ASSESSMENT OF CALF MORBIDITY AND MORTALITY RATE AND ASSOCIATED RISK FACTORS ON SMALLHOLDER DAIRY FARMS IN SELECTED DISTRICTS OF CENTRAL REGION, ETHIOPIA

MSc THESIS

BY

BIRUK ALEMU BASORE

HAWASSA UNIVERSITY

COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCE

FACULTY OF VETERINARY MEDICINE

MAY, 2024

HAWASSA, ETHIOPIA

HAWASSA UNIVERSITY
FACULTY OF VETERINARY MEDICINE

ASSESSMENT OF CALF MORBIDITY AND MORTALITY RATE AND ASSOCIATED RISK FACTORS ON SMALLHOLDER DAIRY FARMS IN SELECTED DISTRICTS OF CENTRAL REGION, ETHIOPIA

MSc Thesis

By
Biruk Alemu Basore

A Thesis Submitted to the Faculty of Veterinary Medicine, Hawassa University for Partial Fulfillment of the Requirements for the Degree of Master of Science in Veterinary Epidemiology

Advisor:
Gizachew Hailegebreal (DVM, MVSc, Asst.Prof.)

May, 2024
Hawassa, Ethiopia

ADVISOR'S APPROVAL SHEET

SCHOOL OF GRATUATE STUDIES

HAWASSA UNIVERSITY

(Submission sheet-1)

This is to certify that the thesis entitled "Assessment of Calf Morbidity and Mortality Rate and Associated Risk Factors on Smallholder Dairy Farms in Selected Districts of Central Region, Ethiopia" submitted in partial fulfillment of the requirements for the degree of Master's with specialization in Veterinary Epidemiology, the graduate program of the Faculty of Veterinary Medicine, has been carried out by Biruk Alemu Basore under my/our supervision. Therefore, I/we recommend that the student has fulfilled the requirements and hence here by can submit the thesis to the Faculty of Veterinary Medicine.

_____	_____	_____
Name of Major Advisor	Signature	Date
_____	_____	_____
Name of Co-Advisor	Signature	Date

SCHOOL OF GRATUATE STUDIES

HAWASSA UNIVERSITY

EXAMINOR'S APPROVAL SHEET

(Submission sheet-2)

We, the under signed, members of the Board of examiners of the final open defense by Biruk Alemu Basore have read and evaluated his/her thesis entitled "Assessment of Calf Morbidity and Mortality Rate and Associated Risk Factors On Smallholder Dairy Farms In Selected Districts of Central Region, Ethiopia" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements of Master's in Veterinary Epidemiology.

Name of Major Advisor: _____ Signature _____

Date _____

Name of Internal Examiner I: _____ Signature _____

Date _____

Name of Internal Examiner II: _____ Signature _____

Date _____

Name of External Examiner: _____ Signature _____

Date _____

SGS Approval: _____ Signature _____

Date _____

Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the School of Graduate Studies (SGS) through the Department/School Graduate Committee (DGC/SGC) of the candidates department.

Stamp of SGS: Date_____Remark_____

- ❑ Use this form to submit the thesis with minor correction suggested by the examining board
- ❑ 3 copies

DECLARATION

I hereby declare that the information presented in my thesis is original and has not been submitted for a degree at any other university. I have acknowledged all sources of materials used in the thesis.

Name: Biruk Alemu Basore
Signature: _____
Place: Hawassa University, Hawassa, Ethiopia
Date of submission: _____

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude and appreciation to Dr. Gizachew Hailegebreal for his enormous guidance, support, and mentorship throughout my research work. His expertise, dedication, and encouragement have been instrumental in shaping my research and academic growth. I am truly grateful for his unwavering commitment and I am honored to have had the opportunity to work my thesis under his supervision. Thank you, Dr. Gizachew Hailegebreal, for your exceptional mentorship.

I'd like to offer genuine gratitude to my friends and familyfor their ongoing support and encouragement throughout my academic path. Their love, understanding, and belief in me have served as my pillars of strength. I am truly grateful for their constant motivation and for always being there for me. Thank you my friends and family for being a source of inspiration.

I would like to express my sincere gratitude to the dairy farm owners in the study districts and the relevant government office for their invaluable support, guidance, and patience throughout the study period. Your dedication and sacrifices have not gone unnoticed, and I am truly thankful for the efforts you have made to address the challenges faced by our communities. Thank you for your unwavering commitment and contributions.

ACRONYMS AND ABBREVIATIONS

CSA	Central statics agency
CSR	Cause-specific rates
HZFEDO	Halaba Zone Finance and Economic Development Office.
ID	Identification number
USA	United States of America

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ANNEXES

ABSTRACT

The dairy sector in Ethiopia is crucial for the agricultural economy by improving smallholder farmers' livelihood. However, challenges with calf morbidity and mortality hinder the industries development. A longitudinal study was conducted from December 2022 to May 2023, on 204 calves in selected 120 smallholder dairy farms of three districts of central region, Ethiopia. The objectives of the study were to estimate calf morbidity and mortality rate, and to identify predisposing risk factors in the first six months of life. Survival analysis using the Kaplan–Meier (K-M) method, and Cox proportional hazard regression were employed to compute the life-to-event data on morbidity and mortality. The total crude morbidity and mortality rates for calves in the study areas were 13 and 4 cases per 100 calf months at risk, respectively. The study revealed that the cumulative incidence of all-cause mortality and all-cause morbidity were 21% and 54%, respectively. Diarrhea was the most commonly diagnosed disease syndrome, leading to 25% morbidity and 14.7% mortality. The morbidity rate in males was 1.86 times higher than female ($p<0.05$). The calf born from assisted dam during calving had a higher risk of morbidity than calf born from not assisted dam (HR=1.93, $p<0.05$). The study also revealed that non-concrete farm floors are related significantly to a greater risk of morbidity (HR = 2.88, $p<0.05$) than concrete floors. The risk of morbidity was decreased by 49%, 53%, 79% and 73% in calves that were fed colostrum, weaned after 90 days, born to local breed dams, and in calves older than 90 days, respectively when other parameters held constant. Likewise, the mortality risk was higher on assisted calving (HR=7.7, $p<0.05$), on calves born outdoors (HR = 27.3, $p<0.05$), on early separation of the calf (HR = 7.68, $p<0.05$), and in non-concrete floor farms (HR=9.18, $p<0.05$). By holding other model parameters constant, the risk of mortality was decreased by 75%, 77%, 95%, 97%, and 85% in calves that were reared in urban area, consumed colostrum of their dam, got presence of dam during hand feeding, weaned after 90 days of their age, and in calves older than 90 days, respectively. The high rates of calf morbidity and mortality in the current study area pose a significant challenge to dairy sector's development. Hence, enhancing good management practices and conducting further confirmatory investigations are suggested to address and reduce risk factors for calf health problems and mortality.

Keywords: *Calf, Central region, Dairy farm, Incidence, Morbidity, Mortality*

1. INTRODUCTION

1.1 Background

Ethiopia has Africa's greatest cattle population, with 70.3 million head. Typically, female cattle make up 56 percent of the entire population, while male cattle make up the remaining 44 percent. Milking cows represent about 15.04 million of them, whereas dairy cows are projected to count around 7.56 million. The heifers (1 year and under 3 years) population is about 13.1 million (18.5%). The estimated number of calves under 6 months and 6 months to under 1 year are 6.5 million (9.1%) and 6.2 million (8.8%), respectively (CSA, 2021).

The dairy sector in Ethiopia is a vital component of the country's agricultural economy, providing livelihoods for many smallholder farmers and contributing to food security and economic growth (Gebreyohanes *et al.,* 2021; Kebede *et al*., 2024). However, challenges with calf morbidity and mortality provide serious barriers to the country's dairy industry's viability and development. Calf health is essential for the future productivity of dairy herds, yet factors such as disease, inadequate nutrition, and poor management practices contribute to high rates of morbidity and mortality among calves on smallholder dairy farms (Wong *et al*., 2022; Cherinnat and Edossa, 2023).

Recent studies have highlighted the incidence rate of calf morbidity and mortality in Ethiopian dairy systems. A study by Ahmedin and Assen (2023) found that infectious diseases, inadequate colostrum intake, and poor hygiene practices were major contributors to calf morbidity and mortality on smallholder dairy farms in Ethiopia. Another study by Tesfaye *et al.* (2020) identified factors such as breed, age, and management practices as significant predictors of calf health outcomes in Ethiopian dairy herds. The complex interactions between environmental conditions, insufficient attention and supplemental feeding, and negligent health management or bad management techniques are also the contributors of calf morbidity and mortality (Lema *et al*., 2001).

According to Wudu *et al.* (2008) and Fentie *et al*. (2020), diarrhea, pneumonia, septicemia, and navels infection are significant health challenges that contribute to calf morbidity and mortality on smallholder dairy farms in Ethiopia. Diarrhea, often caused by infectious agents such as

Escherichia coli and rotavirus, leads to dehydration and nutrient mal-absorption, compromising the overall health and growth of calves. Pneumonia, commonly triggered by respiratory pathogens like *Mannheimia haemolytica* and *Pasteurella multocida*, can result in severe respiratory distress and even death if left untreated, impacting calf welfare and productivity (Tesfaye, 2019).

Septicemia, a systemic bacterial infection, can rapidly progress in calves with weakened immune systems, leading to high mortality rates if not promptly diagnosed and treated (Pas *et al.,* 2023). Additionally, navels infection, often associated with poor hygiene practices during calving, can introduce pathogens into the bloodstream of calves, causing septicemia and increasing the risk of morbidity and mortality (Tesfaye *et al*., 2020). These health issues underscore the critical need for improved management practices and targeted interventions to reduce the incidence of calf morbidity and mortality on dairy farms (Ahmedin and Assen, 2023).

There is no sufficient reports exist regarding the morbidity and mortality rates of calves in the central region of Ethiopia. However, in the region where a substantial number of smallholder dairy farms are located, the incidence of calf morbidity and mortality is a pressing issue that requires attention. The studies by Asmare *et al.* (2016), Hordofa *et al.* (2021), Tora *et al.* (2021b), Alemu *et al.* (2022), Abebe *et al.* (2023), and Ahmedin and Assen (2023) found that calf mortality and morbidity rates in the nearby regions were alarmingly high with infectious diseases such as respiratory infections, diarrhea, and tick-borne diseases being major contributors in addition to limited access to veterinary services, inadequate nutrition, and poor management practices were identified as key factors exacerbating the problem.

Addressing these issues through improved veterinary care, vaccination programs, and capacity building for dairy farm owners is crucial to reducing calf losses and enhancing the resilience of livestock-dependent communities in central region, Ethiopia. Therefore, understanding the risk factors associated with calf health outcomes is important for developing targeted interventions to improve calf management practices and enhance overall herd health (Otten *et al*., 2023).

1.2 Statement of Problem

Calf health problem and death are posing significant challenges to dairy production and the livelihoods of dairy farmer in Ethiopia. Dairy herds commonly experience high rates of calf morbidity and mortality, causing a severe impact on the economic viability and future performance of farms (Palczynski *et al*., 2021; Wong *et al*., 2022). Calf deaths, healthcare costs, and a decline in lifetime output are the main losses of dairy industry in addition to loss of genetic material for herd due to calf morbidity (Davies *et al.*, 2022; Robertson and Cavill, 2022).

According to studies conducted across Ethiopia over the last ten years, the death and disease incidence rates for newborn calves can reach 31% and 67%, respectively. In all production systems, diarrhea and respiratory infections are the two main ailments that affect and kill calves (Wong *et al*., 2022). Besides the production system, the management also affects the magnitude of calf morbidity and mortality as reported by Yitagesu *et al.* (2022) in central region, Ethiopia. Furthermore, calf morbidity and mortality rates reported in some studies in southern Ethiopia were marginally higher than economically tolerable levels, therefore, could affect the productivity of smallholder dairying by decreasing the obtainability of replacement heifers (Tora *et al*., 2021b; Abebe *et al*., 2023).

Even though there are some reports on the mortality and morbidity of calves, most of the investigations employed were cross-sectional study techniques, which provide insufficient information about the size of the problem and pertinent risk variables (Abebe *et al*., 2023). Some cohort studies published are also limited in number and only conducted in a few areas where as none of this reported from central region, Ethiopia. However, improving the sustainability of calf growth in small-scale dairy farms needs subsequent cohort study techniques for the firm investigation of the problems. By addressing the specific challenges related to calf morbidity and mortality in this context, this research aims to inform evidence-based interventions that can improve calf health, strengthen dairy production systems, and ultimately benefit smallholder farmers and the broader dairy industry.

1.2 Research Questions

- ✓ What is the rate of calf morbidity and mortality in the study area?
- ✓ What are the respective risk factors that cause morbidity and mortality in calf in the study area?

1.3 Objectives of the Study

1.3.1 General objective

The study was aimed with assessingthe calf morbidity and mortality rate and associated risk factors in urban and peri-urban smallholder dairy farms of selected districts of central region, Ethiopia.

1.3.2 Specific objectives

- ➢ To estimate the rate of calf morbidity and mortality in the study areas
- ➢ To identify the major risk factors that contributes to calf morbidity and mortality in selected districts of central region, Ethiopia

2. LITERATURE REVIEW

2.1 A Synopsis of Ethiopia's Dairy Production System

The dairy production system in Ethiopia is a growing livestock production systemwhich contributes 63% to the total value of ruminant output. Smallholder farmers in dairy sector represent about 85% of the population and are responsible for 98% of milk production (Getabalew *et al*., 2019). In 2019/2020 in Ethiopia, the estimate of total cow milk production for the rural areas of the country was about 4.96 billion liters (CSA, 2021). The sector holds the primary source of income for urban and peri-urban poor communities. The demand for the milk market in the towns inclined most of the dairy farms to be concentrated in urban and peri-urban areas of the country (Getabalew *et al*., 2019).

Dairy production systems can be generally categorized as pastoral, agro pastoral, and sedentary. Agro pastoral systems incorporate both crops and livestock production, whereas pastoral systems are mostly found in the lowlands where livestock rearing is the predominant type of production to sustain the livelihood of pastoral society without cropping (Legese *et al*., 2014). Both systems rely entirely on minimal input, low milk yield, and little market orientation for production. Indigenous cattle, camels, and goats are the main sources of milk in these systems; sheep are a minor, location-specific contributor. Sedentary systems are mostly found in mid- to high-altitude regions, with a few exceptions in the lowlands (Tegegne *et al*., 2013).

There are three basic sedentary dairy production systems: the urban system, the peri-urban system, and the rural system. These systems differ in terms of their location, agro-ecology, primary production goal, use of resources, size of production, management of resources, market orientation, and accessibility to inputs and services(Tegegne *et al*., 2013; Tsegaye *et al.,* 2022). Several factors, including a lack of grazing land, sickness and parasites, a lack of land for growing better feed, poor veterinary care, and the low milk production potential of local zebu cattle, poor artificial insemination (AI) services, and labor scarcity affect the potential milk production of dairy cattle in most regions of Ethiopia. It is critical to improve veterinary services, introduce more effective forage crops, and plant fodder trees to reduce the aforementioned limits (Getabalew *et al*., 2019).

Overall, while the dairy production system in Ethiopia still faces many challenges, there have been positive developments in recent years that suggest the potential for growth and improvement in the sector. Continued investment in infrastructure, technology, and extension services will be crucial to further develop the dairy industry in Ethiopia and ensure food security for the country's growing population (Gebreyohanes *et al.*, 2021).

2.2 The Body System and Immunity of the Calf

The calf's body and immune systems are vital to its general development and well-being. Because of their developing immune systems, calves are prone to a wide range of illnesses and infections from birth. However, calves' immune systems mature as they grow and develop, giving them defense against infections (Vlasova and Saif, 2021).The calf's immune system and body system are interconnected, dynamic networks of parts that serve to shield the animal from illnesses and infections. Appropriate management techniques, including as making certain the calf consumes enough colostrum, following immunization schedules, and maintaining a healthy diet are critical to promoting the immune system's growth and operation (Chase *et al.*, 2008; Smith, 2015).

2.2.1 Calfbody system

A sophisticated and complicated network of organs and tissues make up a calf's body system, which functions as a whole to promote the animal's growth and healthy development. This system has various components, including the digestive system, respiratory system, circulatory system, musculoskeletal system, and nervous system (Radostits *et al*., 2017).

A calf's gastrointestinal system is in charge of breaking down and absorbing nutrients from feed to promote growth and development. Calves that have not yet been weaned have a monogastric-type stomach biologically. From a physiological and dietary standpoint, milk in the rumen and reticulum of newborn calves is regarded as aberrant and undesirable. Esophageal groove closure must take place before liquid feeding. Therefore, the milk and milk substitute passes through the closed esophageal groove without passing through the fore stomach and enters the abomasum for digestion (Sasidharan and Kannan, 2021).

