JOURNAL OF CLINICAL CASE STUDIES, REVIEWS & REPORTS
CSK SCIENTIFIC PRESS
Review Article
Volume 2 | issue 2

Bovine Brucellosis: A Zoonotic Disease of Public Health and Economic Concern in Ethiopia

Bekiyad Shasho Daro[*1], Yared Adisu Deneke[2], and Jiregna Gari Negasa[3]

[*1]*Department of Veterinary Epidemiology, College of Veterinary Medicine, Haramaya University, P.O. Box-138, Dire Dawa, Ethiopia*
[2]*Department of Veterinary Public Health, College of Veterinary Medicine, Haramaya University, P.O. Box-138, Dire Dawa, Ethiopia*
[3]*Department of Veterinary Microbiology, College of Veterinary Medicine, Ambo University, P.O. Box-19, Ambo, Ethiopia*

[*]**Corresponding Author:** Bekiyad Shasho Daro, Department of Veterinary Epidemiology, College of Veterinary Medicine, Haramaya University, P.O. Box-138, Dire Dawa, Ethiopia. ORCID iD: http://orcid.org/0000-0001-5060-2657

Submitted: 29 Jan 2024 **Accepted:** 05 Feb 2024 **Published:** 10 Feb 2024

Citation: *Bekiyad Shasho Daro, Yared Adisu Deneke, and Jiregna Gari Negasa (2024). Bovine Brucellosis: A Zoonotic Disease of Public Health and Economic Concern in Ethiopia. J of Clin Case Stu, Reviews & Reports 2(2), 1-8.*

Abstract
Bovine brucellosis is a bacterial disease that affects cattle and other animals; the main species of bacteria causing this disease are Brucella abortus and Brucella melitensis. The objective of this appraisal is to articulate the epidemiology, molecular characteristics, and socio-economic importance of bovine brucellosis. It is one of the most widespread zoonoses transmitted by animals which can bring about a serious public health and economic consequences acting as a constraint to livestock production in low-income countries like Ethiopia. The global and regional distribution of bovine brucellosis varies depending on the prevalence of infection in animals, the control measures implemented, the surveillance systems, the environmental factors and the human behavior. Consumption of raw dairy products is the most common way of the disease transmission. Direct contact, venereal transmission, breast-feeding, and sexual contact are other means of transmission. Previous studies have suggested that the prevalence of the disease in exotic and cross-bred, older animals, female cattle, and cattle that have aborted previously, as compared to indigenous animals, male cattle, and cows that have no abortion history respectively. Signs of the disease vary depending on stage of infection, age and sex of the animal, and the presence of other diseases. Diagnosis can be done by different methods like bacteriological culture, molecular techniques, and serological tests. There are many different species and strains, which can be distinguished by their genetic characteristics. Even if diseased, the treatment is not likely to be recommended; because, it is ineffective, costly, and has a risk of creating antibiotic-resistant strains of Brucella abortus. That is why the prevention and control are based on a combination of measures, such as vaccination, identification, test-and-slaughter, quarantine, biosecurity, and public education. Since there is lack of policies and programs for bovine brucellosis control and eradication in Ethiopia, further researches have to be conducted in order to address these challenges.

Keywords: Bovine Brucellosis, Economic Impact, Public Health Importance, Risk Factors

Introduction

Bovine brucellosis is a bacterial zoonotic disease that affects cattle and humans, causing abortion, infertility, reduced milk production, and other economic losses in livestock, and fever, headache, joint pain, and other chronic symptoms in humans [1]. The disease is caused by Brucella abortus, and occasionally by B. melitensis, which are transmitted through contact with infected animals or their products, such as milk, meat, or placenta. Bovine brucellosis is considered the world's most common bacterial zoonosis and one of the top five priority zoonotic diseases in Ethiopia [2].

