incidence of all-cause morbidity and mortality in calves under six months on 20 dairy farms in Hawassa city.

Age interval (months)	Number at risk	Cases	Number censored	Survival prob.	Cum. Incidence	Std. Error	95% CI
Morbidity							
0–1	221	50	0	0.7738	0.2262	0.0281	0.1766–0.2873
1–2	171	20	10	0.6805	0.3195	0.0315	0.2621–0.3857
2–3	141	19	2	0.5882	0.4118	0.0336	0.3493–0.4808
3–4	120	14	1	0.5193	0.4807	0.0344	0.4159–0.5501
4–5	105	3	4	0.5041	0.4959	0.0345	0.4306–0.5652
5–6	98	1	6	0.4988	0.5012	0.0345	0.4358–0.5705
6–	91	0	91				
Mortality							
0–1	221	25	0	0.8869	0.1131	0.0213	0.0779–0.1628
1–2	196	5	10	0.8627	0.1363	0.0231	0.0974–0.1892
2–3	181	4	3	0.8444	0.1556	0.0245	0.1263–0.2272
3–4	174	3	1	0.8298	0.1702	0.0255	0.1526–0.2606
4–5	170	6	10	0.7996	0.2004	0.0274	0.1526–0.2606
5–6	154	0	14	0.7996	0.2004	0.0274	0.1526–0.2606
6–	140	0	140				

Table 4. Kaplan-Meier estimate of the hazard of morbidity and mortality in calves from birth to six months on 20 dairy farms in Hawassa city.

Age interval (months)	Number at risk	Cases	Number censored	Hazard	Std. Error	95% CI
Morbidity						
0–1	221	50	0	0.2551	0.0358	0.1850–0.3252
1–2	171	20	10	0.1282	0.0286	0.0721–0.1843
2–3	141	19	2	0.1456	0.0333	0.0803–0.2109
3–4	120	14	1	0.1244	0.0332	0.0594–0.1895
4–5	105	3	4	0.0296	0.0171	0.0000–0.0630
5–6	98	1	6	0.0106	0.0106	0.0000–0.031
6–	91	0	91	0.0000	–	–
Mortality						
0–1	221	25	0	0.1199	0.0229	0.0730–0.1668
1–2	196	5	10	0.0265	0.0119	0.0033–0.0498
2–3	181	4	3	0.0225	0.0112	0.0005–0.0446
3–4	174	3	1	0.0174	0.0101	0.0000–0.0372
4–5	170	6	10	0.0370	0.0151	0.0074–0.0667
5–6	154	0	14	0.0000	–	–
6–	140	0	140	0.0000	–	–

Of the 20 calves died of diarrhea, 65% were in their first month of life, 15% in the second month of life and 20% were aged 3–5 months old. The results of the bacteriological and parasitological analysis of fecal samples from 33 diarrheic calves showed that 27.3% *Escherichia coli*, 12.1% *Salmonella* spp., and 12.1% *Cryptosporidium* spp. and 3% simultaneous infection with *Salmonella* and *Cryptosporidium* spp. All cases of *E. coli* and 75% *Cryptosporidium* spp. were isolated from calves less than one month of age, while *Salmonella* spp. was isolated from calves two or more months of age (Table 7).

4. Discussion

The cumulative incidence of all-cause morbidity observed in the present study (50.12%) is higher than a previous report of 29.3% in the same study area (Megersa et al., 2009) and 34.1% in North Shewa

Table 6. Risk factors associated with the incidence of all-cause morbidity and mortality in calves under six months of age in multivariable Cox proportional hazard regression model.

Risk factor	Morbidity			Mortality		
	HR	95% CI for HR	*P*	HR	95% CI for HR	*P*
First time calves ingested colostrum (≤6 vs. >6 h)	1.9	1.24–2.90	0.003	2.73	1.45–5.15	0.002
Calving difficulty (No vs. Yes)	2.96	1.94–4.54	<0.001	4.62	2.49–8.58	<0.001
Calving season (Dry vs. Wet)	1.64	1.09–2.47	0.017	2.74	1.45–5.17	0.002

Table 5. Log-rank test of predictors (covariates) of calf morbidity and mortality for equality of survival function.