The respiratory system is essential for providing oxygen to body tissues and removing carbon dioxide, supporting overall metabolic function whereas circulatory system play a role in transporting oxygen, nutrients, hormones, and waste products throughout the body. The heart pumps oxygen-rich blood to tissues via arteries and returns oxygen-depleted blood to the heart through veins which supports cellular function and helps regulate body temperature. Moreover, Musculoskeletal System provides structural support, movement, and protection for internal organs and the nervous system plays a critical role in regulating physiological processes such as digestion, respiration, and movement (Radostits *et al*., 2017).

A number of variables that affect the calf's body systems are intimately linked to improving calf health.Providing a balanced and nutritious diet, ensuring proper hydration, implementing a vaccination program, maintaining biosecurity measures, offering clean and comfortable housing, and regularly monitoring calves for signs of illness are all essential in promoting calf health. These practices help support the immune system, prevent diseases, and ensure overall well-being. By focusing on these aspects, calf health can be optimized, leading to better growth, development, and productivity (Wudu *et al.,* 2008; Palczynski *et al.,* 2021).

2.2.2 Calf immunity

Calf immunity is essential in the overall health, growth, and development of young calves. However, newborn calf’s immune system is functional but immature (Gorden and Plummer, 2010). Although newborns have all necessary immunological components, many of them do not function until the calves are at least two to four weeks old, and they may continue to develop until puberty. When compared to adult cows, calf immune system components are substantially less common but still present. As a result, the immune system of a newborn calf reacts to pathogens that cause disease later and is weaker than it would otherwise (Windeyer and Gamsjäger, 2019).

Newborn calves rely on passive immunity from colostrum to provide initial protection due to their immature immune system. Passive immunity inherited from cows contains antibodies that help boost the calf's immune response and protect against infections. This inherited immunity provide antibody that stimulates and controls the innate defenses against infection that are present in calve. As calves grow, they develop their own active immunity through exposure to pathogens and vaccination (Carter *et al*., 2021). A calf that is deprived of colostrum not be able

to mount a strong immune response when it presented with an overwhelming disease challenge (Wudu*,* 2004).

Several factors can influence calf immunity, including nutrition, stress, housing conditions, and management practices. Therefore, providing high-quality colostrum shortly after birth is important for boosting passive immunity in newborn calves. Ensuring a clean and comfortable environment, with proper ventilation and hygiene practices, can help reduce stress and minimize the risk of disease transmission. Implementing a vaccination program tailored to the specific needs of the herd can help protect calves against common pathogens and boost their active immunity (Uyama *et al.,* 2022; Robi *et al.,* 2023).

In order to prevent illness in young calves and to support their healthy growth and development, calf immunity is crucial. By focusing on factors that influence calf immunity, farmers can optimize calf health and well-being. Implementing strategies to enhance calf immunity, such as providing colostrum, maintaining a clean environment, and implementing vaccination programs, can help ensure that calves grow into healthy and productive cows (Palczynski *et al*., 2021).

2.3 Importance of Colostrum to Newborn Calves

First milk after birth generated by the dam, called colostrum, nutrient-rich fluid that contains high concentrations of antibodies, growth factors, vitamins, minerals, and other essential nutrients. It is also lower in fat and lactose compared to mature milk, making it easier for newborn calves to digest. The antibodies present in colostrum, known as immunoglobulin, help boost the calf's immune system and protect them from infections while because antibodies do not reach the fetus' circulatory system through the placenta of the cow, a newborn calf lacks disease protection (Uruakpa *et al*., 2002).

IgG, IgM, and IgA are the main types of antibodies found in colostrum. These antibodies play complementary roles in providing passive immunity and protection against infections in neonatal calves. Its composition and benefits in supporting calf immunity, growth, and gut health make it a critical component of early calf care. Farmers should prioritize providing high-quality colostrum to newborn calves shortly after birth to ensure their optimal development and long-term health (Abuelo *et al*., 2021).

2.4 Morbidity and Mortality in Dairy Calves

2.4.1 Major causes of calf morbidity and mortality

Calf morbidity and mortality are major constraints in Ethiopian dairy cattle production that severely limit available replacement stock. Calf morbidity and mortality reports in Ethiopia mostly focus on market-oriented dairy production systems and common causes are dictated below (Yitagesu *et al*., 2022).

Calf diarrhea

Calf diarrhea is a commonly reported disease in young animals and is still a major cause of productivity and economic loss to cattle producers worldwide (Cho and Yoon, 2014). It is also the most frequent disease syndrome in the dairy calf of Ethiopia with the occurrence rate reported from different areas such as 63.3 %, 39%, 64.5%, and 10.17% in the Bahirdar district of northwest Ethiopia, Woliyta-sodo and its suburbs, Hawassa, Gamo zone, (Wudu *et al*., 2008; Asmara and Kiros, 2016; Hordofa *et al*., 2021; and Tora *et al*., 2021b).

There are numerous microorganisms that have been identified as potential causes to calf diarrhea. Several enteric pathogens, such as viruses, bacteria, and protozoa, contribute to the development of this syndrome. Although a single primary pathogen may occasionally be the cause of diarrhea in calves, co-infection is frequently seen in the calf. The herd size, environment and management techniques have an impact on the severity of diarrhea. In typical cow-calf operations, calf diarrhea is challenging to successfully control due to its complex character (Cho and Yoon, 2014).

The causes of calf diarrhea are categorized into infectious and non-infectious. Scours in calves can be caused by bacteria like Salmonella and *E. coli*, which are infectious causes. Scours can be brought on in young cows by parasites like Coccidian and Cryptosporidium as well as viruses including BVD, IBR, Rotavirus, and Corona virus. Calves born in unclean environments are more likely to experience an epidemic of germs, viruses, and parasites (Stoltenow and Vincent, 2003).

The non-infectious form of scour condition exists owing to the pregnant cow's inadequate nutrition; the newborn calf can have scours. The quantity and quality of colostrum will be poor if the cow doesn't get enough protein and energy just before giving birth. A bad environment is another non-infectious reason why newborn calves get scoured. The newborn calf may experience stress if the lot is muddy, crowded, or infected with a virus. When a calf is born in the winter, its temperature may drop quickly, which could stress it out, impair its ability to nurse, and result in scours. Inadequate care given to the newborn calf in the first few hours after delivery can result in poor absorption of colostrum and antibodies (DallAgnol *et al*., 2021; Wong *et al*., 2022).

Calf scours' primary symptoms are watery stools, sunken eyes, lethargy, sadness, and immobility. A watery stool is the first indication of scours, which is typically followed by dehydration (Kumaresan *et al.,* 2012). Scours mostly hurts calves by dehydrating them, causing them to lose electrolytes (body salts), and inflaming their digestive lining, which makes it harder for them to digest food. When these factors combine, it results in weight loss and low blood sugar, which, if untreated, can be fatal. Therefore, the treatment of calf diarrhea should include rehydrating the calf, eliminating acidosis, and restoring electrolytes and the prevention might combine good ranch management practices with basic health and medical requirements for healthy calves and cows (Berchtold, 2009).

Calf pneumonia

A complicated, multi-factorial illness known as calf pneumonia or bovine respiratory disease (BRD) causes inflammation and damage to the lungs and respiratory tract's tissue. It is frequently the cause of underperformance and mortalities in growing calves (Andrews, 1992, Taylor *et al.,* 2010). The disease causing viruses and bacteria that cause calf pneumonia interact with the animal's immune system, which is also impacted by outside stressors. Bovine Respiratory Syncytial Virus (BRSV), Parainfluenza-3 virus (PI-3), and Bovine Herpes Virus-1 (BHV-1), which causes Infectious Bovine Rhinotracheitis, are the main viral causes of respiratory illness (IBR). Because it harms an animal's immune system, bovine viral diarrhea (BVD) may also be linked to pneumonia in some herds. These viruses can spread disease on their own, harm the respiratory tract's defense mechanisms, and put the calf at risk for bacterial pulmonary secondary infections (Constable *et al*., 2016).

Numerous bacteria can either initiate disease on their own or act as secondary invaders after viruses weaken the lung defenses. The significant microorganisms linked to calf pneumonia are *Mycoplasma bovis*, *Pasteurella multocida, Histophilus somni*, and *Mannheimia haemolytica*. An animal's immune system's capacity will have an impact on how susceptible it is to calf pneumonia (Andrews, 1992; Valeris-Chacin *et al.,* 2022).

Giving newborn calf's high-quality colostrum as soon as possible after delivery will offer them the best start in life and lower their risk of contracting the disease. In addition to diet, management procedures, stress, and the environment, a calf's immunity will be impacted by all of these factors, with problems in any of them having a detrimental effect on the calf's capacity to fight disease. The danger of respiratory illness rises when animals of different ages or sources are mixed in the same airspace. Similarly, even high levels of protection cannot stop disease outbreaks if animals are housed in humid or poorly ventilated sheds (Godden *et al*., 2019).

Navel ill

Soon after birth, young calves are susceptible to a frequent and sometimes dangerous illness called Navel ill, which is also referred to as omphalitis or joint ill. If treatment is not received, it might result in systemic sickness and is characterized by inflammation and infection of the navel (umbilical) area (Blowey and Weaver, 2011). Navel ill usually happens soon after delivery, when bacteria enter the calf's body through the stump of its umbilical cord. The risk of navel infection might be raised by elements including filthy bedding, unhygienic childbirth settings, and inadequate personal hygiene habits. Furthermore, navel illness is more likely to develop in calves with compromised immune systems or insufficient consumption of colostrum (Blowey and Weaver, 2011; Naik *et al*., 2011).

The initial signs of navel ill may include swelling, redness, and discharge around the navel area. As the infection progresses, calves may exhibit symptoms such as fever, lethargy, loss of appetite, lameness, and joint swelling. In severe cases, the infection can spread to other parts of the body, leading to septicemia (blood poisoning) and potentially fatal complications (Kashyap *et al*., 2018; Kharb *et al*., 2021). Prompt diagnosis and treatment are essential to managing navel ill effectively. Veterinarians may recommend cleaning and disinfecting the navel area, administering antibiotics to treat the infection, and providing supportive care to help the calf

recover. In some cases, surgical intervention may be necessary to drain abscesses or remove infected tissue (Naik *et al.*, 2011).

Prevention is key when it comes to reducing the risk of navel ill in calves. Good hygiene practices, such as ensuring clean birthing environments and using sterile equipment during calving, can help minimize the risk of bacterial contamination. Adequate colostrum intake within the first few hours of life is also crucial for boosting the calf's immune system and protecting against infections (Riad, 2020). Overall, navel ill is a serious condition that requires prompt attention and proper management to prevent complications and ensure the health of young calves. By understanding the risk factors and symptoms of navel ill, producers can take proactive measures to protect their calves and reduce the incidence of this potentially devastating condition (Naik *et al.,* 2011).

Septicemia

Septicemia, a disorder caused by bacteria or toxins entering the bloodstream and spreading throughout the body, can occasionally develop in a calf. Bacteria that enter the bloodstream and spread throughout the body cause septicemia. They may harm internal organs, leading to various organ failures that ultimately cause the calf's death (Nikkhah and Alimirzaei, 2020). Some bacteria that produce toxins quickly result in death. When internal organs sustain damage and begin to shut down, the calf enters a state of shock. The infection may localize in certain cases, leading to internal abscesses, or it may settle in the joints, leading to painful arthritis (also known as “joint sick”) (Abd El-Moez *et al*., 2013).

In the context of calf health, septicemia can develop as a complication of untreated infections where bacteria enter the bloodstream and cause systemic inflammation and damage. This condition can lead to symptoms such as fever, rapid heart rate, difficulty breathing, lethargy, and organ dysfunction. If left untreated, septicemia can progress rapidly and result in shock, multiple organ failure, and death (Hotchkiss *et al.,* 2016). Treatment for septicemia typically involves aggressive antibiotic therapy to target the underlying infection and supportive care to stabilize the calf's condition. In severe cases, hospitalization and intensive care may be necessary to manage complications and improve the calf's chances of recovery (Evans *et al.,* 2021).

Prevention of septicemia in calves involves implementing good hygiene practices during calving, ensuring proper colostrum intake to boost the immune system, and promptly treating any signs of infection or illness. Regular monitoring of calf health and early intervention can help prevent the development of septicemia and other serious complications (Robi *et al.,* 2024). In general, septicemia is a critical condition that can arise as a consequence of untreated infections such as navel ill in young calves. Understanding the risks and symptoms of septicemia is essential for prompt diagnosis and effective treatment to improve outcomes and safeguard calf health (Pas *et al.,* 2023).

2.5 Impact of Calf Morbidity and Mortality on Livelihood of Small Holder Dairy Farmers

Calf mortality and morbidity pose a significant threat to the livelihood of smallholder dairy farmers, impacting their economic stability and overall well-being. According to studies by Wudu *et al.* (2008), Bekele *et al.* (2009), Hordofa *et al*. (2021), Tora *et al*. (2021b), Alemu *et al*. (2022) and Abebe *et al*. (2023), calf mortality rates among smallholder dairy farms in Ethiopia were resulting in substantial financial losses for farmers who heavily rely on their livestock for income generation. The loss of calves not only translates into immediate economic setbacks due to investment in rearing and healthcare costs but also leads to long-term implications such as reduced milk production and compromised reproductive performance of the herd (Palczynski *et al*., 2021).

Furthermore, calf mortality and morbidity can exacerbate the vulnerability of smallholder dairy farmers, who often lack access to adequate veterinary services and resources. A study highlighted that limited knowledge and awareness of disease prevention and management practices contribute to higher calf mortality rates among smallholder dairy farms (Duguma, 2020; Fentie *et al.*, 2020). The increased veterinary costs associated with treating sick calves further strain the already limited financial resources of these farmers, leading to a cycle of economic hardship and reduced productivity.

Moreover, the emotional toll of losing calves can have a profound impact on the mental well-being of smallholder dairy farmers. Research by Nuvey *et al*. (2020) emphasized that the loss of calves can create feelings of distress and helplessness among farmers, who often have strong emotional bonds with their animals. This emotional stress can negatively affect their motivation to continue farming and may contribute to a decline in overall farm productivity.

Therefore, calf mortality and morbidity significantly affect the livelihood of smallholder dairy farmers by causing economic losses, reducing milk production, increasing veterinary costs, compromising reproductive performance, and impacting emotional well-being. Addressing these challenges requires a holistic approach that includes improved access to veterinary services, training on disease prevention practices, and support for mental health well-being among smallholder dairy farmers.

2.6 Epidemiology of Dairy Calf Mortality and Morbidity in Ethiopia

Dairy calf mortality and morbidity are significant challenges in the livestock industry in Ethiopia. According to a study by Wong *et al*. (2022), death and disease incidence rates in young livestock is as high as 31% and 67%, respectively and diarrhea being the leading causes of death. One of the main factors contributing to the high mortality and morbidity rates of dairy calves in Ethiopia is poor management practices, including inadequate nutrition, lack of proper housing, and limited access to veterinary care. A study by Fentie *et al*. (2020) and Ahmedin and Assen, (2023) revealed that a significant proportion of dairy calves in Ethiopia are not provided with adequate colostrum, which is essential for their immune system development and overall health.

Agro-ecology has a biological explanation as a predisposing factor to causative factors of calf mortality and morbidity.The highest pooled estimate of mortality observed in lowland, which was 20%, followed by 12.5% in highland and 15.6% in midland of Ethiopia were reported. However, it is difficult to consider them representative for the lowland agro-ecology due to scarcity of reports.In lowland agro-ecology, calves typically graze with their mothers after two months of age, resulting in almost extensive production, which may expose calves to infections and, as a result, mortality. Calves' susceptibility to illnesses varies significantly between breeds. Thus, indigenous breed of calf is more resistant to mortality and morbidity than the exotic or cross breed (Tora *et al*., 2021a).

Furthermore, the endemic *Cryptosporidium* and *Giardia* infections in dairy calves are reported in southern Ethiopia by Hailu *et al*. (2020). Infectious diseases such as Colibacillois, Bovine corona virus, Bovine respiratory syncytial virus (BRSV) and Bovine viral diarrhea (BVD) are also prevalent in dairy herds and contribute to calf morbidity and mortality (Fanda, 2023). A study by Msimang *et al*. (2022) highlighted the need for improved biosecurity measures and vaccination programs to control the spread of these infectious diseases and reduce calf losses. Addressing the epidemiology of dairy calf mortality and morbidity in Ethiopia requires a comprehensive

approach that includes improving management practices, ensuring access to quality veterinary care, and implementing disease prevention strategies (Wong *et al*., 2022).

