Ovozoa 13 No. 2, August 2024 p-ISSN 2302-6464 e-ISSN 2722-967X
Available at https://e-journal.unair.ac.id/OVZ/index

Original article

Calf morbidity and mortality rates Associated risk factors in smallholder dairy farms in Kembata Tembaro zone, Southern Ethiopia

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Open access under CC BY – SA license, DOI: 10.20473/ovz.v13i2.2024.67-81
Received April 5 2024, Revised July 8 2024, Accepted August 5 2024
Published online August 2024

ABSTRACT

A study was carried out in the Kembata Tembaro Zone of Southern Ethiopia, focusing on both prospective cohort and cross-sectional surveys. The objective was to measure the rates of calf sickness and death and to pinpoint the factors that contribute to these conditions. Over 180 days, 140 newborn calves from selected small-scale dairy farms were studied. The study evaluated the prevalence of illness, mortality, and specific diseases by calculating incidence rates. Results indicated a 41.7% risk of illness and a 9.5% mortality rate among calves. Factors such as the calf's condition at birth, birth location/environment, the surface on which the calf was born, timing of the first colostrum intake, maternal parity, calf breed, and the breeding service technique significantly influenced mortality rates. Similarly, these factors were also significantly linked to the crude morbidity rate. Calves born naturally were at a lower risk of sickness (HR=0.6, p=0.001) compared to those assisted. Calves born indoors had a lower risk of sickness (HR=0.9, p=0.008) than those born outdoors. Calves that received colostrum within six hours of birth had a lower risk of sickness (HR=0.6, p=0.009) than those that received it later. Additionally, the study found that the floor of the birth place, the mother's parity, the breed of the calf, and the technique of the breeding service were additional risk factors for calf sickness. The time of the first colostrum intake, the mother's parity, and the calf's birth condition were also significant risk factors for calf death.

Keywords: calf, Kembata, morbidity, mortality, prospective cohort

Introduction

In several developing global regions, raising livestock is one of the most essential ways to raise living conditions. Livestock farming has a major role in the national economy and rural communities' means of subsistence in sub-Saharan African countries like Ethiopia. Africa's largest cattle population is found in Ethiopia. Ethiopia is home to Africa's largest population of cattle. Among the key sectors of animal agriculture, dairy farming stands out, with the young animals eventually contributing to the farm's herd. Ethiopia has prioritized farmer-level dairy development in order to boost the amount of milk produced by smallholder dairy farms (Negassa *et al*., 2011).

A sizable and vibrant sector of the agricultural economies of many countries is the dairy business. The industry provides milk and milk products to consumers in urban and suburban areas (Heinrichs and Radostits, 2001). Urban and semi-urban dairy operations are intensive systems for raising cows, employing advanced management techniques, however they are typically linked to poor reproductive success,

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low survival rates, and higher disease susceptibility (Goshu and Singh, 2013).

Dairy farmers around the world are always dealing with calf illness and mortality, particularly in the tropical regions, which are not the best places to raise calves. This is due to the excessive humidity and warmth, which can lead to several illness problems in milk-fed calves and hinder the proper replacement of heifers (Heinrichs and Radostits, 2001). The ability to replace heifers significantly affects a dairy farmer's capacity to increase production by enabling the selective removal of less productive cows (Moran, 2011).

The performance of a dairy farm is negatively impacted both temporarily and permanently by calf morbidity and mortality. They reduce the herd's ability to develop and replace itself (Lorenz *et al*., 2011). Diseases affecting young calves in dairy farms have a significant financial impact on the dairy business due to treatment expenses, loss of genetic quality, and decreased future productivity (Donovan *et al*., 1998). Moreover, the infectious agents responsible for calf diarrhea, such as *E. coli*, *Salmonella*, *Campylobacter*, and *Cryptosporidium*, can also be a threat to humans (Kevin *et al*., 2010). Gut parasites are major health issues for young animals in many tropical and subtropical areas (Keyyu *et al*., 2005). Therefore, managing infections caused by these microorganisms in dairy calves can bring economic, health, and welfare benefits to the dairy industry and also reduce the risk of diseases being transmitted to humans (Varma *et al*., 2005).

In young stock farms, optimal rumen development and growth are achieved by effective dietary strategies that minimize stress and disease. Health and production are significantly impacted by the surroundings and housing of dairy cows. Calves' health is influenced by hygienic conditions and barn cleanliness since clean barns reduce the danger of disease in calves kept there (Wudu *et al*., 2008). Colostrum, the early milk from cows, is rich in immunoglobulins and other vital nutrients for calf health, providing protection against various infections. New-born calves, with underdeveloped immune systems and no previous exposure to infections, are more vulnerable to infectious diseases and poor management practices (Mengesha *et al*., 2013).