Ethiopia has one of the largest cattle populations in Africa, with an estimated 60.39 million heads in 2018 [3]. However, the productivity and profitability of the livestock sector are hampered by various factors, including infectious diseases such as bovine brucellosis. Previous studies have reported variable prevalence rates of bovine brucellosis in different regions of Ethiopia, ranging from 0.06% to 18.9%. The disease is endemic and widely distributed in the country, especially in pastoral and agro-pastoral areas where cattle are kept together with small ruminants or camels that may harbor B. melitensis. Moreover, the lack of adequate diagnostic facilities, vaccination programs, public awareness, and control measures contribute to the persistence and spread of the disease [4].

Livestock production is one of the main sources of income and livelihood for the people in the zone [5]. However, there is limited information on the status of bovine brucellosis and its public health significance in Ethiopia. The findings of previous studies may provide baseline data for designing and implementing appropriate interventions to prevent and control bovine brucellosis and protect animal and human health [6,7].

A bacterial disease caused by Brucella abortus that mainly affects cattle, water buffalo, and bison. It can cause abortion, birth of stillborn or weak calves, retained placenta, and reduced milk production in infected animals. It can also be transmitted to humans through direct contact with infected animals or consumption of contaminated animal products. The frequency of individuals in a population who test positive for a specific disease based on serology (blood serum) specimens [8]. It often reflects the level of exposure or immunity to a pathogen in a population. The determination of the genetic characteristics of an organism or a pathogen using molecular techniques such as DNA sequencing, PCR, or hybridization. It can help identify the species, strain, or genotype of the organism or pathogen and reveal its phylogenetic relationships, genetic diversity, or evolutionary history. Something that increases the risk or susceptibility of an individual or a population to a disease or an adverse outcome. Risk factors can be biological, environmental, behavioral, or social. For example, age, breed, sex, herd size, management practices, and vaccination status are some of the risk factors for bovine brucellosis [9].

The bacteria can be transmitted to humans through contact with infected animals or their secretions, or through consumption of contaminated, unpasteurized dairy products. Human brucellosis can cause fever, fatigue, joint pain, sweating, enlarged liver and spleen, and complications in pregnant women [2]. According to a study by, globally, 500000 cases of human brucellosis are reported annually [1]. The prevalence of human brucellosis differs between areas and has been reported to vary with standards of personal and environmental hygiene, animal husbandry practices, and species of the causative agent and local methods of food processing. In Ethiopia, human brucellosis is considered an underreported and neglected disease due to lack of awareness, diagnostic facilities, and effective control measures [10].

Brucellosis is a bacterial disease that affects various animal species, especially cattle, and can cause serious economic losses and public health risks. In Ethiopia, bovine brucellosis is endemic and poses a threat to the livestock sector and the rural livelihoods. However, there is limited information on the Seroprevalence, molecular characterization and risk factors for bovine brucellosis in different regions of the country. Therefore, the objective of this paper is:

- To review on the epidemiology, molecular characteristics and socio-economic impact of bovine brucellosis and
- To assess the existing policies and programs for control and eradication of bovine brucellosis.

Epidemiology of Bovine Brucellosis

Bovine brucellosis is a bacterial disease that affects cattle and other animals. It can also be transmitted to humans through direct contact with infected animals or their products, such as milk and cheese. Brucellosis is found globally and is a public health concern in many countries. The main species of bacteria causing bovine brucellosis are Brucella abortus and Brucella melitensis [11].

The Global and Regional Distribution and its Prevalence

Bovine brucellosis is a bacterial disease caused by Brucella abortus, which mainly infects cattle and causes abortions or reproductive failure. The disease is one of the most widespread zoonoses transmitted by animals and has serious public health and economic consequences. The global and regional distribution of bovine brucellosis varies depending on the prevalence of infection in animals, the control measures implemented, the surveillance systems, the environmental factors and the human behavior [12]. According to the World Organization for Animal Health (WOAH), bovine brucellosis is found in all continents except Antarctica, but it is more prevalent in some regions than others. The highest incidence is observed in the Middle East, the Mediterranean region, sub-Saharan Africa, China, India, Peru, and Mexico. Currently, countries in central and southwest Asia are seeing the greatest increase in cases [13].