Reports on calf mortality with a wide range of prevalence are rising in the country. Some scholars compiled the finding of research papers on the prevalence of calf mortality in various parts of Ethiopia. As their summarized report, the prevalence of calf mortality was between 0.9% and 37% with pooled prevalence of calf mortality of 14.79% (Tora *et al*., 2021a). The following table compiled current range of calf mortality (6.4% – 22%) and morbidity (10% – 66.7%) rate reports from different districts of Ethiopia (Table 1).

Table 1: Calf mortality and morbidity rate reports compiled from different studies in Ethiopia

Cumulative incidence		**Study area**	**Follow up time per calf months**	**Reference**
Mortality (%)	**Morbidity (%)**			
20	66.7	Wolyta Sodo and its suburbs	6	Asmare and Kiros, 2016
12.97	42.07	Jimma City	6	Ahmedin and Assen, 2023
8.64	30.9	Gamo Zone	6	Tora *et al*., 2021b
-	34.1	North Shewa	6	Mohammed *et al*., 2020
20.04	50.1	Hawassa city	12	Hordofa *et al*., 2021
6.4	10	Central Ethiopia	6	Yitagesu *et al*., 2022
12.85	40.29	Southern Ethiopia	6	Abebe *et al*., 2023
17.9	47.3	North western Ethiopia	6	Alemu *et al.,* 2022
6.4	27.8	Shashemenne town	6	Edao and Meribo, 2021
22	62	Adaa Liben district	6	Wudu *et al.,* 2008
9.3	29.3	Hawassa, Southern Ethiopia	6	Bekele *et al.,* 2009

3. MATERIALS AND METHODS

3.1 Study Area Description

This study was carried out from December 2022 to May 2023 on urban and peri-urban dairy farms of selected districts in central Ethiopia region (Figure 1) namely Misrak Badewacho, Danboya, and Halaba districts. Misrak Badewacho district is located in the Hadiya zone of the central Ethiopia region. Topographical and geographical location of the district ranges 1650-2050 meters altitude above sea level. According to Misrak Badewacho district agricultural statistics information, the cattle population of Misrak Badewacho district has about 93,040 head.The main goal of keeping cattle in the district is milk production. Due to the delayed AI service availability, distance from AI stations, and technician shortages for farmers, breeding system in the district mostly relays on natural mating (Amanuel and Eskindir, 2023).

Danboya district is the potential area for dairy cattle farming in central region of Ethiopia. This district is found in Kambata zone which is one of targeted area by government of Ethiopia in plans to increase milk production four-fold by 2031 through improving the productivity of dairy cows (Petros, 2021; Leggesse *et al*., 2023). The district is located at altitude ranging from 1501 to 2500 meters above sea level, 285 km South West of Addis Ababa and 30 kilometers from Durame, Ethiopia. Mean annual rainfall and mean annual temperature of the district are 1200 to 1800 mm and 19 ^{o}C - 29 ^{o}C, respectively. The area coverage of the district is 151.83 square kilometers (Molla, 2013).

The Halaba district is located about 315 km south of Addis Ababa. It has significant potential for dairy farming due to favorable agro-ecological conditions, availability of suitable land for pasture, and a growing demand for dairy products in the district. The district is known for its suitable climate, access to road, and availability of improved dairy cattle breeds, which are essential factors for successful dairy farming. As a result, dairy production is growing quickly in the area, with many households depending on it for income and consumption (HZFEDO, 2019).

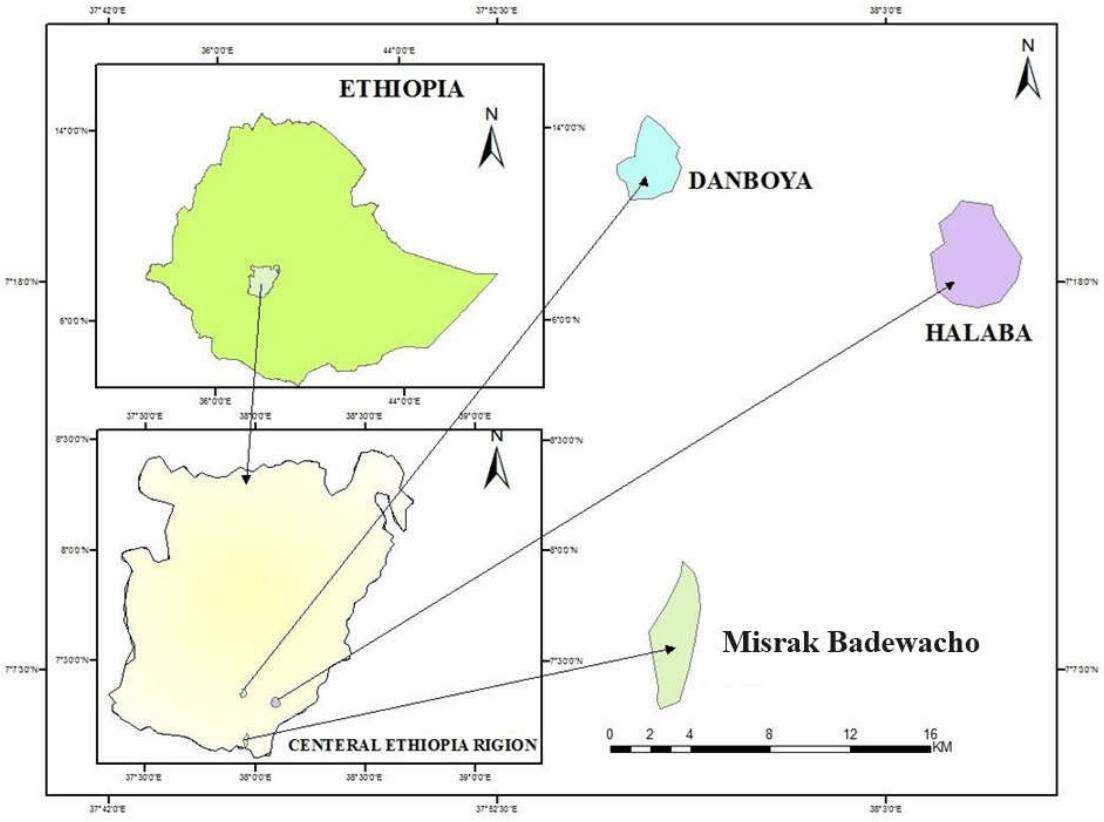

Figure 1: Map of the study area showing three districts of central region of Ethiopia

3.2 Study Population

A smallholder dairy farm is a relatively small-scale agricultural operation that focuses on the production of milk from a limited number of dairy animals, typically owned and managed by a single family or individual. The study population was calves in the small holder dairy farms of the study areas.

The smallholder dairy farms located in the towns were classified as urban dairy farms, practicing semi-intensive management and focusing on market-oriented dairy production. The farms located on the outskirts of the respective towns were categorized as peri-urban dairy farms (Tegegne and Gebrewold, 1998). The categorization of the dairy farms based on herd size was considered as described by Kidane *et al.* (2019) which indicates smallholder farms having 1-5 dairy cows, medium farms 5-30 dairy cows and large farms having >30 dairy cows.

Inclusion and Exclusion Criteria: Both local and cross breeds of dairy calves of both sexes reared under smallholder dairy farms, and calves aged between births to 6 months were included in the study. However, stillborn calves, calves with deformities and wasting diseases, as well as calves that were not born in selected urban and outskirts were excluded from this study. Following recruitment into the study, routine monitoring of study calves was conducted twice per month until 6 month of age for each calf.

3.3 Study Design

An observational prospective cohort study design was employed for this study. Calves were chosed as the sampling units, and individually monitored throughout the research period. Longitudinal prospective observations are preferred over cross-sectional studies, as they are more effective in establishing causal relationships. Study districts were selected purposively based on the availability of small holder lactating dairy cows.

The list of dairy farms data obtained from each district agriculture office was taken as a sampling frame for the study. Halaba, Danboya and Misirak Badawacho district had 83, 74 and 71 registered small holder dairy farms, respectively. A simple random sampling technique using the lottery method was employed to select dairy farms from the sampling frame until required sample size was met. If a chosen farmer refused to participate in the study and did not have a calf or pregnant cows with a due calving date in the 6-month follow up period, another dairy farmer, preferably from the same neighborhood, would take their place.

Throughout the study, each calf was identified and monitored. A retrospective recruitment method (concurrent cohort) was used to select calf less than one month old at the initial visit, with known birth dates and history. At the earliest farm visit, the recruited calf and those born thereafter were assigned an ID. Until the calf reached 6 months, all selected calf underwent regular bi-monthly visits.

3.4 Sampling Technique and Sample Size Determination

For the farm owners' interview, the sample size was determined according to the mathematical model of Arsham (2005). Therefore, the sample size N, was expressed as integer less than or equal to $0.25/SE^2$; $N = 0{:}25/SE^2$. Where, SE is Standard Error and is 0.05 (5%) at 95%

confidence interval; N is a number of samples. Approximately 34 households were estimated, but, 40 households from each district were targeted, and all calf fulfilling the inclusion criteria during the sample collection period from each participant house hold farms were included in the study (Figure 2). The subject calf sample size of estimating calf mortality and morbidity were 204 calf.

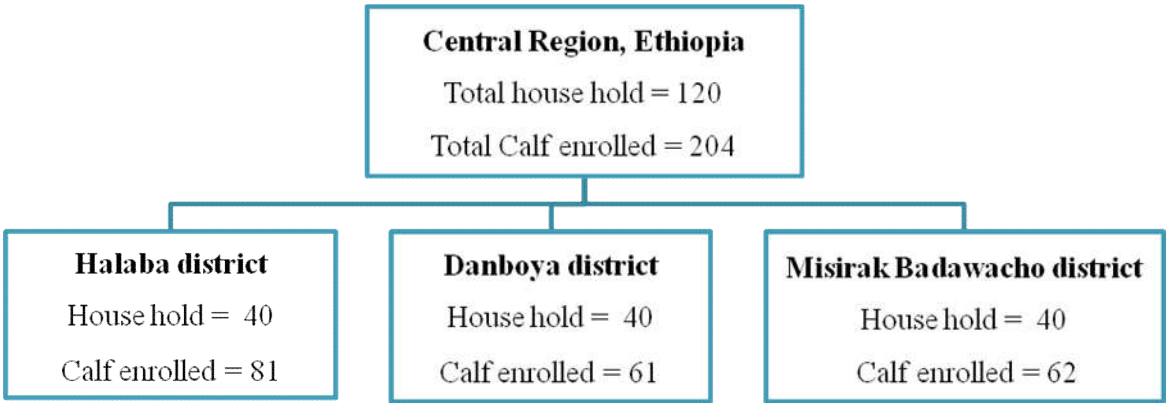

Figure 2: Graphic explanation of sampling procedure (Adopted from Hadgu *et al*. 2021)

3.5 Data Collection

Data on events related to calf health issues and potential risk factors were collected through follow-up and interviews were provided to the owners of small holder dairy farm owners or managers, who closely oversee their animals to collect data on the potential risk factors linked to calf morbidity and mortality at the selected farms. The hypothesized risk factors were grouped into herd-level and calf-level categories.

Farm description, calf colostrum management, calf housing, health, breeding system and general feeding management are some of the factors at the farm level. The calf-level parameters include breed, birth place, calving events, colostrum administration, initial housing, and health problem episodes observed during monitoring. Each calf that was sampled for this study on the farms selected for the research was individually identified by an ID. All incidences of calf illness and mortality were recorded at each visit using a separate data-recording format developed for each farm. Whenever a health issue arose, the affected calf underwent a clinical examination to ascertain the cause. The investigator used standardized case definitions to record mortality, specific illness events, and treatments (Annex III).

Mortality is defined as any death event in calves after 24 hours following birth, irrespective of the cause. Morbidity is any condition with observable clinical indications that emerges in calves and has the potential to cause death or necessitate therapeutic intervention during follow-up. Once a calf reaches six months of age, it was no longer being monitored. Unless losses to follow-up occurred due to sales or for other reasons, each calf monitored a maximum of 12 times in this way. Emergency visits, in addition to routine ones, were made in response to calls from dairy farm owners regarding calf health problems. Details dates and cause of loss were recorded for any calves that lost during the follow-up period. Check-off forms were used to determine the risk factors specific to each calf (Annex II).

3.6 Description of Explanatory Variables

Dependent variables:-The morbidity or death of calves from 24 hours after birth to six months of age is the dependent or response (outcome) variable for this study. Due to the dichotomous nature of the variables, the occurrence of either morbidity or mortality/event were recorded as "yes" and if the event not exist, it recorded as "no" while, later on analytical procedure, it were assigned a value of 0 if the study's event of interest transpired, and 1 otherwise on the excel spread sheet.

Independent variables: - The study examined various independent variables that may influence calf morbidity and mortality. These variables include condition of birth, calving process , time of birth, site of birth, floor of farm, sex, breed, navel disinfection, the calf fed with maternal colostrum?, time of colostrum ingestion, method of colostrum feeding, amount of colostrum ingested, source of colostrum, was the dam presented to the calf during hand feeding?, vigor status, separation time of calf from dam, weaning age, mothering instinct, parity of the dam, dam breed, dam health disorders, breeding method, and calf age.

3.7 Data Management and Analysis

The data collected by regular visits and the questionnaire survey were coded, entered into the Microsoft Excel spreadsheet, and then transferred to STATA version 14 (Stata Corp LLC, Texas, USA, 2017) for statistical analysis. Information obtained through a questionnaire survey was summarized using descriptive statistics such as count and percentage. The survival analysis of the calves was performed by using Kaplan-Meier and Cox-regression methods.

All-cause or cause-specific incidence rates (IR) for morbidity or mortality were calculated by dividing the number of events occurring during the observation period by the total number of calf days at risk as follows:

$$IR = \frac{number\ of\ events\ during\ the\ observation\ period}{total\ number\ of\ calf\ \ days\ at\ risk}$$

The denominator for the given period was the number of calf days at risk, whereas the numerator was the number of instances of the outcome of interest. The total number of days each calf was at risk of developing a new case from birth until 180 days of age or until it would be removed from the herd were determined. A calf that had recovered from one disease was taken into account as being at risk for contracting another illness when calculating the crude morbidity rate (Wudu, 2004).

Since the age of a calf is specified as up to 180 days, the total number of calf days at risk was considered by taking all calf days at riskwithin 180 days. Additionally, true rates calculated for mortality, morbidity, and other specific disease conditions were converted into risk rates based on the formula RR= 1-e $^{-Truerate}$ to facilitate result comparisons with other findings and because directly taking true rate results tend to overestimate calf morbidity and mortality rates (Martin *et al*., 1987).

Kaplan-Meier and Cox regression were performed using STATA software, version 14 to estimate the hazard function of observed hazard differences for various explanatory variables with crude morbidity and crude mortality, the Kaplan-Meier method were first used.Additionally, Cox's proportional hazard model was employed to assess and measure the relationship between explanatory variables and survival up to 180 days of age. Initially, univariable Cox regressions were used to check the relationship between each risk factor and an outcome variable (morbidity/mortality rate).

Factors that showed significant association with the outcome variable level in the Univariable analysis were chosen for the multivariable analysis using Cox regression to assess their independent effects. In the multivariate analysis, the final model was developed for each outcome variable through stepwise backward exclusion of statically insignificant factors

(P>0.05).To test the equality survival function, an 80% likelihood of accuracy was assumed, and confounding variables were controlled by looking for a variable that generated a 20% (p-value of 0.20) change in the coefficients of the other variables; otherwise, it was declared as a confounder.

The Schoenfeld and scaled Schoenfeld residuals plot were used to test the assumption that hazards in the Cox proportional hazard model are proportionate or constant across time, irrespective to predictor or covariate levels (Boden and Andrews, 2015). Finally, the impacts of various predictors on the outcome variable were reported by using the hazard rate (HR) with its 95% confidence interval.

4. RESULTS

4.1 Questionnaire survey result

4.1.1 Demographic characteristics

Household and dairy performance data were documented in the study. The mean family size in the 120 households surveyed was 6.21. Of 120 dairy farm owners interviewed, the age ranged from 21 to 58, with the minimum dairying experience being 1 year and the maximum 11 years (Table 2).