Therefore, it's crucial to examine the current environment of dairy farming, assess the limitations in dairy farming production, and develop relevant and effective plans for the sustainable growth of dairy markets within the country (Tegegne and Gebrewold, 1998). Relying on local cattle species alone to meet the increasing demand for milk and dairy products in Ethiopia is not a quick and practical solution, as local tropical cattle have limited milk production, shorter lactation periods, and slower growth rates (Tewodros, 2008). Thus, alternative approaches, such as crossbreeding local cattle with high-quality European dairy breeds and increasing the density of livestock production, as well as transitioning from subsistence to commercial large-scale livestock production systems, could be considered (Goshu and Singh, 2013).

The current livestock breeding program in Ethiopia aims to enhance the genetic makeup of the local breeds through crossbreeding with superior foreign breeds. As a result, there has been a steady increase in the percentage of crossbred calves in smallholder dairy operations, particularly in the highlands, indicating a population at risk requiring better health management and care. Reducing juvenile and adult stock mortality is one of the main areas of management and health interventions that was recently suggested in the Livestock Development Master Plan (Ministry of Agriculture, 2014).

In the dairy industry, high rates of calf illness and mortality result in substantial financial losses due to reduced productivity, medical costs, poor growth rates, and shortened lifespan. These issues also impact the availability of dairy cows for herd expansion, replacement, and the retention of valuable genetic material for herd improvement, as noted in recent years (Mellado *et al*., 2014). To address these losses, it is crucial to identify the causes of calf morbidity

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and mortality, as well as the contributing factors, and implement effective control strategies (Mee, 2013). Currently, no comprehensive studies have been conducted on calf morbidity and mortality, with detailed epidemiological analyses of risk factors in urban and peri-urban dairy farming systems in the Kembata Tembaro Zone and surrounding areas. Therefore, a thorough investigation is needed to develop tailored recommendations for improving calf health and productivity in these regions. The aim of this research was to determine the prevalence of key causes of calf illness and death and to identify the associated risk factors in the Kembata Tembaro Zone of Southern Ethiopia.

MATERIALS AND METHODS

Description of the study area

The study was conducted in the Kembata Tembaro Zone, situated in the southern region of Ethiopia (refer to Figure 1). This zone is part of the Southern Nations, Nationalities, and Peoples' (SNNP) region in Ethiopia. It is situated south of the Woliata zone, west of the Omo River or Dawro zone, north of the Hadiya zone, and east of the Halaba zone. The absolute location of Kembata Tembaro Zone is lies between Latitude 07°12'30.1"-07°17'08.3"N and Longitude 37°47'48"-37°50'30.6"E. Average temperature and annual rainfall of the area ranges from 14°C to 26°C and 800 mm to 1200 mm. The study had covered Hadero, Shinshicho and Durame towns and their surrounding kebeles in Kembata Tembaro Zone. The estimated livestock population of the Kembata Tembaro Zone is 812175 cattle, composed of 575020 local zebus and 237155 crossbreed. There are 125358 farms in Kembata Tembaro Zone; from these in Durame town and its surrounding 3471 smallholder dairy farms, Shinshicho town and its surrounding 2584 smallholder dairy farms and Hadero town and its surrounding 2172 smallholder dairy farms (Kembata Tembaro Zone Livestock Department, 2021).