No	Variable	Morbidity		Mortality	
		Chisq	*p*	Chisq.	*P*
1	Sex (Male/Female)	1.82	0.1775	0.52	0.4718
2	Breed (Jersey/HF cross)	0.46	0.4978	1.42	0.2340
3	Calving difficulty (Yes/No)	20.57	0.0000	28.13	0.0000
4	Dam's parity (Primiparous/Multiparous)	1.60	0.2054	1.46	0.2267
5	Season of calving (Dry/Wet)	5.22	0.1561	7.99	0.0462
6	Weaning age of calves (≤3 months/>3 months)	2.44	0.1180	1.70	0.1922
7	Ventilation (Good/Poor)	4.04	0.0443	0.00	0.9692
8	Farmer's education (Primary/Secondary or above)	0.29	0.5920	0.24	0.6216
9	Herd size (<30/>30)	2.36	0.1242	0.35	0.5547
10	Maternity pen (Yes/No)	1.35	0.2460	0.90	0.3426
11	Knowledge about colostrum (Yes/No)	8.38	0.0038	8.35	0.0039
12	First time calves ingested colostrum (≤6 h/>6 h)	9.41	0.0022	11.25	0.0008
13	Method of colostrum administration (Sucking/Hand-fed)	0.53	0.4684	0.07	0.7895
14	Umbilical care (Yes/No)	0.20	0.6563	0.00	0.9913
15	Mixing of calves of different ages (Yes/No)	2.64	0.1039	1.49	0.2227
16	Mixing of calves and cows in the barn (Yes/No)	3.63	0.0567	4.24	0.0396
17	Calf housing (Separated from cows/Shared with cows)	3.57	0.0590	0.03	0.8585
18	Hygiene (Good/Poor)	0.28	0.5965	0.80	0.3710
19	Vaccination for cows (Yes/No)	0.14	0.7131	0.63	0.4266
20	Chemoprophylaxis (Yes/No)	0.46	0.4967	6.34	0.0118
21	Dairying as a primary income source (Yes/No)	2.17	0.1409	0.24	0.6216

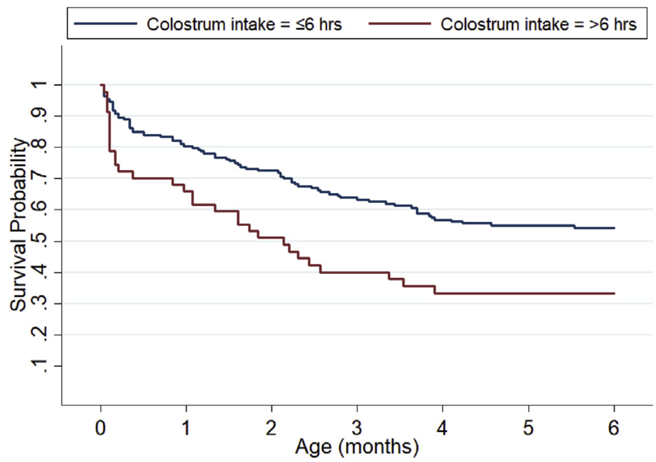

Figure 3. K-M survival curve of all-cause morbidity in calves based on time of colostrum intake.