Table 2: Household characteristics assessed in dairy farms of selected districts

Variable	N	Minimum	Maximum	Mean	total
Family size	120	3	11	6.21	
Age of the farmer	120	21	58	25.67	
Experience on dairy production/year/	120	1	11	7.6	
Herd size and composition					
Calves ≤ 6 months	120	1	3	1.85	223
Calves (>6 ≤12) months	120	0	4	0.61	74
Heifers	120	0	2	0.5	60
Lactating cows	120	1	5	2.45	294
Dry cows	120	0	3	1	121
Bull	120	0	1	0.09	11
Bullock	120	0	1	0.05	6
Total livestock holding	120	2	19	6.4	770

N= number of household

4.1.2 Calf management practices and frequency of calf morbidity and mortality

Detail information about the herd-level management practices, along with calf morbidity and mortality proportions, is presented in Table 3. Among the 120 smallholder dairy farmers interviewed in three selected districts of central Ethiopia, 92 (77%) were urban and 28 (23%) were peri-urban smallholder dairy farms. Of these, 71 (59%) dairy farms were led by men, while 49 (41%) were led by female households. The findings indicate that dairy production served as the primary income source for 34% (41/120) of farmers and as a secondary livelihood for 66% (79/120) of respondents.

The breeding system of dairy cows at the smallholder farms studied included Artificial Insemination, with 77% (92/120) of cows inseminated resulting in 77.5% (158/204) of sampled calves born. Natural mating accounted for 23% (28/120) of cows, leading to 22.5% (46/204) of calves born. Regarding calf caretakers, 78% (94/120) of smallholder dairy farms were managed by owners, while farms managed by hired personnel constituted 22% (26/120). The distribution of calf caretakers showed that 87% (178/204) were owners, with the remaining 13% (26/204) of the calves being cared for by hired caregivers.

During the follow-up period, 174 out of 204 calves (85.3%) were fed with maternal colostrum, while the remaining 30 out of 204 calves (14.7%) did not receive colostrum from their dam. Out of the farmers surveyed, 34% (41 out of 120) used the suckling method to feed colostrum to their calves, while 66% (79 out of 120) used the hand feed method. Correspondingly, 30% (61 out of 204) of the registered calves were fed using the suckling method, and 70% (143 out of 204) were fed using the hand feed method.

Type of feed used to rear calves at smallholder dairy farms were milk and milk replacer, as reported by 91% (109/120) and 9% (11/120) of farmers, with 93% (189/204) and 7% (15/204) of calves, respectively. About 42% (51/120) of farmers provide free access to water on the farm, while 58% (69/120) allow periodic access to water for their calves (Table 3). Farmers managing calving indoors on their farms account for 81% (97/120), while the remaining 19% (23/120) manage calving outdoors. Among calf owners, 46/120 (38.3) use the cow shed as the calf's dwelling, while the remaining 74/120 (61.7%) opt for a separate pen. In 88% (106/120) of farms, there is bedding in the calf house, with the remaining 12% (14/120) lacking such facilities.

Table 3: Distribution of calf morbidity and mortality proportion across herd level management factors in selected districts of central Ethiopia

Herd level variables	Categories	N	Event respective to each categories			
			Morbidity		Mortality	
			N	%	N	%
Sex of house hold head	Male	71	55	77.4	14	19.7
	Female	49	46	93.8	17	34.7
Educational status of house hold	Illiterate	20	13	65	9	45
	Elementary	65	62	95.4	21	32.3
	High school	30	25	83.3	1	3.3
	college	5	1	20	0	0
Dairy production as a source of income	Primary	41	30	73.1	9	21.9
	Secondary	79	71	89.8	22	27.8
Dairying experience	<5 years	27	25	92.6	9	33.3
	≥5 years	93	76	81.7	16	17.2
Dairy farm location	Urban	92	75	81.5	23	25.0
	Peri-urban	28	26	92.8	8	28.6
Calf management						
Breeding	AI	92	76	82.6	24	26.1
	Natural mating	28	25	89.3	7	25
Calf care taker	Owner	94	80	85.1	20	21.3
	Hired	26	21	80.7	11	42.3
When the calf separated from dam (h)	<6hr	78	72	92.3	22	28.2
	≥ 24	42	29	69	9	21
Navel treatment	Yes	42	26	61.9	10	23.8
	No	78	75	96.1	21	26.9
The calf fed with maternal colostrum?	Yes	94	76	80.5	26	27.6
	No	26	25	96	5	19.2
Method of colostrum feeding	Suckling	41	39	95.1	16	39
	Hand feeding	79	62	78.5	15	19
Feeding and watering management						
type of feeding	Milk	109	94	86.2	29	30.8
	Milk replacer	11	7	63.6	2	18.1
Frequency of feeding	One's a day	27	18	66.7	13	48.1
	≥Twice a day	93	83	89.2	18	19.3
Mode of feeding	Free grazing	47	45	95.7	19	40.4
	Stall feeding	60	44	73.3	6	10
	Partial grazing	13	12	92.3	6	46.1
Watering access	Free	51	47	92.1	5	9.8
	Periodic	69	54	78.2	26	37.7
Housing management						
Where calved?	Indoor	97	79	81.4	16	16.5
	Outdoor	23	22	95.6	15	65.2
Housing type	In cow shade	46	39	84.8	20	43.5
	Separate pen	74	62	83.8	11	15
Bedding in calf house	yes	106	96	90.5	27	25.5
	No	14	5	35.7	4	28.6
Frequency of calf pen cleaning	Daily	117	100	85.4	31	26.5
	Twice a day	3	1	33.3	0	0

4.2 Prospective Cohort Study Result

4.2.1 Mortality and Morbidity rates

Of the total calves 204 calves followed during the study, 101 (49.5%) and 31 (15.2%) suffered from morbidity and death, respectively due to various causes. Throughout the study period, all calves contributed 756.5 calf months at risk for morbidity and 767.8 calf months at risk for mortality. The median survival for morbidity was 4.9 calf month whereas for mortality, it was 1.3 calf month. The overall morbidity and mortality rates are 13.3 (95% CI: 11.3-15.2) and 4 (95% CI: 02.8-5.4) cases per 100 calf month, respectively (Table 4).

4.2.2 Mortality and Morbidity rates based on sex, farm location and district

Table 4: Morbidity and Mortality rates in calves under six months of age based on sex, farm location and district

Determinant variables		**Calf at risk**	**Cases**	**Time at risk (month)**	**IR/100 calf month**	**95% CI for IR**
Morbidity						
Sex	Female	121	50	474.1	10.54	8.4-13.3
	Male	83	51	282.4	18.0	16.7-22.4
Farm location	Urban	144	75	551.2	13.6	11.8-16.2
	Periurban	60	26	205.3	12.6	9.3-14.2
Districts	Halaba	81	67	224.9	29.8	22.8-34.6
	Danboya	61	12	263.7	4.5	3.6-5.7
	*MB	62	22	267.8	8.2	7.1-10.4
Total		**204**	**101**	**756.5**	**13.3**	**11.3-15.2**
Mortality						
Sex	Female	121	17	479.8	3.5	2.2-4.8
	Male	83	14	287.9	4.8	3.2-6.7
Farm location	Urban	60	8	208.0	3.8	2.6-5.5
	Periurban	144	23	559.8	4.1	2.9-5.9
Districts	Halaba	81	20	231.2	8.6	6.7-9.2
	Danboya	61	5	265.7	1.8	1.2-1.5
	*MB	62	6	270.8	2.2	1.5-3.6
Total		**204**	**31**	**767.8**	**4.0**	**2.8-5.4**

*IR = incidence rate *MB = Misirak Badawacho

4.2.3 Causes of Morbidity and Mortality

Among the factors contributing to illness and death, diarrhea emerged as the primary cause, accounting for 51 out of 204 cases (25%) and 20 out of 204 cases (14.7%) in terms of morbidity and mortality, respectively. Among the causes of illness, septicemia accounted for 15 out of 204

cases, making it the second most common with a percentage of 7.3%. Pneumonia, on the other hand, ranked third in terms of morbidity, with 14 out of 204 cases (6.8%), and was also the second leading cause of mortality, accounting for 6 out of 204 cases (3%) (Table 5; Table 6).

The risk rate of mortality for diarrhea, pneumonia, septicemia, and other or unknown causes were 15%, 4.6%, 3.1%, and 0.7%, respectively (Table 6). During the follow-up period, 13 calves were sold, while 90 calves remained unaffected by any detectable health problem and were continuously monitored until the end of the study. There were no records of accidental deaths, but one calf was suddenly lost due to unknown cause or without a known syndrome.

Table 5: Incidence of all-cause and cause-specific calf morbidity

Diseases condition	**Number of cases**	**Calf days at risk**	**Per calf month**	**Calf six months at risk**	**Incidence**	
					True rate (6 calf month at risk)	***RR (%)**
Diarrhea	51	19646	654.8	109.1	0.467	37.3
Pneumonia	14	21848	728.2	121.4	0.115	12.2
Septicemia	15	21516	717.2	119.5	0.125	13.3
Navel infection	6	22353	745.1	124.2	0.048	4.9
Eye problem	3	22364	745.4	124.2	0.024	2.4
Others/unknown	12	21669	722.3	120.4	0.099	10.4
All cause morbidity	101	22695	756.5	126.1	0.801	55.1

*Formula used to estimate risk rate is Risk rate = $1-e^{-\text{true rate}}$; *RR= risk rate

Table 6: Incidence of all-cause and cause-specific calf mortality

Diseases condition	**Number of cases**	**Calf days at risk**	**Per calf month**	**Calf six months at risk**	**Incidence**	
					True rate (6 calf month at risk)	***RR (%)**
Diarrhea	20	21910	730.3	121.7	0.164	15.1
Pneumonia	6	22792	759.7	126.6	0.047	4.6
Septicemia	4	22781	759.3	126.5	0.031	3.1
Others/unknown	1	22935	764.5	127.4	0.007	0.7
All-cause mortality	31	23035	767.8	127.9	0.242	21.5

*Formula used to estimate risk rate is Risk rate = $1-e^{-\text{true rate}}$; RR= risk rate

4.2.4 Survival Analysis

Kaplan-Meier survival analysis

K-M survival analysis was conducted to analyze the time until death or occurrence of a disease. It's mainly used to handle censored data, where not all individuals in study have experienced the event of interest by the end of study period. So that the estimates of survival probabilities over time, identifying risk factors of morbidity and mortality, handling time to event data, and comparison of survival curve between different groups were done by using K-M survival analysis. The K-M survival curve of calf morbidity shows a decrease on the survival probability of calves with increasing of their age. This indicates the disease event occurrence probability (cumulative incidence or failure) rises with increasing of calf age (Figure 3). The K-M mortality survival curve also demonstrates a slight decline in the likelihood that calves will survive as they get older (Figure 4). The K-M life table below summarizes the cumulative likelihood of survival and the cumulative incidence of morbidity and death from birth to six months of age (Table 7).

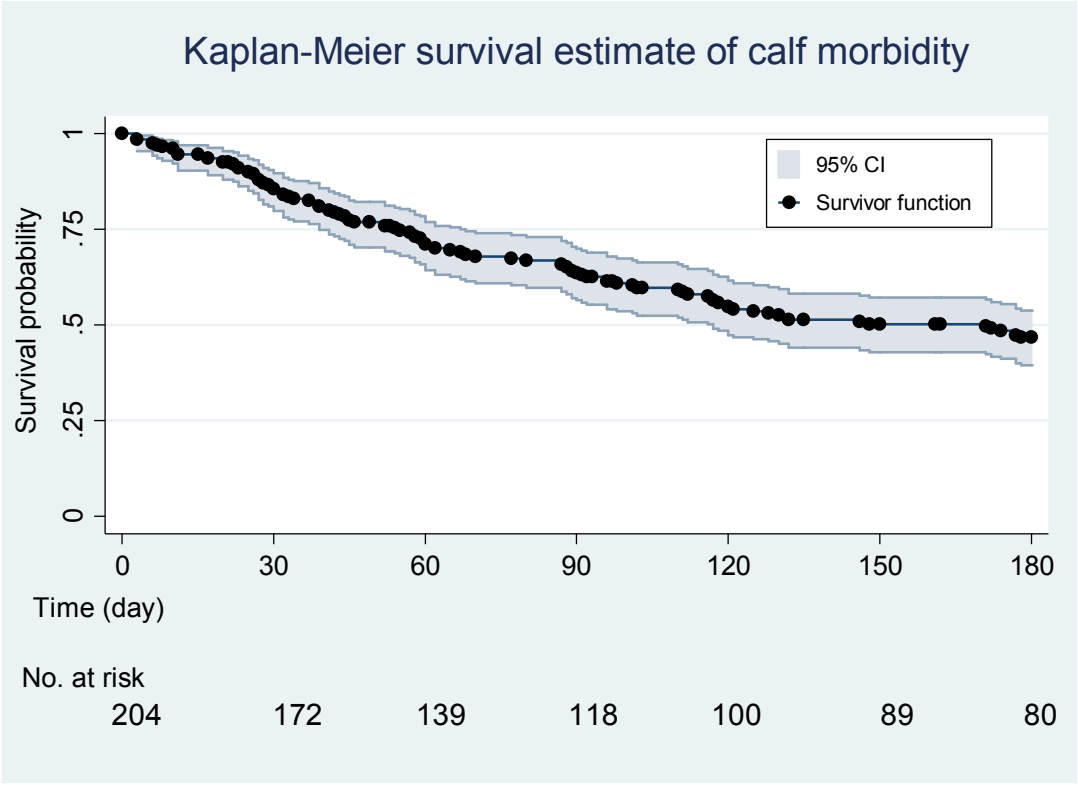

Figure 3: K-M survival curve of all-cause morbidity in calves from birth to 180 day of age

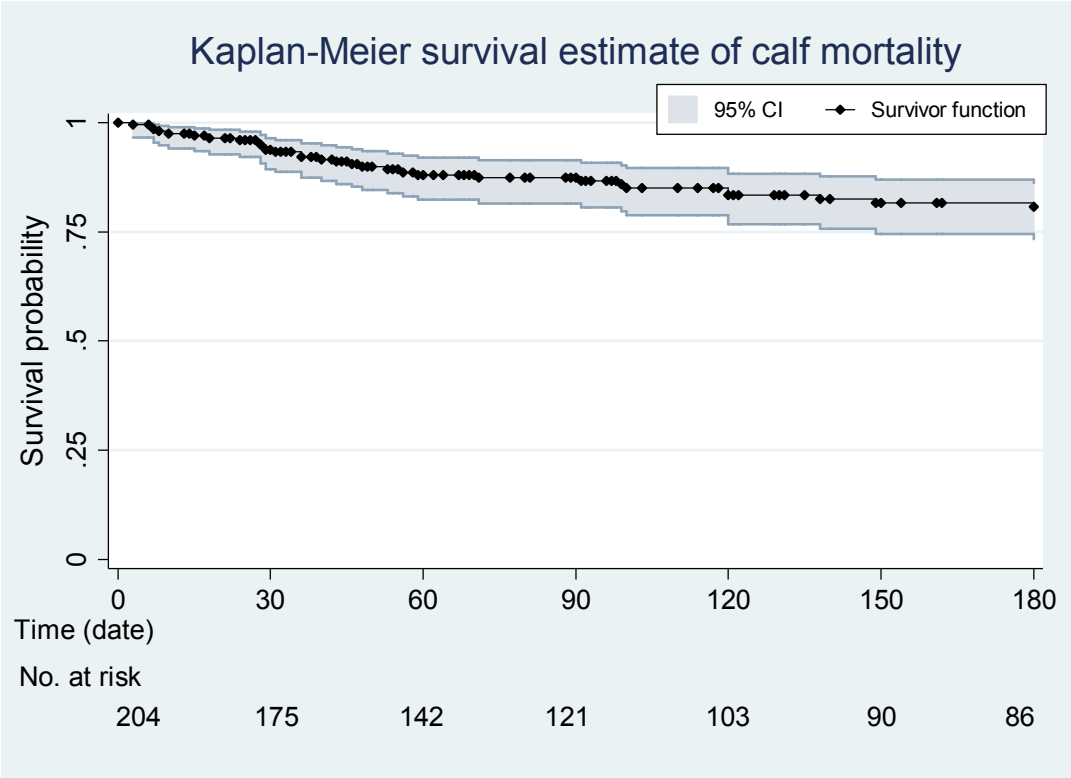

Figure 4: K-M survival curve of all-cause mortality in calves from birth to 180 day of age

Table 7: Age specific cumulative survival and incidence of all-cause morbidity and mortality in calves under 180 days old

Age interval (days)	No. at risk	Cases	Censored	Proportion surviving (SE)	Cum incidence (95% CI)	Hazard (95% CI)
Morbidity						
0-30	204	27	5	0.86 (0.024)	0.13 (0.09 - 0.19)	0.005 (0.003-0.007)
30-60	172	27	6	0.73 (0.032)	0.27(0.21 - 0.34)	0.006 (0.004 - 0.008)
60-90	139	16	5	0.64 (0.034)	0.35(0.29 - 0.43)	0.004 (0.002 - 0.006)
90-120	118	15	3	0.56 (0.036)	0.44 (0.37- 0.51)	0.005 (0.002 - 0.007)
120-150	100	10	1	0.50 (0.036)	0.49 (0.43 - 0.57)	0.003 (0.001 - 0.006)
150-180	89	6	3	0.46 (0.036)	0.54 (0.46 - 0.60)	0.002 (0.000 - 0.004)
180-	80	0	80	0.46 (0.036)	0.54 (0.46 - 0.60)	0.000
Mortality						
0-30	204	12	17	0.94 (0.017)	0.06 (0.03 - 0.10)	0.002 (0.000 - 0.003)
30-60	175	10	23	0.88 (0.024)	0.12 (0.08- 0.17)	0.002 (0.000 - 0.003)
60-90	142	1	20	0.87 (0.025)	0.12 (0.08 - 0.18)	0.0003 (0.00 - 0.0008)
90-120	121	3	15	0.85 (0.027)	0.15 (0.10 - 0.21)	0.000(0.00 - 0.002)
120-150	103	4	9	0.82 (0.031)	0.18 (0.13 - 0.25)	0.001 (0.00 - 0.003)
150-180	90	0	4	0.82 (0.031)	0.18 (0.13 - 0.25)	0.000
180-	86	1	85	0.79 (0.036)	0.21 (0.14 – 0.28)	0.00 (0.00 - 0.002)

* CI = confidence interval * SE = standard error

4.2.5 Determinants for calf morbidity and mortality

Univariable analysis (Log-rank test)

The study employed Log rank test to evaluate the equality of survival curves and to select candidate predictors for the multivariable Cox proportional hazards regression analysis. Of all variables analyzed in the Log-rank test, 15 variables were found significantly ($p \leq 0.05$) associated with the morbidity risk of calves. These variables included the calving condition, time of birth, site of birth, floor of the calf house, calf sex, whether or not the calf ingested colostrum,time at which the calf ingested the first colostrum, method by which calf fed colostrum, amount of colostrum ingested, whether the dam presented to the calf during colostrum feeding by hand, separation time of calves from their dams, weaning age, dam's breed, dam's health disorder, breeding method, and calve age. Thus, these variables were selected for the multivariable analysis. Similarly, the following factors were found to be significantly ($p < 0.05$) associated with the risk of calf mortality in the Log-rank test and subsequently selected for the multivariable analysis: calving condition, time of birth, site of birth, floor of the calf house, method of colostrum feeding, amount of colostrum fed, weaning age, dam's breed, and calf age (Table 8).