In Africa, bovine brucellosis is endemic in most countries and poses a major threat to livestock production and public health [14]. The disease is often underreported due to the lack of diagnostic facilities, awareness and political will. In Ethiopia, bovine brucellosis has been reported in different regions and agro-ecological zones, with Seroprevalence ranging from 0.8% to 8.8%. The risk factors for bovine brucellosis in Ethiopia include herd size, breed, age, sex, abortion history, grazing system, contact with wildlife and consumption of raw milk [15].

The Main Transmission Routes and Risk Factors

The most common way to be infected is by eating or drinking unpasteurized/raw dairy products. When sheep, goats, cows, or camels are infected, their milk becomes contaminated with the bacteria. If the milk from infected animals is not pasteurized, the infection will be transmitted to people who consume the milk and/or cheese products [16]. Breathing in the bacteria that causes brucellosis may also lead to infection. This risk is generally greater for people in laboratories that work with the bacteria. In addition, slaughterhouse and meat-packing employees have also been known to be exposed to the bacteria and ultimately become infected [17].

Bacteria can also enter wounds in the skin/mucous membranes through contact with infected animals. This poses a problem for workers who have close contact with animals or animal excretions (newborn animals, fetuses, and excretions that may result from birth). Such workers may include, slaughterhouse workers, meat-packing plant employees, veterinarians [12]. People who hunt animals may also be at risk. When they are in contact with infected animals, exposure to the bacteria may occur through skin wounds, accidentally ingesting undercooked meat, or inhaling the bacteria while dressing their game. Commonly infected animals include: bison, elk, caribou, moose and wild hogs [18].

Venereal transmission by infected bulls to susceptible cows appears to be rare. Transmission may occur via artificial insemination when Brucella-contaminated semen is deposited in the uterus; however, apparently, not when deposited in the midcervix. Person-to-person spread of brucellosis is extremely rare. Infected mothers who are breast-feeding may transmit the infection to their infants. Sexual transmission has been rarely reported. While uncommon, transmission may also occur via tissue transplantation or blood transfusions [19].

The prevalence of the disease in exotic and cross-bred animals is higher than in indigenous cattle. The prevalence of the disease increases with age as older animals have more exposure to the infection. Female cattle are more susceptible to the infection than the male ones due to reproductive hormones and abortion events. Cattle that have aborted previously are more likely to be infected than those that have not [20]. Larger farms with poor hygiene and biosecurity practices are more prone to the infection than smaller farms with better management. Cattle that are frequently moved or mixed with other herds are more likely to be exposed to the infection than those that are isolated [21].

Clinical Signs and Diagnosis

The clinical signs of bovine brucellosis vary depending on the stage of infection, the age and sex of the animal, and the presence of other diseases. The most common signs are abortion (usually in the last trimester of pregnancy), retained placenta, metritis, orchitis, epididymitis, and arthritis. However, some infected animals may show no signs or only mild signs of infection, making the diagnosis difficult [22].

The diagnosis of bovine brucellosis can be done by using different methods, such as bacteriological culture, molecular techniques, and serological tests. Bacteriological culture is the gold standard method for confirming the presence of Brucella abortus in samples such as milk, blood, aborted fetuses, or tissues. However, this method is time-consuming, labor-intensive, and requires biosafety level-3 facilities [23]. Molecular techniques, such as polymerase chain reaction (PCR), can detect the DNA of Brucella abortus in samples with high sensitivity and specificity. However, these techniques are also expensive and require specialized equipment and trained personnel. Serological tests are the most widely used methods for screening and surveillance of bovine brucellosis. These tests detect antibodies against Brucella abortus in serum samples using different antigens and formats [9]. Some of the commonly used serological tests are the Rose Bengal Plate Test (RBPT), the complement fixation test (CFT), the enzyme-linked immunosorbent assay (ELISA), and the fluorescence polarization assay (FPA). However, these tests have some limitations, such as cross-reactivity with other bacteria, lack of standardization, and interference by vaccination [24].