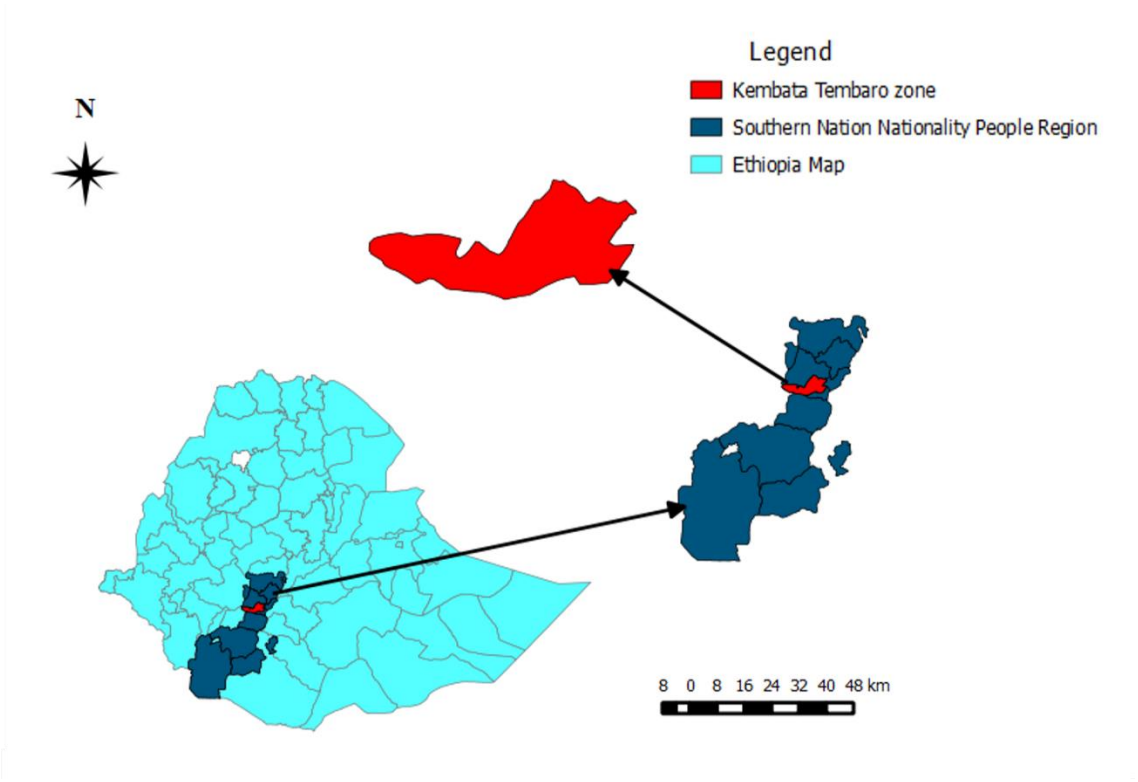

Figure 1 Map of the study area

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The study was conducted on small-scale dairy farms in the urban and suburban areas of Hadero, Shinshicho, and Durame towns in the Kembata Tembaro Zone, SNNP region, Ethiopia. Urban dairy farms, located within the towns, were characterized by semi-intensive, market-oriented milk production, while suburban farms were situated on the outskirts. A total of 63 farms were included in the study, comprising 34 suburban and 29 urban farms. The study cohort consisted of 89 female and 51 male calves. Following the definition by Muraguri *et al*. (2005), small-scale dairy farms were identified as those with 1 to 20 cattle of any age and sex. The study included dairy calves of all breeds and both sexes up to six months old, excluding stillborn calves, those with congenital malformations, and calves suffering from wasting diseases. The enrolled calves were monitored biweekly until six months of age, with additional emergency visits as needed for health issues.

Ethics approval and consent to participate

All ethical issues were considered. All laboratory activities comply with institutional, national and international guidelines. The work was guided by the technical staffs in Wolaita Soddo Regional Laboratory and evaluated and approved by Hawassa University Faculty of Veterinary Medicine examiners board.

Study design

The study was conducted using a prospective cohort study design. The study utilized questionnaires and field observations to identify risk factors linked to calf morbidity and mortality. Researchers conducted interviews with smallholder farmers during the study to gather herd-level data on various factors, including farm characteristics, calf and dam conditions, management practices, health issues, and environmental risks. This information supported the findings of the cohort analysis.

Calf recruitment criteria

One hundred and forty newborn calves from small-holder dairy farms that were sampled were enrolled and monitored for 180 days, or six months. Calves that were less than one month old at the time of the initial visit, with known birth dates and medical histories, were retrospectively enrolled (concurrent cohort) and included in the prospective cohort. Calves born inside the designated farms throughout the study period were gradually added to the recruitment pool. The calves studied were not calves that were bought or entrusted. When the first farm visit occurred, the calves that were recruited and those born after the first visit were ear tagged. The investigator and kebele animal health professionals (assigned enumerator) visited all of the selected calves every two weeks until the calves were six months old. Calves were included in the study for a six-month follow-up period. Subjects lost during this timeframe were recorded, noting the date and reason for attrition. Potential risk factors associated with each calf were assessed using a standardized control form administered at study onset.

Sample size determination

The desired sample size was calculated using the standard formula described in (Dohoo *et al*., 2009) and an expected relative risk of 10.1% adopted from previous results in Hawassa by Agegnehu and Rahmeto (2020) as follows:

$n = \frac{Z^2_{\alpha} .pq}{L^2}$

where *n* = sample size; *Zα* = the value of standard normal distribution at 95% level of confidence (Z*α* = 1.96); p= expected relative risk 10.1%; q=1-p; L= the required absolute precision of the estimate (5%); $1.96^2 x 0.101 x 0.899 / 0.0025 = 140$; accordingly, the calculated sample size was 140 calves.

Sampling technique

Purposively, study sites were chosen according to their potential for dairy production. All local, crossbred dairy calves between the ages of birth and six months comprised the sampling units. The size of the farmer's herd and willingness to participate in the study were the two main criteria used in the farmer selection procedure. Thus, out of all the dairy farms in the research locations, those with five or more cows

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were purposefully chosen to enhance the likelihood of having more calves.