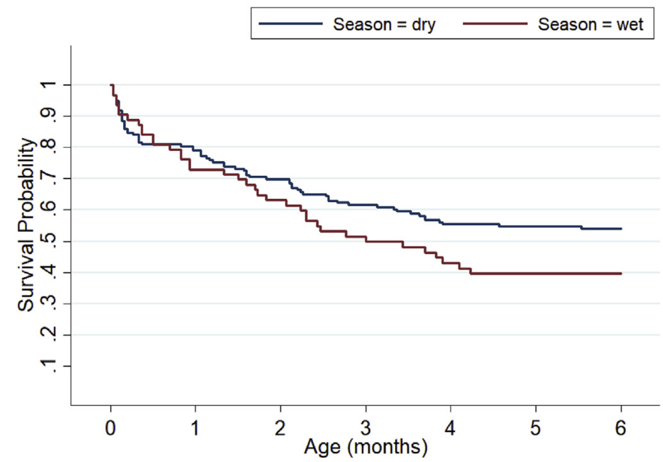

Figure 5. K-M survival curve of all-cause morbidity in calves based on season of birth.

(Mohammed et al., 2020), but lower than the results from other parts of the country, namely 58.4% in the districts Bahir Dar Zuria and Gozamen (Ferede et al., 2014), 62% in Ada'a Liben district (Temesgen et al., 2008) and 66.7 % in the town of Wolayta Sodo (Asmare and Kiros, 2016). Similarly, the current cumulative incidence of all-cause mortality (20.04%) is more than double the 9.3% reports from the same study area (Megersa et al., 2009), but lower than the 22–30.7% reported by other researchers (Temesgen et al., 2008; Ferede et al., 2014; Kebamo et al., 2019), although it is comparable to the 20% observed by Asmare and Kiros (2016). Because of methodological differences in the calculation of the cumulative incidence, it is difficult to clearly attribute the differences in the cumulative incidence of morbidity and mortality between the present and previous studies to differences in geographical and management conditions. In our study, we used the K-M method to calculate the cumulative incidence considering the observed event times and censoring times. The time of the event and how long calves were observed without event occurring were not taken into account in the previous studies. In addition, the previous longitudinal studies did not provide the exact age of the calf at the start of the follow-up. It is evident that events would be observed more frequently in subjects with longer follow-up times than in subjects with a short follow-up. The evaluation of raw event frequencies without specifying the time leads to distorted results. Likewise, in the case of biased results, no distinction is made between whether a subject suffered an event or was censored (Singh and Mukhopadhyay, 2011). Compared to published studies from other countries, the current cumulative mortality incidence is in the range of reports (13–30%) from eastern and southern Africa (Phiri et al., 2010). The calf mortality rates reported from European countries vary between 1% and 9% (Svensson et al., 2006; Gulliksen et al., 2009; Torsein et al., 2011) which is much lower than the present results. The low cumulative morbidity and zero mortality achieved by some farms in the present study suggest that disease and deaths in other farms can be prevented through improved husbandry using existing strategies. Nonetheless, the calf mortality determined is higher than the calf mortality rate of less than 3%–5% that can be achieved through good calf management and defined as the minimum standard for the western production system (Heinrichs and Radostits, 2001). This therefore justifies the need to take appropriate measures to reduce the loss to an economically negligible level.

As found in the K-M hazard analysis, the risk of morbidity and mortality in calves was greatest during the first month of life and then decreased significantly when the calves were up to six months of age. Consistent with our results, other scientists have also found a higher proportion of calf morbidity and mortality during the first month of life and a significant decrease with age (Pardon et al., 2012; Ferede et al., 2014; Fentie et al., 2020). The higher risk of morbidity and mortality in the first month can be attributed to delayed colostrum intake, assistance with calving, and other factors. In general, the relatively higher risk of early life mortality and morbidity of calves means that dairy farmers

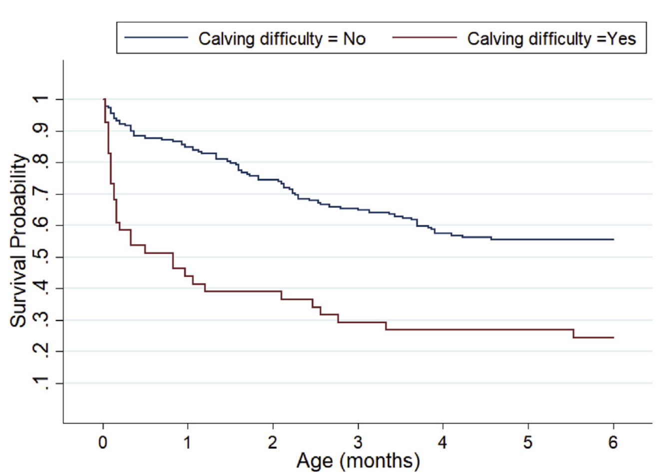

Figure 4. K-M survival curve of all-cause morbidity in calves based on calving condition.