Table8: Log-rank test of predictors of mortality and morbidity in calves for survival function equality

No	Predictors	Category	Morbidity		Mortality	
			Chisq.	P	Chisq.	P
1	Dairy farm location	Urban-Per-urban	0.26	0.600	0.07	0.79
2	Condition of birth	Easy vs. dystocia	2.35	0.120	2.18	0.14
3	Calving condition	Assisted vs. not	9.36	0.009	10.7	0.004
4	Time of birth	Day vs. night	12.8	0.000	15.8	0.000
5	Site of birth	Outdoor vs. Indoor	4.41	0.035	7.86	0.005
6	Floor of farm	Non concrete Vs. Concrete	27.6	0.000	8.92	0.002
7	Sex	Male vs. female	6.71	0.009	3.91	0.047
8	Breed	Cross vs. Local	0.02	0.899	0.14	0.71
9	Navel disinfection	Yes vs. no	2.6	0.107	0.00	0.96
10	The calf fed with maternal colostrum?	Yes vs. no	14.1	0.000	4.10	0.042
11	Time of colostrum ingestion	≤6 hr vs. >6 hr	15.3	0.001	2.65	0.440
12	Method of colostrum feeding	Suckling vs. hand feeding	0.79	0.037	4.26	0.039
13	Amount of colostrum ingested	<4 liter vs. ≥4 liter	107.6	0.000	61.2	0.000
14	Source of colostrum	Dam vs. another cow	3.40	0.180	6.52	0.038
15	Dam status during hand feeding	Present vs. not	5.89	0.015	2.87	0.090
16	Vigor status	Good vs. poor	0.12	0.730	0.26	0.611
17	Separation time	< 6hr vs. ≥24 hr	6.51	0.038	2.21	0.330
18	Weaning age	< 90 days vs. ≥90 days	16.96	0.000	50.77	0.000
19	Mothering instinct	Good vs. poor	0.75	0.38	0.35	0.55
20	Parity of the dam	Primiparous Vs. Multifarious	2.57	0.109	0.09	0.76
21	Dam breed	Cross vs. Local	11.55	0.000	5.01	0.025
22	Dam health disorders	Yes vs. no	7.75	0.005	1.19	0.27
23	Breeding method	AI vs. natural	4.14	0.041	0.71	0.400
24	Age of calf	< 90 days vs. ≥90 days	25.81	0.000	6.76	0.0093

Multivariate Cox regression analysis of risk factors for calf morbidity

Of selected risk factors in Univariate analysis, seven factors showed a significant ($p< 0.05$) association with the morbidity risk in the multivariate Cox regression analysis. These are calving condition, floor condition of the calf house, calf sex, colostrum feeding, weaning age, breed of the dam and calf age. Holding the influence of other variables constant, the risk of morbidity was 1.93 times greater in calves born to dams assisted during calving than in calves born normally. Calves born in farms with non-concrete floor had a 2.88 times higher risk of morbidity than calves born in farms with concrete floor. Male calves had a 1.86-fold increased risk of morbidity compared to female calves, holding the effect of other variables constant. When other model parameters were held constant, the risk of morbidity was decreased by 49%, 53%, 79% and 73%

in calves that were fed colostrum after birth, in calves that were weaned after 90 days, in calves born to local breed dams, and in calves older than 90 days, respectively (Table 9). The final model was examined for the proportional hazards assumption and discovered not to violate it (global test: Chisq. = 12.53; df = 7; p= 0.84).

Table 9: Multivariate Cox proportional hazard regression analysis of explanatory variables associated with calf morbidity

No	Variables	Category	*HR	95% CI	p- value
1	Calving	Assisted vs. not	1.93	1.46-2.56	0.000
2	Floor of farm	Non concert vs. Concert.	2.88	1.67 – 4.96	0.000
3	Sex	Male vs. female	1.86	1.14-3.02	0.012
4	Colostrum feeding	Yes vs. no	0.51	0.26 - 0.99	0.048
5	Calf weaning age	≥90 vs.<90 days	0.47	0.29-0.74	0.001
6	Dam breed	Local vs. Cross	0.21	0.11 -0 .42	0.000
7	Age of calf	≥90 vs.<90 days	0.23	0.14 – 0.37	0.000

*HR = hazard ratio

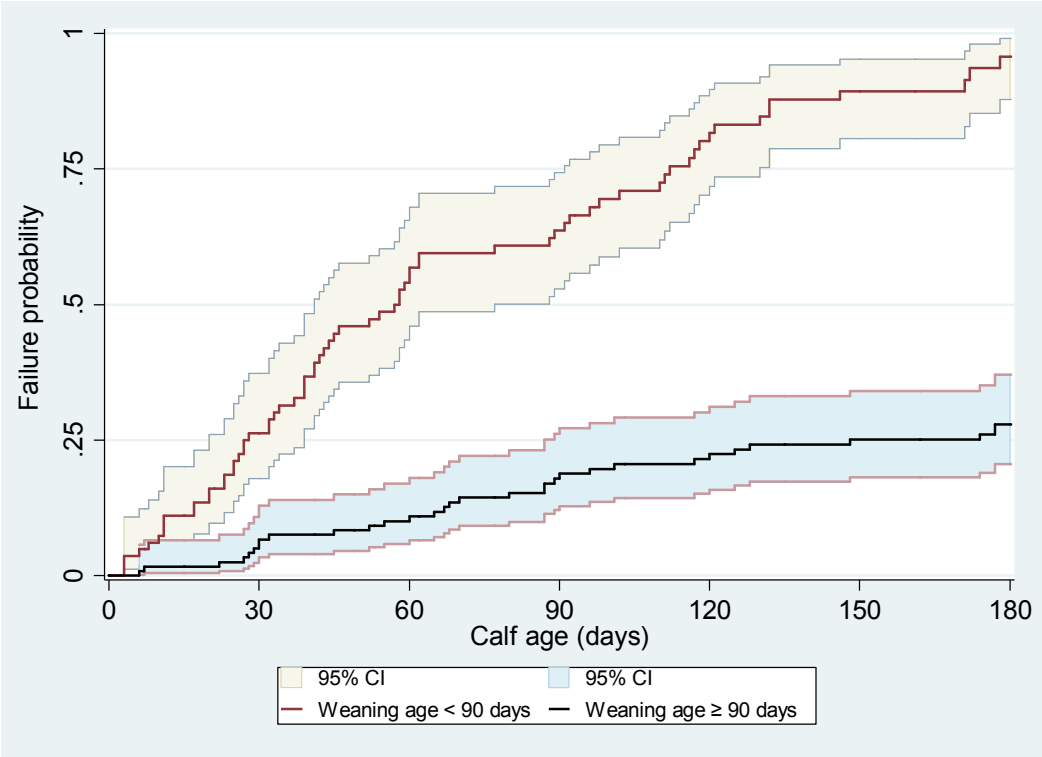

Figure 5: K-M failure estimate graph of comparison of calf morbidity with weaning age category

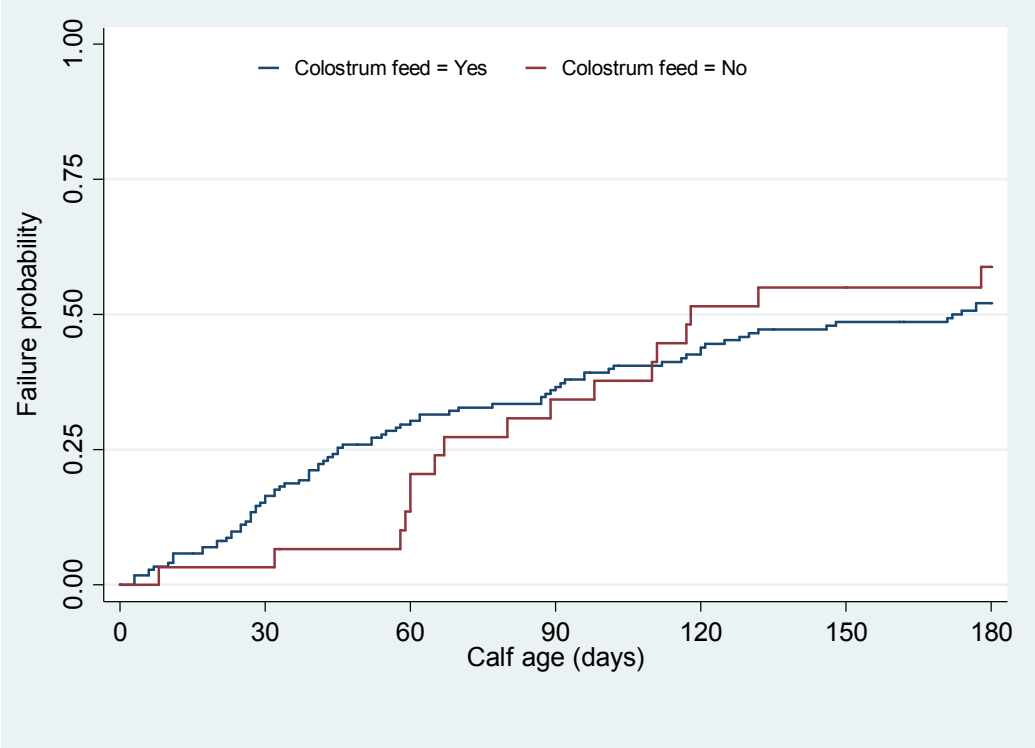

Figure 6: K-M failure estimate graph of comparison of calf morbidity with colostrum feeding

Multivariate Cox regression analysis of risk factors for calf mortality

Among the possible risk factors assessed, the multivariate Cox proportional hazard regression analysis revealed that nine factors showed significant association with mortality risk. These factors werefarm location, calving condition, site of birth, floor of farm, source of colostrum, presence of dam up on hand feeding, separation time, weaning age, and calf age.Holding the influence of other variables constant, the risk of mortality was 7.7 times greater in calves born to dams assisted during calving than in calves born normally. Calves born outdoorhad 27.3 fold greater risk of mortality than the calves born indoor. Calves born in farms with non-concrete floor had a 9.18times higher risk of morbidity than calves born in farms with concrete floor. The calves separated six hours after birth had a 7.68 fold increased risk of motility compared to calves separated in or after twenty four hours after birth, holding the effect of other variables constant. When other model parameters were held constant, the risk of mortality was decreased by 75%, 77%, 95%,97%, and 85% in calves that were reared in urban area, in calves consumed colostrumof their dam, in calves that got presence of dam during hand feeding, in calves weaned in or after 90 days of their age, and in calves older than 90 days, respectively(Table10). The final model was examined for the proportional hazards assumption and discovered not to violate it (global test: Chi sq. = 17.4; df = 9; p= 0.19).

Table 10: Multivariate Cox proportional hazard regression analysis of explanatory variables associated with calf mortality

No	Variables	Category	HR*	95% CI	P-value
1	Farm location	Urban vs. periurban	0.25	0.07- 0.88	0.032
2	Calving process	Assisted vs. not	7.70	2.94 -20.2	0.000
3	Site of birth	Outdoor vs. Indoor	27.3	5.73- 130	0.000
4	Floor of farm	Mud vs. Concrete	9.18	2.79-30.2	0.000
5	Source of colostrum	Dam vs. other cow	0.23	0.09- 0.57	0.002
6	Dam status during hand feeding	Present vs. not	0.05	0.01- 0.27	0.001
7	Separation time	< 6 hr vs. ≥24 hr	7.68	2.09-28.1	0.002
8	Weaning age	≥ 90 vs. < 90 days	0.03	0.00- 0 .16	0.000
9	Calf age	≥ 90 vs. < 90 days	0.15	0.04-0.50	0.000