Data collection

Data were collected on potential risk factors influencing dairy calf survival and welfare. These factors were categorized at the farm and calf levels. Farm-level variables encompassed farm characteristics, housing conditions, herd health, and overall management practices. Calf-level variables included pedigree, birth location, calving details, colostrum management, initial housing, routine management procedures, and health events during the observation period. Standardized case definitions were employed to classify mortality, specific diseases, and treatments.

Routine farm visits encompassed several key activities including surveying the calf breeders for any health problems that occurred in their calves during the visit and recording the history of any health problems in the calves; calves underwent thorough physical examinations including vital parameter assessment (temperature, respiratory rate, and heart rate) when indicated by clinical signs; inspecting the cleanliness of the calf housing, with an evaluation of the stable floor condition, including the type of accommodation, ventilation, and drainage systems, as well as assessing the overall hygiene within the facility and its surrounding areas; reviewing the feeding regimen for the calves, including an analysis of the feed types administered, such as concentrates, hay, and straw or crop residues. In addition to scheduled visits, emergency consultations were also carried out in response to urgent requests from dairy owners regarding calf health issues.

Data management and statistical analysis

Morbidity and mortality estimation

The primary endpoints of this study are morbidity and mortality. Any illness with identifiable clinical indications that required therapeutic intervention throughout the follow-up period or resulted in death is considered morbid. However, mortality is the definition of any death that is seen, regardless of the reason. Since the animals in this long-term study were enrolled at various points in time and monitored for varying lengths of time, the occurrence of diseases was described using incident density, or actual rate. Morbidity, mortality, and other risk of a particular disease states were determined by calculating the actual incidence, i.e., the rate at which an event occurred per unit of time at risk (Muraguri *et al*., 2005). Thus, incidence ratios (IRs) or cause-specific incidence rates were estimated using the following formula:

$$IR(x)=\frac{\text{number of events occured during observation period}}{\text{total calf days at risk}}$$

The number of days a calf was at risk during a given period is the denominator, while the occurrence of a particular outcome served as the numerator. The total number of days at-risk was calculated by counting the days a calf was susceptible to reinfection from birth until six months of age or until its removal from the herd. Calves that recovered from the disease were included in the calculation of crude prevalence, which reflects the likelihood of recurrence. Recurrent cases of the same disease were counted as distinct cases in calculating disease frequency only if the subsequent case occurred after the clinical signs of the first case have resolved (Wudu, 2004). In this study, calf age was defined as up to six months; therefore, the number of days at risk was converted to months at risk. To allow comparison with other studies and to address the tendency of direct incidence calculations to overestimate calf morbidity and mortality rates (Gitau *et al*., 2012), actual incidence rates for mortality, morbidity, and other specific conditions were adjusted using risk ratios and transformed according to the formula ($RR= 1^{-e\ -True\ Rate}$) (Martin *et al*., 2007).

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Examination of risk factors for morbidity and mortality

In total, 27 potential risk factors associated with calf morbidity and mortality were examined. These factors were categorized into five groups: calf-specific (5 factors), dam-related (5 factors), management practices (8 factors), farm attributes (7 factors), and environmental risk factors (2 factors). For the purpose of simplifying the analysis and interpretation of the results, all response variables were dichotomized.

Survival analysis and modeling risk factors

The relationship between potential risk factors and calf morbidity and mortality was analyzed using STATA version 14 (Stata Corp., College Station, Texas, USA, serial number: 501406202773), employing Cox regression methods. Cox proportional hazards models were specifically used to assess and quantify the association between explanatory variables and calf survival up to 180 days of age. Initially, univariate Cox regression was conducted to identify significant associations between individual risk factors and outcomes. Variables showing a significant association at the 5% level in univariate analysis were included in multivariate analysis to assess their independent influences. Next, the model for each outcome variable were refined using a stepwise backward elimination process, removing non-significant variables ($p > 0.05$).

RESULTS

Questionnaire-based herd-level study

Respondents' household characteristics

The household and performance characteristics of the surveyed smallholder dairy farmers are shown in Table 1. Of all the smallholder farmers surveyed in Kembata-Tembaro district, 46% were living in the city and 54% were living in suburban smallholder dairy farms, 77.8% of the household heads were male and 22.2% female, and the age of the household head was 36.5%. The age of the household members was below 45 years and 63.5% were above 45 years. In terms of literacy of the respondents, 9.5% of the dairy farmers were illiterate, 34.9% had primary education, 41.3% had high school diploma and the remaining 14.3% were professional, of which only 3.2% were engaged in livestock and animal husbandry.