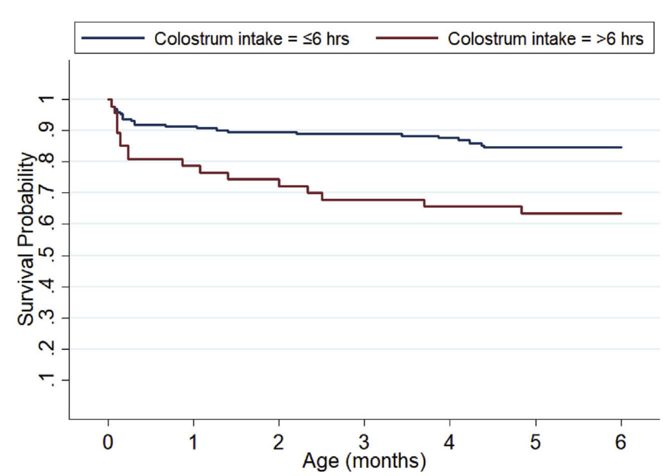

Figure 6. K-M survival curve of all-cause mortality in calves based on time of colostrum intake.

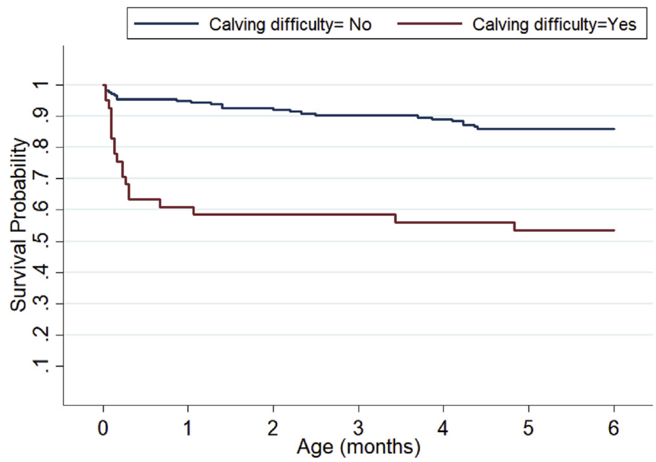

Figure 7. K-M survival curve of all-cause mortality in calves based on calving condition.

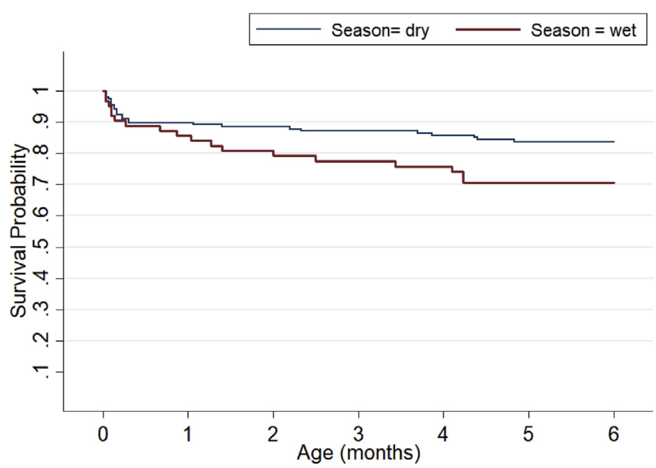

Figure 8. K-M survival curve of all-cause mortality in calves based on season of birth.

must implement appropriate calf management practices at an early age, when calves are very susceptible to infection.