*HR = hazard ratio

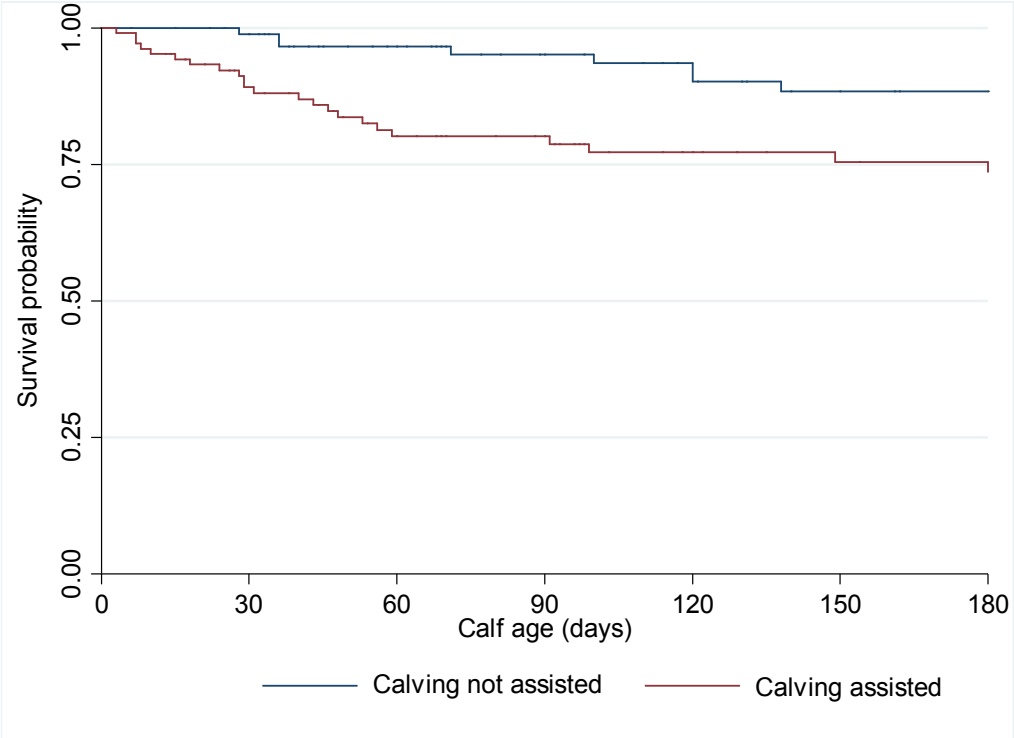

Figure 7: K-M survival estimate curve of mortality by calving condition category

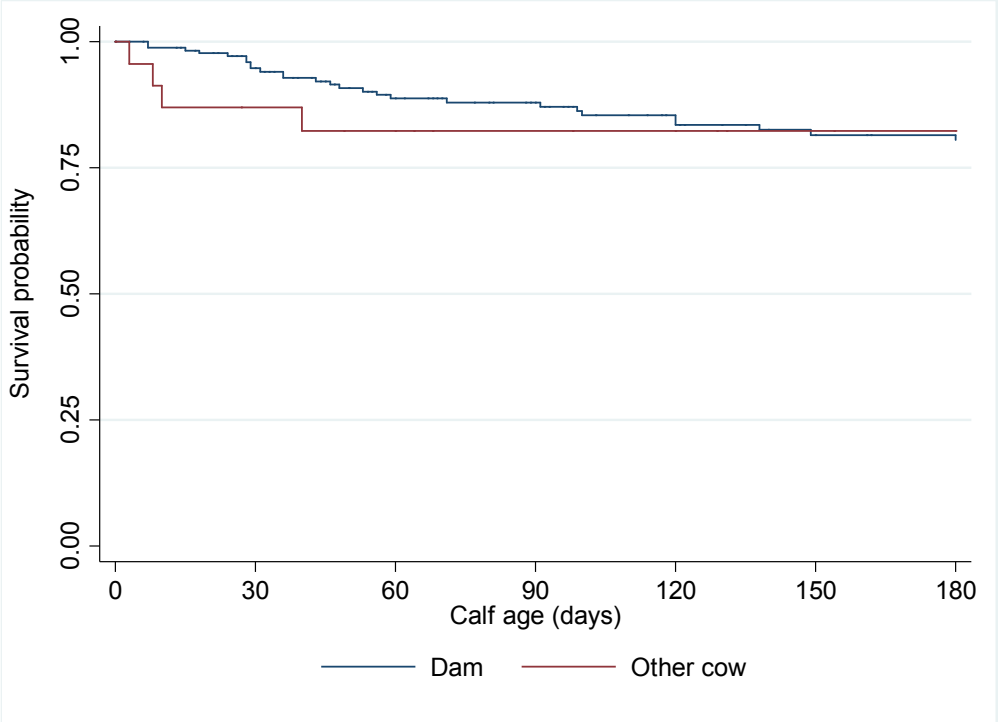

Figure 8: K-M survival estimate curve of mortality by source of colostrum

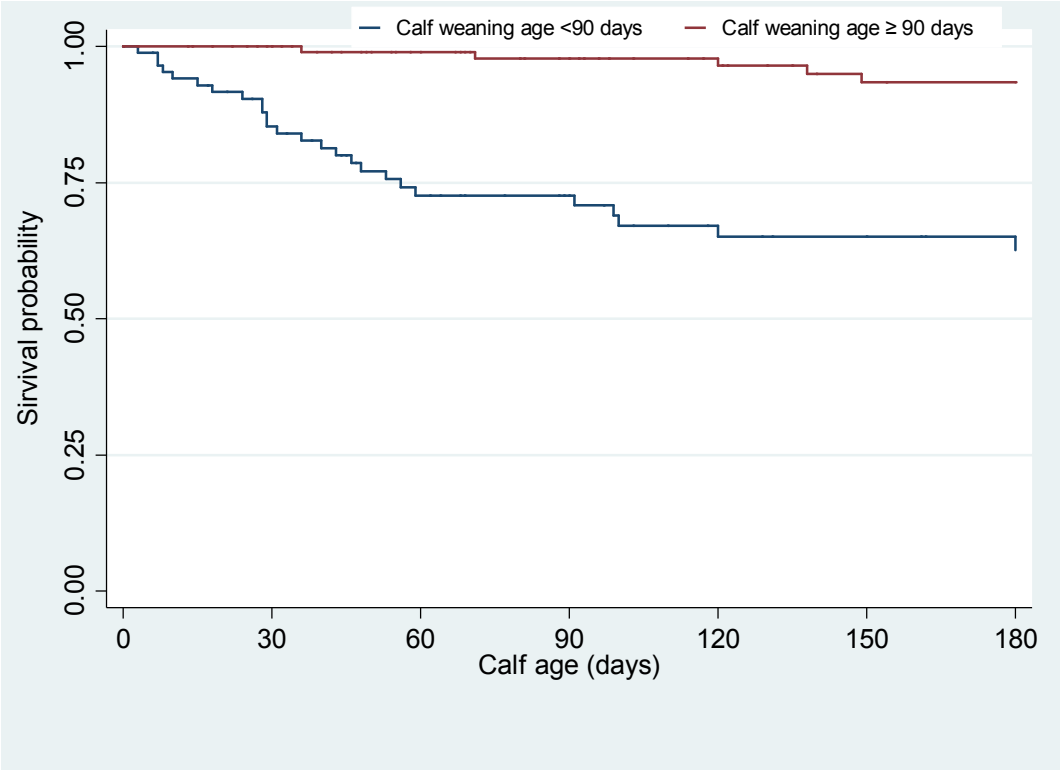

Figure 9: K-M survival curve of mortality by weaning age category

5 DISCUSSION

The current prospective longitudinal study conducted on 204 calves across 120 smallholder dairy farms in Halaba, Danboya and Misirak Badawacho districts of the central region, Ethiopia. Throughout 180 days follow-up period, the study recorded 101 (49.5%) cases of morbidity and 31 (15.2%) deaths due to different risk factors and disease syndromes. The numbers recorded for calf deaths and illnesses were alarming and stand out as some of the highest reported figures in Ethiopia.

According to the results of the present investigation, the all-cause morbidity and mortality rates for calves in the study areas were, respectively, 13 and 4 cases per 100 calf months at risk. The current findings were approximately similar to the mortality and morbidity rates of calf reported by Hordofa *et al.* (2021) and Abebe *et al.* (2023) who reported 13.81 cases per 100 calf months and 4.12 cases per 100 calf months, and 12.7 cases per 100 calf months and 3.7 cases per 100 calf months at risk respectively. Alemu *et al*. (2022) were reported a greater overall morbidity and mortality incidence rates than the current, which designated 64 cases per 100-calf 6-months at risk and 19 cases per 100-calf 6-months at risk, respectively. The difference in the compassions might be due to sample size difference of studies, population characteristics, and geographic conditions of study areas (Lombard *et al.,* 2007).

Further, the current investigation showed that the cumulative incidence of all-cause mortality and morbidity was 21% and 54%, respectively. These findings are comparable to the figures reported by Hordofa *et al*. (2021) in Hawassa, which are 20 and 50.1% cumulative mortality and morbidity, respectively. In contrast, results reported by Wudu *et al*. (2008) indicate a slightly higher cumulative incidence of 22 and 62%, respectively than the current findings for overall mortality and morbidity. Similarly, the current findings are higher than the cumulative mortality and morbidity reported by Bekele *et al.* (2009), Tora *et al.* (2021b), Alemu *et al.* (2022), Abebe *et al.* (2023), and Ahmedin and Assen (2023) with corresponding incidence of 9.3 and 29.3%, 8.64 and 30.9%, 16 and 47%, 13.5 and 39.8%, and 12 and 42%, respectively.

The mortality and morbidity figures of current study rank among the highest previously published reports as compared to above. The current mortality record is also greater than the economically acceptable threshold of calf mortality rate that is 3 to 5% under conditions of good

calf management (Radostits *et al*., 1994; Heinrichs and Radostits, 2001). The high rate of morbidity and mortality in the current finding might be due to poor management practice in the current study farms that includes poor hygiene practice on calving assistance, early separation of the calf from dam, and dam giving the birth outdoor contribute to disease transmission and health problems in calves.

Fourteen risk factors were fitted into the multivariable Cox regression model for all-cause calf morbidity. Of these explanatory factors, the calving condition, floor of the farm, calf sex, colostrum feeding, calf weaning age, dam breed, and calf age were found to be significant risk factors. The potential risk factors of mortality identified in the multivariable Cox proportional regression analysis model were farm location, calving condition, site of birth, farm floor, colostrum supply, presence of dam up on hand feeding, separation time of calves from dams, weaning age, and calf age.

The current study indicated that calves that were assisted during calving faced a much greater risk of morbidity (HR = 1.9) and mortality (HR = 7.7) compared to those born normal. These findings are consistent with the studies conducted by Asmare and Kiros (2016), Hordofa *et al*. (2021), Abebe *et al.* (2023), and Ahmedin and Assen (2023), as stated in their respective reports. Difficulties during calving can lead to higher risks of illness and mortality in calves due to contamination of the colostrum, delayed initiation of colostrum feeding, and decreased colostrum intake. Furthermore, calving difficulty triggers the production of adrenocorticotropic hormone, which increases adrenal cortex activity and optimizes the synthesis and release of cortisol, thereby reducing immunity (Godden, 2008; Vasseur *et al*., 2009).

The study also found that calves raised on non-concrete floors had a 2.88 times higher risk of morbidity and a 7.7 times higher risk of mortality compared to those raised on concrete floors. This aligns with Ahmedin and Assen's (2023) finding, which showed that calves kept on mud floors, faced a higher risk of death than those housed on concrete floors. It is stated that concrete flooring offers a stable, easy-to-clean surface, reducing the likelihood of bacterial growth, unlike mud floors, which are challenging to keep dry and clean (Asmare and Kiros, 2016). Furthermore, it was reported that while mud flooring is gentler on joints, it presents hygiene issues, potentially increasing the risk of microbial infections compared to calves raised on concrete floors (Heinemann *et al*., 2021; Belay and Mekibib, 2022).

Colostrum is vital for providing antibodies and nutrients to the calf, enhancing its immune system, reducing the risk of infections and diseases (Godden *et al*., 2019). The current study found that calves fed colostrum had a 49% lower risk of morbidity compared to those that did not receive colostrum. This finding agreed with the results of Tora *et al.* (2021b) and Alemu *et al*. (2022). The higher risk of morbidity associated with not receiving initial colostrum could be due to the lack of passive transfer of colostral immunity (Raboisson *et al*., 2016; Fischer *et al*., 2021). Calves that miss out on colostrum intake are more susceptible to diseases as colostrum plays a crucial role in providing essential antibodies and immune factors to newborn calves. Colostrum is rich in antibodies, particularly Immunoglobulin G, which is essential for the calf's immune system development (Godden, 2008; Lopez and Heinrichs, 2022).

The study revealed that male calves had 1.86 times higher likelihood disease compared to females, with no significant difference in mortality risk. This increased morbidity risk among male calves aligns with previous research by Bekele *et al*. (2009), Meribo and Mustefa (2021), and Abebe *et al*. (2023), which also found a higher incidence rate of morbidity in males than females. Abebe *et al.* (2023) explained that male calves generally receive less care in terms of feeding, medical attention, and overall management, leading to increased susceptibility to infections. In contrast, female calves are considered valuable for future breeding purposes, making them more economically important on farms.

Based on the present investigation, calves weaned at or after 90 days exhibited a 53% lower risk of illness and 97% reduced risk of mortality compared to those weaned earlier. This finding is in agreement with Tora *et al*. (2021b) who reported that calves weaned before 4 months old face higher mortality rates than those weaned at 4 months or older. These calves, weaned later or at 90 days, likely benefit from a more developed immune and digestive system. Early weaning can stress calves, which are still maturing physically and may struggle with dietary and social changes (Chirivi, 2022; Kononoff, 2023).When compared to those born to cross breed dams, the risk of morbidity decreased by 79% in calves born from local breeds dams. This aligns with Tora *et al.* (2021b) finding, which showed that crossbred calves had a higher morbidity risk than local breed calves. The lower morbidity risk in local breed calves in this study might be attributed to factors such as environment adaptation, disease resistance, nutritional efficiency, maternal care, and genetic diversity inherent in local cattle breeds compared to crossbreeds.

The study revealed that calves aged 3 or older had a 77% lower risk of morbidity and an 85% reduced mortality risk compared to calves less than 3 months. It was observed that 71.3% of all morbidity and 71% of all mortality cases occurred in calves under 3 months. This observation aligns with previous studies by Wudu *et al*. (2008), Ferede *et al*. (2014) and Abebe *et al.* (2023). Additionally, Ahmedin and Assen (2023) highlighted that the initial four months of a calf's life present the highest risk of morbidity and mortality. These findings underscore the critical nature of a calf's early months, necessitating the greatest care during this period. Premature calf deaths diminish a herd's replacement stock, resulting in genetic loss due to limited selection opportunities and reduced genetic progress.

The median survival times for morbidity due to diarrhea, pneumonia, and septicemia cases were 52, 32, and 67 days, respectively. These findings suggest that high calf morbidity from diarrhea, pneumonia, and septicemia is most likely to occur in neonatal calves under 90 days old. Diarrhea, with a prevalence of 25% (51/204) for morbidity and 14.7% (20/204) for mortality, emerged as the most common cause among the identified factors. Pneumonia stood as the second leading cause of mortality. Similar results have been documented in various regions of the country, including northern, southwestern, southern, and northwestern Ethiopia (Mohammed *et al.,* 2020; Alemu *et al*., 2022; Abebe *et al*., 2023; Ahmedin and Assen, 2023). These findings may be attributed to poor hygiene, management practices, and inadequate veterinary care, compounded by insufficient colostrum intake that reduces passive immunity and heightens vulnerability to diarrhea-causing pathogens in young calves (Al-Alo *et al*., 2018; Mohammed *et al*., 2020; Hordofa *et al*., 2021; Abebe *et al*., 2023).

In contrast to the majority of published findings which reported pneumonia as the second leading cause of mortality and morbidity (Wudu *et al.,* 2008; Fentie *et al*., 2020; Tora *et al.,* 2021b; Abebe *et al*., 2023), the current finding revealed that septicemia was the second leading cause of morbidity. These finding agree with the finding of Bekele *et al.* (2009) who reported septicemia as the second leading causes of mortality followed by pneumonia. This study also revealed that Septicemia was the third cause of mortality. Evans *et al*. (2021) reported septicemia as the major cause of mortality against the current finding. The occurrence of septicemia in current study area might be due to contaminated environments, equipment, and feed that can increase the risk of bacterial infections entering the bloodstream of calves, leading to septicemia.

Out of all dairy farms, 21.6% (26/120) employed calf caretakers to rear their calves. Death losses were lower on farms where the owner cared for the calves than on farms where workers or hired labor handled the tasks. This observational finding agrees with certain findings reported by Alemu *et al.* (2022). The bond between the owner and the animal may have a significant impact on the animal's wellbeing and health. This demonstrates that owners can be motivated to implement the required safety measures to ensure a high survival rate.

Some farmers at current study dairy farms leave neonates with their mothers for a few hours to suckle as much colostrum as possible, while others separate calves from their mothers soon after delivery. The risk of death was 7.68 fold greater in early separated calves than the calves with their mothers and consumed colostrum immediately than in calves that were immediately removed from their mothers and hand-fed colostrum with some delay. This finding agreed with the finding of Abebe *et al*. (2023). In fact, calves those wereseparatefrom their mothers after birth had not received enough amount of colostrum (10% to 12% of their body weight) recommended by Godden *et al*. (2019) to protect them from infectious pathogens that cause mortality.

The current investigation also revealed that calf born outdoor had 27.3 fold greater risk of mortality than calf born indoor. According to the observation on the study period and Fentie *et al.* (2020), the possible reasons to higher calf mortality rates for calves born outdoors compared to those born indoors might be calves born outdoors are exposed to various weather condition, inadequate supervision and assistance, and lack of biosecurity measures.A dairy's colostrum management is one of most important management factor in the calf health and survival (Godden *et al*., 2019) which include facilitation of dam colostrum for new born calf. The finding of this study revealed that calf that consumed its dam colostrum was at 77% lower risk of mortality than the calf that consumed colostrum from other cows. This might be due to acquiring of immunity from its own dam to fight pathogenic organisms encountered on the home farm. The infectious disease can be transmitted via colostrum and milk and so, feeding colostrum from the calf's own dam minimize the potential spread of such diseases (Godden, 2008). The current investigation also revealed that the presence of dam during hand feeding of calf had 95% reduced risk of mortality compared to absence of dam during hand feeding of calf. This might indicate that free contact systems where cow and calf had unrestricted access to each otherhad positive impact on the health of the calf.

Limitation of the study

In the current study, the health disorder and deaths of the calves were diagnosed by observing their clinical signs and reviewing their case history. The researcher did not use any diagnostic tests or laboratory procedures, but relied on visual cues and information about the calves' past health issues to determine the cause of their illness or death. This method of diagnosis might not be as accurate as laboratory tests, but it can still provide valuable insights into the health status of the animals and help to identify potential risk factors for disease. The limitation mentioned in this statement is related to the lack of budget and nearby laboratory diagnosis center for samples from calves with health disorders. This means that the causative agents responsible for the health disorders were not identified. As a result, future studies should focus on identifying the specific causative agents to gain a better understanding of the health issues in calves.