About 66.7% of the respondents knew that it was beneficial to feed calves with colostrum instead of normal milk and fed them with colostrum within 6 hours after birth. However, the remaining 33.3% of the respondents did not know that it was beneficial to feed calves with colostrum early. Thus, the newborn calves were forced to partially suckle the remaining colostrum (which is then excreted) and were then let to suckle the colostrum only after the remaining placenta was expelled. Modes of calf feeding were free grazing (12.7%) stall feeding (63.5%) and grazing with partially supplement (23.8%). Source of water for calves was tap water (36.5%), from river (31.7%) and from open well (4.8%). Only 7.9% of dairy farm owners had not provides the bedding materials and the rest 92.1% farm owners provide bedding material.

Table 1 Characteristics of smallholder households and dairy farm performance surveyed

herd level variables, parameters	frequency	percent
sex of house hold		
female	14	22.2%
male	49	77.8%
age of house hold		
≤45 years	23	36.5%
>45 years	40	63.5%

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educational status of house hold		
illiterate	6	9.5%
elementary	22	34.9%
high school	26	41.3%
professional	9	14.3%
experience calf caretaker		
≤5 years	28	44.5%
>5 years	35	55.5%
location of farm		
urban	29	46.0%
peri-urban	34	54.0%
duration of farm		
< 5 years	11	17.5%
5-10 year	30	47.6%
>10	22	34.9%
calving facilities		
present	44	69.8%
absent	19	30.2%
awareness to colostrum feed		
yes	42	66.7%
no	21	33.3%
time of first colostrum feeding		
≤ 6 hours	42	66.7%
> 6 hours	21	33.3%
mode of feeding		
free grazing	8	12.7%
stall feeding	40	63.5%
partial grazing	15	23.8%
source of water		
tap water	40	63.5%
river	20	31.7%
open well	3	4.8%
bedding		
present	58	92.1%
absent	5	7.9%

Calf-level study/longitudinal observation

Cohort distribution and dynamics

A cohort of 140 calves (104 crossbred and 36 local) was selected from 63 small urban and suburban dairy farms in the Kembata Tembaro district, with nearly all calves being born on the research farm. Calves purchased during the study period were excluded due to incomplete data. During the observation period, the cohort consisted of 89 female calves (63.6%) and 51 male calves (36.4%), resulting in a total of 23,972 calf-days at risk, or approximately 133 calves at risk per six-month period. As shown in Table 2, out of the 140 calves followed in the study, 15 calves exited the cohort early due to death or sale, resulting in an overall dropout rate of 10.7%, which included 9 females (6.4%) and 6 males (4.3%).

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Table 2 Number of calves observed and reasons of withdrawals from the longitudinal cohort

visit at monthly basis	number of calves	withdrawals		
		deaths	sales	total
first visit	91	-	-	-
January	33	4	1	5
February	16	4	0	4
March		3	1	4
April		0	0	0
May		2	0	2
June		0	0	0
July		0	0	0
total	140	13	2	15

Morbidity and mortality estimates

Morbidity

The total prevalence and cumulative frequency of the different pathologies/syndrome included in the study are shown in Table 3. The morbidity risk was 41.7%. Of the pathologies identified during the observation, diarrhea in calves was the most common cause of calf morbidity with an incidence of 14.8%, followed by septicemia (11.3%) and pneumonia (10.4%). The incidence of other calf head diseases was relatively low.

Mortality

Calf mortality data, categorized by disease, are presented in Table 4. The overall calf mortality risk in this study was 9.5%. The primary cause of mortality was watery or bloody diarrhea, responsible for the deaths of 5 out of the 13 calves that died. Septicemia also significantly contributed to calf mortality, accounting for 4 of the deaths. Additionally, 2 calves died from pneumonia, and the remaining 2 calves succumbed to unknown causes, including sudden death.

Table 3 Incidence (true rate and risk rate) of crude morbidity and specific disease conditions in Kembata Tembaro zone

disease condition	n	calf days at risk	calf six months at risk	incidence	
				true rate (calf six months at risk)	risk rate (%)
diarrhea	21	23374	130	0.16	14.8
pneumonia	14	24198	134	0.11	10.4
septicemic conditions	16	23918	133	0.12	11.3
navel ill	3	24585	137	0.02	2.2
miscellaneous cases	5	24740	137	0.04	3.6
non specific	2	24859	138	0.02	1.5
crude morbidity rate	61	20475	114	0.54	41.7

Risk rate = $1\text{-e-}^{\text{true rate}}$; n: number of cases

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Table 4 Incidence (true rate and risk rate) of crude mortality and specific disease conditions in Kembata Tembaro zone

disease condition	n	calf days at risk	calf six months at risk	incidence	
				true rate	risk rate (%)
diarrhea	5	24516	136	0.04	3.9
pneumonia	2	24865	138	0.02	1.5
septicemic conditions	4	24815	138	0.03	2.9
non specific	2	24933	139	0.01	1.4
crude mortality rate	13	23972	133	0.10	9.5