Calves that took their first colostrum meal six hours after birth had a higher risk of morbidity (HR = 1.9) and mortality (HR = 2.74) than calves that were fed colostrum within the first six hours became. This observation agrees with the findings of Ferede et al. (2014), Temesgen et al. (2008) and others. According to Moran (2011), the likelihood of a calf getting sick increases by 10% for every hour of delay in colostrum feeding in the first 12 h of life. Since the concentration of IgG in colostrum and its absorption from the small intestine decrease over time, it is advisable to give a sufficient amount of colostrum immediately after birth (within 1–2 h and before 6 h) to ensure the transfer of passive immunity (Arnold, 2014). Nonetheless, a significant proportion (35%) of farmers in the current study area were unaware of the benefits of colostrum and withheld colostrum from calves for at least six hours as it was widely believed that ingestion of colostrum could cause diarrhea and hair loss in newborns. This practice of withholding the colostrum from the newborn calves or withdrawing essential antibodies from them is certainly a decisive factor for the higher risk of morbidity and mortality found in these farms.

The present study showed that calves that born to difficult calving had a higher risk of morbidity (HR = 2.96) and mortality (HR = 4.62) compared to calves born normally at all follow-up times. This result agrees with previous reports (Lombard et al., 2007; Gulliksen et al., 2009; Assen et al., 2016). Assisted delivery increases the risk of illness and death due to delayed suckling or decreased colostrum intake and a high likelihood of contamination during delivery (Vasseur et al., 2009). In addition, due to stress during delivery, there is a release of adrenocorticotropic hormone, which stimulates the adrenal cortex to increase the synthesis and secretion of cortisol, resulting in immunosuppression (Brown and Vosloo, 2017). According to Gulliksen et al. (2009), dystocia is the most important cause of perinatal mortality (stillbirth after 270 days or up to 24 h after birth). Therefore, dairy farmer management interventions such as timely birth assistance for difficult calving and better feeding and health management during pregnancy are very important to reduce calf mortality from dystocia.

Calves born during the rainy season had a 1.64 and 2.74 times higher probability morbidity or mortality than calves born during the dry season. The rainy season here comprises the months April to August, which in Hawassa and most parts of Ethiopia are characterized by short to heavy rains. It is evident that the wet and cold environment of the calves at this time of year creates a conducive condition for microorganisms to multiply and thus for calves to become infected, leading to diarrhea, pneumonia and other disease states. A similar result was reported in a Norwegian study (Gulliksen et al., 2009). In contrast, other studies in Ethiopia (Ferede et al., 2014) reported that there was no significant difference in calf morbidity or mortality between the two seasons. However, these studies included calves of a wide range of ages and this might have made the difference insignificant.

In various countries it has been shown that therapeutic and prophylactic treatments with antibiotics and anthelmintics reduce calf morbidity and mortality (Uetake, 2013). In the present study area, 65% of the dairy farmers stated that they administered some antibiotics such as a penicillin-streptomycin combination and oxytetracycline as well as anthelmintics mainly albendazole, to calves when they were three months old. The morbidity and mortality incidences were lower in the farms with prophylactic treatments, although in the multivariable model was not statistically significant. Perhaps this would have increased the calves' protection against infectious diseases and thus improved their survival. Still, improving management practices and calf rearing conditions is far better than the use of chemotherapy drugs, given the economic and welfare benefits of prevention.

Table 7. Age distribution of diarrhea and the etiological agents isolated in cross-bred calves under six months of age.

Age in months	Cases	No of samples	E. coli	*Salmonella* spp.	Cryptosporidium spp.	Salmonella & Cryptosporidium
0–1	35	24	9	–	3	–
1–2	15	7	–	2	1	–
2–3	11	1	–	1	–	1
3–4	6	–	–	–	–	–
4–5	1	1	–	1	–	–
5–6	1	–	–	–	–	–
Total	69	33	9 (27.3)	4 (12.1)	4 (12.1)	1 (3)

Note: The figures in parenthesis are percentages out of 33 diarrheal cases.