6 CONCLUSION AND RECOMMENDATIONS

The dairy farming plays a vital role in supporting smallholder farmers and driving economic growth in Ethiopia. However, the current study revealed that the cumulative incidence of all-cause mortality and all-cause morbidity were 20% and 53%, respectively within the six months of their life. This economically unacceptable high rate of calf morbidity and mortality in smallholder dairy farms ultimately impacts the number of healthy calves available to sustain the sector and improve the livelihoods of farmers. The high incidences were registered in the calves under 90 day's age, indicating the need of serious care on neonatal calves. The study identified various disease syndromes contributing to calf health issues and deaths, with diarrhea being the most common disease syndrome. There were pneumonia, septicemia, navel infection, eye problem and other unknown causes of incidence registered on the farms posing significant loss. Of the potential risk factors studied, farm location, calving condition, birth site, farm floor, colostrum availability, presence of dam up on hand feeding, separation time, weaning age, and calf age weresignificantly associated with either of morbidity and mortality or both. The stakeholders in the dairy industry in Ethiopia should work towards improving calf health, reducing mortality rates, and ultimately enhancing the sustainability and profitability of smallholder dairy farms based on the following recommendations forwarded.

- ✓ Improving and implementing better management practices of small holder dairy farms.
- ✓ Ensuring that calves receive an adequate amount of high-quality colostrum within the first few hours of neonatal life.
- ✓ Conducting further studies on detailed diagnosis of disease syndromes and identification of underlying causes.

7 REFERENCES

Abd El-Moez, S.I., Ata, N.S. and Zaki, M.S. (2013): Bacterial causes of sudden death in farm animals. *Life Science Journal*, *10* (1): 1188-1201.

Abebe, R., Dema, T., Libiyos, Y., Teherku, W., Regassa, A., Fekadu, A. and Sheferaw, D. (2023): Longitudinal study of calf morbidity and mortality and the associated risk factors on urban and peri-urban dairy farms in southern Ethiopia. *BMC Veterinary Research*, *19* (1): 15.

Abuelo, A., Cullens, F., Hanes, A. and Brester, J.L. (2021): Impact of 2 versus 1 colostrum meals on failure of transfer of passive immunity, pre-weaning morbidity and mortality, and performance of dairy calves in a large dairy herd. *Animals*, *11* (3): 782.

Ahmedin, U.M. and Assen, A.A. (2023): Calf morbidity, mortality, and management practices in dairy farms in Jimma City, Southwestern Ethiopia. *BMC Veterinary Research*, *19* (1): 249.

Al-Alo, K.Z.K., Brujeni, G.N., Lotfollahzadeh, S., Moosakhani, F. and Gharabaghi, A. (2018): Correlation between neonatal calf diarrhea and the level of maternally derived antibodies. *Iranian Journal of Veterinary Research*, *19* (1): 3.

Alemu, Y.F., Jemberu, W.T., Mekuriaw, Z. and Abdi, R.D. (2022): Incidence and predictors of calf morbidity and mortality from birth to 6-months of age in dairy farms of northwestern Ethiopia. *Frontiers in Veterinary Science*, *9*: 859401.

Amanuel, D. and Eskindir. (2023): Effectiveness of Artificial Insemination after Estrus Synchronization in Dairy Cattle Breeding in Hadiya Zone, Southern Ethiopia.

Andrews, A.H. (1992): Calf respiratory diseases. *Bovine Medicine: Diseases and Husbandry of Cattle*, Pp.202-212.

Arsham, H. (2005): Questionnaire design and surveys sampling. *University of Baltimore*, Pp. *114*.

Asmare, A.A. and Kiros, W.A. (2016): Dairy calf morbidity and mortality and associated risk factors in Sodo town and its suburbs, Wolaita zone, Ethiopia. *Slovak Journal of Animal Science*, *49* (1): 44-56.

Bekele, M., AbdubaYacob, A.Y., AlemayehuRegassa, A.R., FufaAbuna, F.A., KassahunAsmare, K.A. and KebedeAmenu, K.A. (2009): Prevalence and incidence rates of calf morbidity and mortality and associated risk factors in smallholder dairy farms in Hawassa, Southern Ethiopia. *Ethiop. Vet. J.*, 13 (2): 59-68.

Belay, T. and Mekibib, B. (2022): Assessment of Calf Management and Hygiene Practices Adopted in Large and Small-Scale Dairy Farms in Wondo Genet Area, Southern Ethiopia. *Veterinary Medicine: Research and Reports*, Pp.329-337.

Berchtold, J. (2009): Treatment of calf diarrhea: intravenous fluid therapy. *Veterinary Clinics of North America: Food Animal Practice*, *25* (1): 73-99.

Blowey, R.W. and Weaver, A.D. (2011): Neonatal disorders. *Color Atlas of Diseases and Disorders of Cattle*, Pp.13.

Boden, E., & Andrews, A. (2015): *Black's veterinary dictionary*. Bloomsbury Publishing.

Carter, H.S., Renaud, D.L., Steele, M.A., Fischer-Tlustos, A.J. and Costa, J.H. (2021): A narrative review on the unexplored potential of colostrum as a preventative treatment and therapy for diarrhea in neonatal dairy calves. *Animals*, *11* (8): 2221.

Chase, C.C., Hurley, D.J. and Reber, A.J. (2008): Neonatal immune development in the calf and its impact on vaccine response. Veterinary cilinics of North America: Food Animal Practice, 24 (1): 87-104.

Cherinnat, T.M. and Edossa, F.B. (2023): Study of calf health and management problems in urban and per-urban dairy farms of selected districts of East Wollega Zone of Oromia Regional State, Western Ethiopia. *International Journal of Veterinary Science and Research*, *9* (3): 053-058.

Chirivi, M. (2022): 2022 Awards Program of the American Dairy Science Association. *Journal of Dairy Science*, *105* (12): 10049-10066.

Cho, Y.I. and Yoon, K.J. (2014): An overview of calf diarrhea-infectious etiology, diagnosis, and intervention. *Journal of veterinary science*, *15*(1): 1.

Constable, P.D., Hinchcliff, K.W., Done, S.H. and Grünberg, W. (2016): Veterinary medicine: a textbook of the diseases of cattle, horses, sheep, pigs and goats. *Elsevier Health Sciences.*

CSA., (2021): Central statistical agency of Ethiopia, Agricultural sample survey 2020/2021. Report on livestock and livestock characteristics. *Statistical Bulletin 589. Vol. II*. Addis Ababa, Ethiopia.

DallAgnol, A.M., Lorenzetti, E., Leme, R.A., Ladeia, W.A., Mainardi, R.M., Bernardi, A., Headley, S.A., Freire, R.L., Pereira, U.P., Alfieri, A.F. and Alfieri, A.A. (2021): Severe outbreak of bovine neonatal diarrhea in a dairy calf rearing unit with multifactorial etiology. *Brazilian Journal of Microbiology*, *52* (4): 2547-2553.

Davies, S.J., Esposito, G., Villot, C., Chevaux, E. and Raffrenato, E. (2022): An Evaluation of Nutritional and Therapeutic Factors Affecting Pre-Weaned Calf Health and Welfare, and

Direct-Fed Microbials as a Potential Alternative for Promoting Performance—A Review. *Dairy*, *3* (3): 648-667.

Donovan, G.A., Dohoo, I.R., Montgomery, D.M. and Bennett, F.L. (1998): Calf and disease factors affecting growth in female Holstein calves in Florida, USA. *Preventive veterinary medicine*, *33*(1-4): 1-10.

Duguma, B. (2020): A survey of management practices and major diseases of dairy cattle in smallholdings in selected towns of Jimma zone, south-western Ethiopia. *Animal Production Science*, *60* (15): 1838-1849.

Edao, A. and Meribo, A. (2021): Major causes of calf morbidity and mortality in smallholder dairy farms in Shashemene town, Ethiopia.*NASS Journal of Agricultural Sciences,* 03 (2): 51-57

Evans, L., Rhodes, A., Alhazzani, W., Antonelli, M., Coopersmith, C.M., French, C., Machado, F.R., Mcintyre, L., Ostermann, M., Prescott, H.C. and Schorr, C. (2021): Surviving sepsis campaign: international guidelines for management of sepsis and septic shock. *Critical care medicine*, *49* (11): 1063-1143.

Fahim, N.K. and Negida, A. (2019): Sample size calculation guide-part 2: how to calculate the sample size for an independent cohort study. *Frontiers in Emergency Medicine*, *3* (1), pp.e12

Fanda, Y. S. (2023): A Review on Epidemiology, Economic Importance and Common Causes of Dairy Calf Morbidity and Mortality. *Int. J. Adv. Res. Biol. Sci*, *10* (11), 17-23.

Fentie, T., Guta, S., Mekonen, G., Temesgen, W., Melaku, A., Asefa, G., Tesfaye, S., Niguse, A., Abera, B., Kflewahd, F.Z. and Hailu, B. (2020): Assessment of major causes of calf mortality in urban and periurban dairy production system of Ethiopia. *Veterinary Medicine International. Pp:1-7*

Ferede, Y., Mazengia, H., Bimrew, T., Bitew, A., Nega, M., Kebede, A., Ferede, Y., Mazengia, H., Bimrew, T. and Bitew, A. (2014): Pre-weaning morbidity and mortality of crossbred calves in Bahir Dar Zuria and Gozamen districts of Amhara region, northwest Ethiopia. *Open Access Library Journal*, *1* (3): 1-8.

Fischer, T.A.J., Lopez, A., Hare, K.S., Wood, K.M. and Steele, M.A. (2021): Effects of colostrum management on transfer of passive immunity and the potential role of colostral bioactive components on neonatal calf development and metabolism. *Canadian Journal of Animal Science*, *101* (3): 405-426..

Gebreyohanes, G., Yilma, Z., Moyo, S. and OkeyoMwai, A. (2021). Dairy industry development in Ethiopia: Current status, major challenges and potential interventions for improvement. *ILRI Position Paper*

Getabalew, M., Alemneh, T. and Akeberegn, D. (2019): Dairy production in Ethiopia-existing scenario and constraints. *Biomedical Journal of Scientific & Technical Research*, *16* (5): 12304-12309.

Godden, S. (2008): Colostrum management for dairy calves. *Veterinary Clinics of North America: Food Animal Practice*, *24* (1): 19-39.

Godden, S.M., Lombard, J.E. and Woolums, A.R. (2019): Colostrum management for dairy calves. *Veterinary Clinics: Food Animal Practice*, *35* (3): 535-556.

Gorden, P.J. and Plummer, P. (2010): Control, management, and prevention of bovine respiratory disease in dairy calves and cows. *Veterinary Clinics: Food Animal Practice*, *26* (2): 243-259.

Hadgu, A., Lemma, A., Yilma, T., &Fesseha, H. (2021): Major causes of calf and lamb mortality and morbidity and associated risk factors in the mixed crop-livestock production system in Jamma District, South Wollo, Ethiopia. *Veterinary Medicine International*.*Pp. 1-14*

Hailu, M., Asmare, K., Gebremedhin, E. Z., Sheferaw, D., Gizaw, D., Di Marco, V., and Vitale, M. (2020): Cryptosporidium and Giardia infections in dairy calves in southern Ethiopia. *Parasite epidemiology and control*, *10*: 00155.

Heinemann, C., Leubner, C.D., Hayer, J.J. and Steinhoff-Wagner, J. (2021): Hygiene management in newborn individually housed dairy calves focusing on housing and feeding practices. *Journal of animal science*, *99* (1): 391.

Heinrichs, A.J. and Radostits, O.M. (2001): Health and production management of dairy calves and replacement heifers. *Herd Health-food Animal Production Medicine*

Hordofa, D., Abunna, F., Megersa, B. and Abebe, R. (2021): 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. *Heliyon*, *7* (12).

Hotchkiss, R.S., Moldawer, L.L., Opal, S.M., Reinhart, K., Turnbull, I.R. and Vincent, J.L. (2016): Sepsis and septic shock. *Nature reviews Disease primers*, *2* (1): 1-21.

HZFEDO. (2019): Halaba Zone Finance and Economic Development Office.

Kashyap, G.D.J.A., Dar, J.A., War, Z.A., Gupta, D., Sahu, N., Singh, S., Kamdi, B., Singh, V. and Rai, S.K. (2018): Bacteriological and pathological study of a case of navel ill and its complications. *Journal of immunology and immunopathology*, 20 (1): 52-55.

Kebede, I.A. Gebremeskel H.F., Ahmed A.D. (2024): Dairy Farm in Ethiopia: Overview. *Austin J Vet Sci and Anim Husb.*11 (1): 1134.

Kharb, S., Yadav, A., Kumar, T. and Sindhu, N. (2021): Umbilical infections in calves reared under traditional system and their management. *Indian J. Vet. Med*, *41* (1): 61-64.

Kidane, A.B., Delesa, K.E., Mummed, Y.Y. and Tadesse, M. (2019): Reproductive and productive performance of Holstein Friesian and crossbreed dairy cattle at large, medium and small scale dairy farms in Ethiopia. *International Journal of Advanced Research in Biological Sciences*, *6*: 15-29.

Kononoff, P. J. (2023): Journal of Dairy Science 2022 Editorial Report. *Journal of Dairy Science*, *106* (4): 2193-2197.

Kumaresan, A., Layek, S.S., Mohanty, T.K., Patbandha, T. and Prasad, S. (2012): Managing calf scours-A Herd health approach. *IntasPolivet*, *13* (1): 8-14.

Legese, G. and Fadiga, M.L. (2014): Small ruminant value chain development in Ethiopia: Situation analysis and trends. *ICARDA/ILRI project report.*

Leggesse, G., Gelmesa, U., Jembere, T., Degefa, T., Bediye, S., Teka, T., Temesgen, D., Girma, Y., Berhe, A., Gemeda, L. and Takele, D. (2023). Ethiopia National Dairy Development Strategy 2022–2031.*ILRI*

Lema, M., Kassa, T. and Tegegne, A. (2001): Clinically manifested major health problems of crossbred dairy herds in urban and periurban production systems in the central highlands of Ethiopia. *Tropical Animal Health and Production*, *33*: 85-93.

Lombard, J. E., Garry, F. B., Tomlinson, S. M., and Garber, L. P. (2007): Impacts of dystocia on health and survival of dairy calves. *Journal of dairy science*, *90* (4), 1751-1760.

Lopez, A.J. and Heinrichs, A.J., (2022): Invited review: The importance of colostrum in the newborn dairy calf. *Journal of dairy science*, *105* (4): 2733-2749.

Martin, S.W., Meek A.H. and Willeberg P. (1987): Veterinary Epidemiology: Principle andMethods. Iowa, Iowa state University Press.

Meribo, A, and Mustefa K. (2021): Major causes of calf morbidity and mortality in smallholder dairy farms in Shashemene town, Ethiopia. *Int J Adv Res Biol Sci*. 8 (5):70–79.

Mohammed, R., Kefyalew, H. and Kassaye, D. (2020): Incidence of calf morbidity and its predictors in North Shewa, Amhara, Ethiopia. *Veterinary Medicine International*, Pp. 1-10.

Molla, M. (2013): Cattle production and marketing systems in doyogena, Danboya and tembaro districts of southern ethiopia. *Msc thesis.*

Msimang, Veerle, Melinda K. Rostal, Claudia Cordel, Catherine Machalaba, S. T., Whitney Bagge, Felicity J. Burt, William B. Karesh, J. T. Paweska, and Peter T. N. (2022): Factors affecting the use of biosecurity measures for the protection of ruminant livestock and farm workers against infectious diseases in central South Africa. *Transboundary and Emerging Diseases* 69 (5): 1899-1912.

Naik, S.G., Ananda, K.J., Rani, B.K., Kotresh, A.M., Shambulingappa, B.E. and Patel, S.R. (2011): Navel ill in new born calves and its successful treatment. *Veterinary World*, *4* (7): 326.

Nikkhah, A. and Alimirzaei, M. (2022): Colibacillosis and Colisepeticemia in Newborn Calves: Towards Pragmatic Treatment and Prevention. *World's Veterinary Journal*, *12* (3): 230-236.

Nuvey, F.S., Kreppel, K., Nortey, P.A., Addo-Lartey, A., Sarfo, B., Fokou, G., Ameme, D.K., Kenu, E., Sackey, S., Addo, K.K. and Afari, E. (2020): Poor mental health of livestock farmers in Africa: a mixed methods case study from Ghana. *BMC public health*, *20*: 1-12.

Otten, N.D., Skarbye, A.P., Krogh, M.A., Michelsen, A.M. and Nielsen, L.R. (2023): Monitoring bovine dairy calf health and related risk factors in the first three months of rearing. *ActaVeterinariaScandinavica*, *65* (1): 45.