Risk rate = $1\text{-e-}^{\text{true rate}}$; n: number of cases

Association of explanatory variables with morbidity and mortality

Risk factors of crude morbidity

According to univariable Cox-regression six risk factors were found significantly associated with calf morbidity ($p < 0.05$) (Table 5). In the multivariate analyses, incidence models were refined using a stepwise backward elimination method, removing variables that did not reach statistical significance ($p > 0.05$). However, after multivariable modelling at $p < 0.05$, Condition of birth, Site of birth, Floor of birth place, Time of first colostrum ingestion, Parity of dam, breed and technique of breeding service were found to be significantly associated with crude morbidity (Table 6).

Table 5 Potential risk variables significantly associated with the incidence of crude morbidity based on univariable analysis using cox regression

variables	categories	HR	95% CI for HR	p value
condition of birth	easy v assisted	0.6	0.4 – 0.9	0.001
site of birth	in door vs out door	0.8	0.2 – 0.9	0.035
floor of birth place	concrete vs mud	0.4	0.07 – 0.6	0.001
time of first colostrum ingestion	<6 hours vs > 6 hours	0.6	0.2 – 0.9	0.032
parity of dam	primiparous vs multiparous	1.7	1.2 – 7.0	0.001
technique of breeding service	AI vs natural	0.5	0.2 – 0.8	0.012

HR: hazard ratio (which has similar meaning to relative risk); CI: confidence interval

Table 6 Potential risk variables significantly associated with the incidence of crude morbidity based on multivariable analysis using cox regression

variables	categories	HR	95% CI for HR	p value
condition of birth	easy vs assisted	0.6	0.3 – 0.7	0.001
site of birth	in door vs out door	0.7	0.3 – 0.8	0.008
floor of birth place	concrete vs mud	0.4	0.3 – 0.7	0.001
time of first colostrum ingestion	<6 hours vs >6 hours	0.6	0.1 – 0.7	0.009
parity of dam	primiparous vs multiparous	1.6	1.4 – 2.9	0.011
technique of breeding service	AI vs natural	0.6	0.4 – 0.9	0.001
breed	cross vs local	1.5	1.1 – 11.3	0.038

HR: hazard ratio (which has similar meaning to relative risk); CI: confidence interval

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According to the model, calves that were born without assistance had a relative risk of morbidity that was 0.6 times that of calves born with assistance. Calves born in stables had a 0.7 times higher relative risk of morbidity compared to those born outdoors. The relative risk of morbidity for calves born on concrete was 0.4 times higher than for those born on mud. Additionally, calves that ingested colostrum six hours after birth had a relative risk of morbidity 0.5 times that of calves born on concrete. The relative hazard of morbidity was 1.6 times higher for calves born to primiparous dams compared to those born to multiparous dams. Calves born through artificial insemination had a 0.6 times lower relative hazard of morbidity compared to those born through natural mating. Furthermore, crossbred calves had a relative hazard of morbidity 1.6 times higher than that of local breed calves.

Risk factors of crude mortality

Three explanatory variables were found to be significantly associated with mortality ($p < 0.05$) according to the univariable Cox regression analysis (Table 7). In multivariate analysis, models of mortality were fitted by gradual elimination of nonsignificant variables ($p > 0.05$). According to multivariable modeling, $p < 0.05$, Condition of birth, Time of first colostrum ingestion and Parity of dam were found significantly associated with crude mortality (Table 8).

Table 7 Explanatory variables significantly associated with the incidence of crude mortality based on univariable analysis using Cox regression

variables	categories	HR	95% CI for HR	p value
condition of birth	easy vs assisted	0.5	0.06 – 0.8	0.0016
time of first colostrum ingestion	<6 hours vs >6 hours	0.3	0.04 – 0.8	0.024
parity of dam	primiparous vs multiparous	1.7	1.3 – 3.7	0.001

HR: hazard ratio (which has similar meaning to relative risk); CI: confidence interval

Table 8 Potential risk factors significantly associated with the incidence of crude mortality based on multivariable analysis using Cox regression

variables	categories	HR	95% CI for HR	p value
condition of birth	easy vs assisted	0.6	0.3 – 1.0	0.047
time of first colostrum ingestion	<6 hours vs >6 hours	0.4	0.04 – 1.0	0.039
parity of dam	primiparous vs multiparous	1.5	1.2 – 3.4	0.001

HR: hazard ratio (which has similar meaning to relative risk); CI: confidence interval

According to this model, the relative risk of death for calves from primiparous cows was 1.5 times higher than for calves from multiparous cows, keeping the effects of other variables constant. Calving rates were 0.6 times higher for assisted calves, and the relative risk of death for calves that received colostrum after 6 hours was higher. Thus, the higher risk of death due to delayed colostrum intake may be related to a failure of passive transfer of colostral immunity.