Diarrhea was the most commonly observed disease syndrome and the leading cause of calf mortality in the present study. Consistent with the present results, other studies in Ethiopia have also identified diarrhea and pneumonia as the two most important health problems in calves (Temesgen et al., 2008; Ferede et al., 2014; Mohammed et al., 2020). Similar results have also been reported from studies overseas (Sivula et al., 1996; Abu El-Hamd et al., 2017). Calves were at the greatest risk of developing diarrhea in the first month of life and the incidence of diarrhea decreased with age. This result is in line with other reports (Radostits et al., 2007; Gulliksen et al., 2009; Pardon et al., 2012). The higher incidence of diarrhea at young age could be related to poor hygienic handling of feeding utensils and inadequate timely provision of colostrum (i.e. poor transfer of passive immunity). Contrary to our results, some studies reported that pneumonia was the leading cause of calf mortality and the incidence was higher in calves over a month old (Gulliksen et al., 2009; Pardon et al., 2012). The authors stated that the incidence of pneumonia was associated with overcrowding, poor ventilation, and stressful conditions. As suggested by Sivula et al. (1996) pneumonia is not diagnosed by farmers as early as diarrhea.

Examination of fecal samples from diarrheic calves using available diagnostic facilities revealed the presence of *E. coli, Salmonella* spp., and *Cryptosporidium* spp. in the studied farms. The proportion of *E. coli* and *Salmonella* spp. detected in the present study is comparable to the results of Asmare and Kiros (2016). Although we were unable to perform serotyping due to the lack of a suitable kit, the characteristic hemolysis on blood agar, the clinical symptoms manifested by the diarrheic calves, age of the calves affected, the situation of the dairy calves' environment and the self-limiting nature of the disease indicated that the isolated *E. coli* was the pathogenic (diarrhea-producing) strain. Regarding *Cryptosporidium* spp., the present finding is higher than the prevalence reported by Temesgen et al. (2008) (7.2%), while Asmare and Kiros (2016) found a much higher prevalence of 52.6% compared to our finding to have. Overall, the isolation of *E. coli, Salmonella* spp., and *Cryptosporidium* spp. in the present study points to their important role in calf diarrhea complex and also to the zoonotic potential. It is worth noting that samples from healthy calves were not analyzed in this study, so the pathogens identified in samples of diarrheic calves may also be present in healthy calves. This is one of the limitations of the present study that needs to be considered in future studies.

In general, the diagnosis of the causes of calf morbidity and mortality in this study was based solely on the observation of clinical signs in the affected calves. This is the main limitation of the study that should be well addressed in future studies of calf morbidity and mortality in Ethiopia. The majority of the dairy farms (approx.80%) in the study area had a herd size of less than 10 cows and as a result calves were sampled for the study from relatively larger farms with 10 or more cattle. Failure to include those farms with small herds is another limitation of the current study that should also be addressed in future studies.

5. Conclusion

The present study showed that the cumulative incidence of all-cause morbidity and mortality in calves from birth to six months of age is 50.1% and 20.04%, respectively. The cumulative mortality incidence observed in the current study is above the economically justifiable level that can be achieved through good management. The study found that the risk of morbidity and mortality was greatest in the first month of life. Among the 21 potential risk factors studied, delayed colostrum intake, calving difficulty and calving season were the three factors identified to significantly affect calf morbidity and mortality in the study population. In addition, the study showed that diarrhea, pneumonia, and septicemia are the main causes of morbidity and mortality in calves. Hence, continuous training of dairy farmers is required to raise their awareness of some easy-to-fix issues, such as feeding adequate colostrum, timely obstetrics for difficult calving, and other management practices.

Declarations

Author contribution statement

Debele Hordofa: Performed the experiments.

Fufa Abunna and Bekele Megersa: Analyzed and interpreted the data.

Rahmeto Abebe: Conceived and designed the experiments; Contributed reagents materials, analysis tools or data; Wrote the paper.

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Data availability statement

No data was used for the research described in the article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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