Palczynski, L.J., Bleach, E.C., Brennan, M.L. and Robinson, P.A. (2021): Stakeholder perceptions of disease management for dairy calves: "it's just little things that make such a big difference". *Animals*, *11* (10): 2829.

Pas, M.L., Bokma, J., Lowie, T., Boyen, F. and Pardon, B. (2023): Sepsis and survival in critically ill calves: Risk factors and antimicrobial use. *Journal of veterinary internal medicine*, *37* (1): 374-389.

Petros, U. M. (2021). Adoption of climate smart cattle production practices and determinants among small holders farmers, the case of kedidagamelaworeda in kambatatembaro zone in SNNPR. *MSc thesis, Haramayauniversity, Ethiopia.*

Raboisson, D., Trillat, P. and Cahuzac, C. (2016): Failure of passive immune transfer in calves: A meta-analysis on the consequences and assessment of the economic impact. *PloS one*, *11* (3): 015-0452.

Radostits, O.M., Gay, C.C., Hinchcliff, K.W. and Constable, P.D. (2017): A textbook of the diseases of cattle, horses, sheep, pigs and goats. *Vet. Med*, *10*: 2045-2050.

Radostits, O.M., Leslie, K.E. and Fetrow, J. (1994): Herd health: food animal production medicine. *Ed.* 2, Pp. 631.

Riad, E.M. (2020): Calf Diseases and Prevention. *Egyptian Journal of Chemistry and Environmental Health*, *6* (1): 19-22.

Robertson, J.F. and Cavill, R.S. (2022): Calving pen management. *Livestock*, *27* (5): 209-214.

Robi, D.T., Mossie, T. and Temteme, S. (2023): Eukaryotic Infections in Dairy Calves: Impacts, Diagnosis, and Strategies for Prevention and Control. *Veterinary Medicine: Research and Reports*, pp.195-208.

Robi, D.T., Mossie, T. and Temteme, S. (2024): A Comprehensive Review of the Common Bacterial Infections in Dairy Calves and Advanced Strategies for Health Management. *Veterinary Medicine: Research and Reports*, 24 (15): 1-14.

Sasidharan, M. and Kannan, A. (2021): The transition of digestion in dairy calves. *Reviews of veterinary*, Pp.121.

Smith, B. (2015): Large Animal Internal Medicine. *5th Edi.*

Stoltenow, C.L. and Vincent, L.L. (2003): Calf scours: causes, prevention, and treatment.

Taylor, J.D., Fulton, R.W., Lehenbauer, T.W., Step, D.L. and Confer, A.W. (2010): The epidemiology of bovine respiratory disease: What is the evidence for predisposing factors. *The Canadian veterinary journal*, *51* (10): 1095.

Tegegne, A. and Gebrewold, A. (1998): Prospects for peri-urban dairy development in Ethiopia.

Tegegne, A., Gebremedhin, B., Hoekstra, D., Belay, B. and Mekasha, Y. (2013): Smallholder dairy production and marketing systems in Ethiopia: IPMS experiences and opportunities for market-oriented development. *IPMS Working Paper*.

Tesfaye, N. (2019): Review on the major causes and associated risk factors of calf morbidity and mortality in dairy farms of Ethiopia. *J. Dairy Vet. Anim. Res*, *8* (2): 83-92.

Tesfaye, T., Getachew, S., Tadele, A. and Olbamo, T. (2020): Study on the causes of calf morbidity and mortality and its associated risk factors in South Omo Zone, South-Western Ethiopia. *Journal of Animal Science and Veterinary Medicine*, *5* (6): 191-201.

Tora, E., Abayneh, E., Seyoum, W. and Shurbe, M. (2021b): Longitudinal study of calf morbidity and mortality on smallholder farms in southern Ethiopia. *PloS one*, *16* (9): 0257139.

Tora, E., Shrube, M., Kaba, T. and Seyoum, W. (2021a): Prevalence of calf mortality in Ethiopia: A systematic review and meta-analysis. *Veterinary Medicine International*, Pp.1-10.

Tsegaye, K., Nurfeta, A. and Mekasha, Y. (2022): Dairy production and marketing systems in urban/peri-urban and rural dairy production systems in Bona Zuria district of Sidama Region, Ethiopia. *International Journal of Livestock Production*, *13* (3): 66-78.

Uruakpa, F.O., Ismond, M.A.H. and Akobundu, E.N. (2002): Colostrum and its benefits: a review. *Nutrition research*, *22* (6): 755-767.

Uyama, T., Kelton, D.F., Winder, C.B., Dunn, J., Goetz, H.M., LeBlanc, S.J., McClure, J.T. and Renaud, D.L. (2022): Colostrum management practices that improve the transfer of passive immunity in neonatal dairy calves: A scoping review. *Plos one*, *17* (6): 0269824.

Valeris-Chacin, R., Powledge, S., McAtee, T., Morley, P.S. and Richeson, J. (2022): Mycoplasma bovis is associated with Mannheimiahaemolytica during acute bovine respiratory disease in feedlot cattle. *Frontiers in Microbiology*, *13*: 946792.

Vasseur, E., Rushen, J. and De Passillé, A.M., (2009): Does a calf's motivation to ingest colostrum depend on time since birth, calf vigor, or provision of heat. *Journal of dairy science*, *92* (8): 3915-3921.

Vlasova, A.N. and Saif, L.J., (2021): Bovine immunology: Implications for dairy cattle. *Frontiers in immunology*, *12*: 643206.

Windeyer, M.C. and Gamsjäger, L. (2019): Vaccinating calves in the face of maternal antibodies: challenges and opportunities. *Veterinary Clinics: Food Animal Practice*, *35* (3): 557-573.

Wong, J.T., Lane, J.K., Allan, F.K., Vidal, G., Vance, C., Donadeu, M., Jackson, W., Nwankpa, V., Abera, S., Mekonnen, G.A. and Kebede, N. (2022): Reducing Calf Mortality in Ethiopia. *Animals*, *12* (16): 2126.

Wudu, T. (2004): Calf morbidity and mortality in dairy farms in DebreZeit and its envirions, Ethiopia (MSc thesis). *DebreZeit: Faculty of Veterinary Medicine, Addis Ababa University*.

Wudu, T., Kelay, B., Mekonnen, H.M. and Tesfu, K. (2008): Calf morbidity and mortality in smallholder dairy farms in Ada'aLiben district of Oromia, Ethiopia. *Tropical animal health and production*, *40*: 369-376.

Yitagesu, E., Fentie, T., Kebede, N., Jackson, W. and Smith, W. (2022): The magnitude of calf morbidity and mortality and risk factors in smallholder farms across livestock production systems in central Ethiopia. *Veterinary Medicine and Science*, *8* (5): 2157-2166.

8. ANNEXES

Annex I: Questionnaire for herd level management data collection associated with dairy calf morbidity and mortality in Central region, Ethiopia

1. General information

Date of interview……..Zone……Woreda…….…….Kebele……..Tel……

2. Farm, household, and land-holding characteristics

2.1. Name of the household head/respondent……

2.2. Sex of household head a) male b) female

2.3. Age of household head……

2.4. Marital status a) married b) single c) Widow d) Divorced

2.5. Household educational status a) illiterate b) read and writes c) elementary school d) High school graduate e) professional

2.6. Family size: Male…….Female…….Total……

2.7. System of Agricultural production a) livestock c) mixed crop-livestock

2.8. Landholding: Cultivable/farming land (ha)……Private grazing land (ha)…. Total……

3. Dairy Production System

3.1. What are your major livestock activities?

a) Dairy production b) Small ruminant production c) poultry production

3.2. Dairy production as a source of income a) primary b) secondary/sideline activity

3.3. How long have you engaged in dairy production?.....

3.4. Dairy farm location a) Urban b) peri-urban

3.5. Herd size and composition

Herd composition		**Local**	**Cross**	**Total**
Calves (<6m)	Male			
	Female			
Calves (6-12m)	Male			
	Female			
Heifers				
Lactating cows				
Dry cows				
Bull				
Bullock				
Total herd size				

4. Calf Management data

4.1. Breeding methods used a) AI b) natural mating c) both

4.2. Calf care taker (attendant)

4.2.1. Ownership a) owner (family member) b) hired

4.2.2. Sex a) male b) female

4.2.3. Experiencea) ≤5 years b) >5 years

4.3. Pregnant cow management and per parturient care a) yes b) No

4.3.1. If yes, what kind of management? ……

4.3.2. Calving facilities a) calving pen b) the same barn

4.3.3. Bedding in maternity area a) yes b) no

4.3.3.1. If yes, what type of bedding a) stalks b) straw?

4.3.4. Calving assistance a) routinely b) rarely c) never

4.3.4.1. When do you provide calving assistance?.....

4.3.5. At what time do you separate the calf from his dam……

4.3.6. Navel treatment a) practiced b) not practiced

If practiced, type of treatment/chemical used…….

4.4. Awareness about the importance of colostrum to neonatal calves a) yes b) no

4.4.1. Do you feed colostrum to your calves a) yes b) No

4.4.2. If yes, a) partial colostrum b) complete colostrum

4.4.3. Method of feeding a) suckling b) hand feeding

4.4.4. If hand feeding, source of feeding a) dam b) another cow

4.4.5. Time of first colostrum feeding a) within 6 hrs b) within 6-24 hrs c) > 24 hrs

4.4.6. Duration of feeding a) for 24 hrs b) 24 hour-4 days c) > 4 days

4.5. Feeding and watering management

4.5.1. Type of feed a) milk b) milk replacer

4.5.2. Amount of milk/milk replacer given

a) Known, amount (Lt)…… b) unknown, residual milk

4.5.3. Time (in days) of introducing feed other than milk or milk replacer ……..

4.5.5. Mode of feeding a) free grazing b) stall feeding c) partial grazing

4.5.6. Watering a) free access b) periodic

4.6. Housing management

4.6.1. Housing type a) indoor b) outdoor/hutch

4.6.2. Location of the calf pen a) In cow shed b) in separate pen/shed (cubicle)

4.6.3 If separate pen a) individual pen b) group pen

4.6.4 If group pen, number of calves kept /pen…….

4.6.5. Bedding in calf house a) present b) absent

4.6.6. If present what is the bedding material a) straw b) stalk

4.6.7. Frequency of calf pen cleaning a) every calf entry b) daily c) twice a day

4.6.8. Which group of calves often receives better managerial attention?

a) Male calves b) female calves c) both

4.6.9. Weaning age (month) a) local….....b) cross……..

5. Calf morbidity and mortality data

5.2. Is calf mortality the problem of your farm? a) Yes b) No

5.3. A Total number of calves (<1yr) the farm lost during the last year:

Local……..….Cross……Total..…….

5.4. At which age group mortality was higher?

a) Prenatal age (until 24 hrs after birth)

b) Neonatal age (death between 1 and 28 days of age)

c) Older age (death between 1 and 6 months of age)

5.5. Diseases those are responsible for the sickness and death of calves in order of importance.

a)……....b)…….....c)…….……d)……..…..e)……

5.6. Which breeds of calves are highly susceptible to diseases? a) Local b) Cross

5.7. Measures taken to prevent disease problems……..……...

5.8. Calf weaning practices

5.8.1. Who weans the calf mostly?

a) The cow's refusal c) the Owner d) Refusal of the calf e) others

6. Dairy cow health disorders and health management activities

6.1. Major Dairy cow health disorders…….

6.2. Pregnant cow vaccination a) yes b) no

6.3. Dry cow therapy a) yes b) no

Thank you for your time!

AnnexIII: Calf level data recording sheet associated with dairy calf morbidity and mortality in Central region, Ethiopia

Name of the owner…….Woreda……..kebele……..……Tel…..…….

Calf ID……..Dam ID…….…….

I. Calf and management-associated factors

1. Date of birth……month….....year….....
2. Condition of birth a) Easy b) Dystocia/assisted
   2.1. If assisted, who assist the calving process? a) Owner b) Veterinarian
3. Time of birth a) night b) day
4. Site of birth a) indoor/cow's barn b) outdoor /field
5. Floor of farm a) concrete b) mud
6. Sex a) male b) female
7. Breed a) local b) cross
9. Navel disinfection a) yes b) no If yes, a chemical used……
10. The calf fed with maternal colostrum? a) yes b) no
    If no, why……..
11. If yes, time of colostrum ingestion a) before 6 hr b) 6-12hr c) 12-24 d) >24hr
12. Method of colostrum feeding a) suckling b) hand feeding/bucket
    12.1. If hand fed, amount given……..
    12.2. Source of colostrum a) dam b) another cow
    12.3. Was the dam presented to the calf during hand feeding a) yes b) no
13. Vigor status as soon as birth?

a) Good vigor/quick sucklingb) Poor vigor/ delayed suckling

14. Time of separation of the calf from dam/postpartum hr?

a) before 1st nursing b) after 1st nursing c) before 24 hrs.age d) after 24 hrs.age

15. Birth weight: Kg.….....Weaning weight: Kg……
16. Weaning age (m)……

II. Dam-associated factors

1. Mothering instinct a) good mothering b) poor mothering
2. Parity of the dam a) Primiparous/first b) Multifarious/second and above
3. Dam breed a) local b) cross
4. If cross, exotic blood level a) <=50% b) 50-75% c)>=75%
5. Dam age…….
6. Age at first calving ……
7. Calving interval……
8. Other dam health disorders……..

III. Sire associated factors

9. Source of breeding service a) AI b) natural mating/bull service

VI. Calf case incidence record

10. Date of appearance of clinical signs…….…….

11. Major clinical signs…….……

12. Diagnosis……

13. Treatment……

14. Treatment outcome a) recovered b) died

15. If died, date of death…….

AnnexIIII: Standardized case definitions used during the recording of diseases and mortality events between birth and 180 days of age in Central region, Ethiopia

Disease condition	Case definition
Diarrhea/scours	Manure is of looser consistency than normal calves. Any condition characterized by the passing of loose or watery feces with increased frequency, which could or could not be accompanied by other systemic signs like dehydration, decreased appetite, or fever
Respiratory disease	Increased resting respiratory rate, fever (>39.5^0c) with one or more additional signs such as coughing, nasal discharge, depression, decreased appetite, or rough hair coat
Naval ill/Omphalitis	Warm enlargement of the umbilical cord, or foul-smelling discharge from the umbilical structures due to infection
Septicemia cond.	Any condition characterized by depression, anorexia, and fever without any distinct involvement of a specific body system
LSD	Characterized by skin nodules, fever, necrotic plaques in mucosae, and lymphadenopathy.
Rabies	A history of rabid dog bites preceded nervous signs like drooling of saliva, aggressiveness and beat their heads by any inanimate objects, extended recumbence and complete loss of appetite then ended up with death
Congenital problems	Any problems that were acquired inborn.
Miscellaneous cases	Different health problems that could not be grouped in any one of the other groups mentioned before and diagnosed relatively less frequently (traumatic injury, birth defects, ringworm, warts e.t.c…)
Perinatal mortality	Live births that died until 24 hr of birth of life without an obvious disease
Neonatal mortality	Death between 1 and 28 days of age
Older calf mortality	Death between 1 and 6 months of age

Source: (Wudu, 2004; Windyer*et al*., 2014)

Annex IV: The Pictures of study calves taken during the study period

8 BIOGRAPHIC SKETCH

Biruk Alemu Basore, the author of this thesis was born in Durame, Kambata Zone, Central Regional State, Ethiopia, to his father, Alemu Basore, and mother, Amarech Duguno, in 1992. He received his elementary (1-6) and primary (7-8) education at Teza Gerba and Durame Kutir 1 Primary School, respectively. He completed his high school and preparatory program at Durame Secondary and Preparatory School. Aftercompleting his preparatory program in 2007 G.C., he enrolled in Haramaya University College of Veterinary Medicine in 2008 G.C. and graduated with a Doctor of Veterinary Medicine (DVM) degree in 2014 G.C. After graduation, he began working as a veterinary clinician at the Kedida Gamela Woreda Livestock and Fishery Office in June 2015 G.C., where he remained for nearly a year and half. He then served as a veterinary drug institution inspector for the Ethiopian Agricultural Authority (formerly, The Ethiopian Veterinary Drug and Feed Administration and Control Authority) from October 1, 2017 until October 30, 2021 G.C. He then after, served as an Animal Health Field Officer at Brooke Hospital for Animals (Brooke Ethiopia) from November 1, 2021 to October 31, 2023 G.C. He was the employee of World Vision Ethiopia as an emergency livelihood officer from November 14 to March 31, 2023 G.C. He began the new position as livelihood officer in CARE Ethiopia since June 10/2024. He enrolled in the Faculty of Veterinary Medicine, School of Graduate Studies, Hawassa University, to pursue a Master of Science (MSc) degree in Veterinary Epidemiology in October 2021 G.C.