DISCUSSION

This study was undertaken to ascertain the incidence of calf morbidity and mortality on smallholder dairy farms in the Kembata Tembaro Zone and to determine the risk factors contributing to these outcomes. The research aimed to achieve these objectives through the use of herd-level questionnaires and longitudinal observations at the calf level.

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Herd-level results based on semi-structured questionnaires and observations

The proportion of women employed in dairy farming (female owners) in the study area was high (22.22%) compared to a previous report that found only 11% of smallholder dairy farms in Debre Ziet were female-operated (Mekonnen *et al*., 2006). This indicates that smallholder dairy farming is enabling women to become self-employed and contributing to poverty reduction for this particular group. One of the reasons for this could be the current support for women by local government.

The study found that the majority of farmers (66.7%) knew about colostrum but 33.3% of dairy farmers did not know the appropriate time to feed colostrum to calves. In this study, 66.7% of the owners practiced feeding colostrum to newborns of <6 hours after birth. This was considered by different researchers as a good practice of ensuring enough colostrum to the calves in the early hours to keep the animals health and protect liability to some neonatal diseases and mortality (Wudu *et al*., 2008; Yeshwas, 2015; Tekalign, 2020).

Morbidity and mortality

In this study, calf morbidity and mortality rates were observed to be 41.7% and 9.5%, respectively, which are notably high. These findings exceed the mortality risk reduction achievable through proper calf management by a factor of 3-5 times and are above economically acceptable levels (Gitau *et al*., 2012; Heinrichs and Radostits, 2001). The level of calf mortality reported in this study aligns generally with findings from Hawassa city (Bekele *et al*., 2009). However, the current mortality rate is comparatively higher than some previously reported rates from Ethiopia (Shiferaw *et al*., 2002; Amuamuta *et al*., 2006; Tora *et al*., 2021), yet relatively lower than other reports from the same region (Ababu *et al*., 2006; Godden, 2008; Wudu *et al*., 2008; Gebremedihin, 2014; Tsegaw *et al*., 2016). The discrepancies between the current findings and earlier reports from Ethiopia could be attributed to various risk factors at the calf and herd level, differing management practices, the age and breed of calves examined, agroecological conditions, and the methodologies employed to measure mortality (incidence/risk or prevalence).

Morbidity statistics are generally scarce for many enterprises and, unlike mortality rates, are challenging to compare across different studies. When available, significant variability often exists, due in part to the lack of reliable morbidity records from milk producers and differing diagnostic methods. For example, some studies report calf morbidity based on producer diagnosis and treatment, while other studies rely on veterinarian diagnosis (Wudu, 2004). The current study's morbidity rates are relatively high compared to previous reports from Ethiopia, which documented rates of 29.3% and 30.9% (Bekele *et al*., 2009; Tora *et al*., 2021), but are lower than other reports that recorded rates as high as 62% (Wudu *et al*., 2008; Yeshwas *et al*., 2014; Yeshwas, 2015). The morbidity rates observed in this study, at 58.4% and 47.3%, are relatively moderate within this context.

Cause specific morbidity and mortality

In this study, calf diarrhea was found to be the main calf health problem, with a risk of 14.8%, followed by sepsis (11.3%) and pneumonia (10.4%). The risk of diarrhea in calves in this study was higher than previous studies in Ethiopia (Bekele *et al*., 2009; Tsegaw *et al*., 2016; Tora *et al*., 2021), with values of 10%, 10.4%, and 10.43%, respectively. In contrast, the present results were lower than previous studies in Ethiopia (Wudu *et al*., 2008; Yeshwas, 2015; Assefa and Ashenafi, 2016), with values of 34%, 25.2%, and 42.9%, respectively. This result is supported by other studies (Wudu *et al*., 2008; Yeshwas, 2015), which recorded calf diarrhea as the most common disease. Despite calf diarrhea being a prevalent health issue among growing dairy calves, the low incidence observed in this study underscores the importance of maintaining hygienic practices in handling feeding equipment and calf housing. Furthermore, the majority of smallholder farmers demonstrated an awareness of the optimal timing for colostrum

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feeding, which, according to observations and interviews, may significantly contribute to the reduced incidence of calf diarrhea.

The next dominant calf health problem in this study was septicemic conditions with incidence rate of 11.3% and this was different from some studies which was pneumonia next to calf diarrhea (Gebremedihin, 2014; Yeshwas, 2015; Assefa and Ashenafi, 2016; Tsegaw *et al*., 2016; Tora *et al*., 2021). The relatively low incidence of pneumonia in this study may be due to the small number of livestock on the farms. The incidence of other health problems in calves was low.

Determinants of calf morbidity and mortality

The relationship between roughly 27 proposed explanatory variables and crude mortality and morbidity was examined on small-holder dairy farms in the Kembata Tembaro Zone. Nevertheless, these variables underwent a rigorous procedural examination employing Cox-regression for both univariable and multivariable analysis. The condition of birth, the timing of the first colostrum ingestion, and the dam's party were examined as potential risk variables for calf mortality in the final model (multivariate Cox regression). Some of the established determinants of calf morbidity included the birthplace, condition, floor, time of the initial colostrum intake, breed, and parity of the dam.

Birth conditions were significantly associated with calf mortality and morbidity. Calves born with assistance exhibited higher mortality and morbidity rates compared to those born unassisted. These findings are consistent with previous studies (Yeshwas, 2015; Tora *et al*., 2021). Additionally, the timing of colostrum intake was crucial, with calves receiving colostrum after 6 hours of age experiencing higher mortality and morbidity than those receiving it within the first 6 hours of life. This is in line with prior research (Wudu *et al*., 2008; Yeshwas, 2015; Tsegaw *et al*., 2016; Tora *et al*., 2021), which emphasizes that maximum absorption of colostral immunoglobulins occurs within this timeframe. Failure to transfer colostral immunity passively within 6 hours is linked to an increased risk of mortality and morbidity.

The number of parities of the dam was also significantly associated with calf health outcomes. Calves from primiparous dams faced higher mortality and morbidity risks compared to those from multiparous dams, corroborating similar reports (Yeshwas, 2015; Tsegaw *et al*., 2016; Tora *et al*., 2021), although contrary findings have been noted by Assefa and Ashenafi (2016). The improved immune status in calves from multiparous dams may be attributed to the higher concentration and quality of colostrum produced by older cows, who have been exposed to more pathogens over their lifetimes, thereby having higher levels of immunoglobulin G (IgG) than first-calf heifers (Esubalew and Debeb, 2017).

Another factor significantly associated with calf morbidity is breed. Landraces were more disease resistant than hybrids. This result was confirmed by other results (Wudu, 2004; Yeshwas, 2015). The effect of exotic genetic influences on calf morbidity in tropical environments has been extensively studied. Many scientists have thoroughly studied how race affects mortality and morbidity. The susceptibility of *Bos taurus* breeds to climate and disease stresses in tropical regions is generally associated with increased morbidity in hybrids (Swai *et al*., 2010; Agegnehu and Rahmeto, 2020). Consequently, it is crucial to adhere to the recommendations of Yahya *et al*. (2011), who suggested that crossbred dairy cows with intermediate levels of exotic blood (62.5% - 75%, Friesian) are more suitable for health and production in tropical environments. Additionally, the place of birth was significantly associated with calf morbidity, with calves born outdoors exhibiting a higher risk of morbidity compared to those born indoors. This finding aligns with previous studies (Assefa and Ashenafi, 2016), likely due to the challenges associated with coping with outdoor environmental conditions. Furthermore, the soil conditions at birth were significantly associated with calf morbidity. Calves raised on farms with

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clay floors were more ill than calves raised on concrete floors. This result was consistent with other results (Lindsay, 2012; Assefa and Ashenafi, 2016). This may be because clay soils are difficult to keep clean and dry. A muddy, wet environment has been shown to be a cause of increased morbidity, as pathogenic bacteria can multiply rapidly (Lindsay, 2012).

From the descriptions above, the following points were forwarded as recommendation: Taking measures against these determinants individually will definitely improve the calf health and production performance; emphasis should be placed on providing complete colostrum as soon as possible within 6 hours after birth through continuous sensitization and reinforcement; focus should be placed on continuous training of dairy farmers to increase awareness on calf health management practices.

CONCLUSION

In the Kembata Tembaro district, calf morbidity and mortality rates were found to be 41.7% and 9.5%, respectively, exceeding economically acceptable levels. These high rates hinder calf growth and herd regeneration, negatively impacting smallholder dairy farms. Calf diarrhea was the leading health issue. Key risk factors included the conditions of birth, colostrum intake within six hours, and dam parity. Effective management practices, such as ensuring timely colostrum intake and providing appropriate birth conditions, are essential to reduce calf morbidity and mortality.

ACKNOWLEDGEMENT

The authors express thanks to staffs in staff of Wolaita Soddo Regional Laboratory and evaluated and approved by Hawassa University Faculty of Veterinary Medicine examiners board.

AUTHOR'S CONTRIBUTIONS

Conceived the idea, designed the mainframe of this manuscript, acquisition data, interpretation and analysis data, manuscript drafting, and revised the manuscript by the authors. All authors read and approved the final manuscript.

CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

FUNDING INFORMATION

This study was funded by the authors

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