Treatment and Prevention

The treatment of bovine brucellosis is not recommended because it is ineffective, costly, and poses a risk of creating antibiotic-resistant strains of Brucella abortus. Moreover, treated animals may still remain as carriers and shedders of the bacteria [25]. Therefore, the prevention and control of bovine brucellosis are based on a combination of measures, such as vaccination, identification, testing, culling, quarantine, biosecurity, and public education. Vaccination is one of the most important tools for reducing the prevalence and incidence of bovine brucellosis in endemic areas. The most commonly used vaccines are live attenuated strains of Brucella abortus, such as strain 19 and RB51. These vaccines induce protective immunity in cattle by stimulating both humoral and cellular responses. However, these vaccines also have some drawbacks, such as causing abortion in pregnant animals, inducing antibodies that interfere with serological diagnosis, and being potentially infectious to humans [6].

Identification and testing are essential for detecting infected animals and tracing their contacts. Culling is the removal of infected animals from the herd to prevent further transmission and contamination. Quarantine is the isolation of new or suspect animals until they are proven to be free of infection [26]. Biosecurity is the implementation of hygienic practices to prevent the introduction or spread of infection within or between herds. Public education is the dissemination of information and awareness about bovine brucellosis to farmers, veterinarians, consumers, and other stakeholders to promote compliance with prevention and control measures [27].

Molecular Characterization of Bovine Brucellosis

Genetic Diversity and Evolution of Brucella Species and Strains
Brucella has many different species and strains, which can be distinguished by their genetic characteristics. Some of these genetic characteristics are single nucleotide polymorphisms (SNPs), which are variations in the DNA sequence of a gene. SNPs can be used to trace the evolutionary history and geographic origin of Brucella species and strains [28]. One of the main methods to study the genetic diversity and evolution of Brucella is whole genome sequencing (WGS), which is the process of determining the complete DNA sequence of an organism's genome. WGS can reveal the SNPs and other genetic features of Brucella, such as genes, plasmids, insertion sequences, and genomic islands. WGS can also help to identify new or atypical Brucella strains that do not fit into the typical classification based on phenotypic or serological tests [29].

Some studies have used WGS to analyze the global evolution and phylogeography of Brucella melitensis, the most common cause of human brucellosis. For example, performed an analysis of the SNP of the complete genomes of 98 B. melitensis strains isolated in different regions of the world [30]. They identified five main genotypes and 13 subgenotypes of B. melitensis, and determined their regions of origin and pathways of distribution. They also found that some subgenotypes were associated with specific hosts, such as sheep, goats, or camels [31].

Another example is, who focused on the Brucellaceae family, which includes Brucella and other related genera, such as Ochrobactrum and Pseudochrobactrum [32]. They compared 145 Brucellaceae genomes with over 40 others from the wider order Rhizobiales to resolve phylogenetic ambiguities. They showed that Brucella is a monophyletic group within the Ochrobactrum diversity, and that Ochrobactrum itself is polyphyletic, splitting into two clades. They also recognized substantial unindexed diversity in Ochrobactrum spp. and Pseudochrobactrum spp. These studies demonstrate how WGS can provide valuable insights into the genetic diversity and evolution of Brucella species and strains, as well as their relationships with other members of the Brucellaceae family. This knowledge can help to improve the diagnosis, prevention, and control of brucellosis in animals and humans [29].

Advantages and Limitations of Different Molecular Techniques for Typing and Identifying Brucella Isolates

16S rRNA gene sequencing is based on the amplification and sequencing of a highly conserved region of the bacterial 16S rRNA gene. It can provide accurate identification of Brucella species and subspecies, as well as phylogenetic analysis. However, it is relatively expensive, time-consuming, and requires specialized equipment and expertise [33]. Real-time PCR can provide rapid and sensitive identification of Brucella species and subspecies, as well as quantification of bacterial load. However, it is also costly, requires specific primers and probes, and may be affected by PCR inhibitors or cross-contamination [34].

Enterobacterial repetitive intergenic consensus (ERIC) PCR can provide high-resolution typing of Brucella isolates, as well as epidemiological analysis and outbreak investigation. However, it is technically demanding, prone to variability and reproducibility issues, and may not discriminate between closely related strains [35]. The amplification and analysis of multiple loci containing variable-number tandem-repeats (VNTRs), which are short DNA sequences repeated in tandem, can provide high discriminatory power, stability, and evolutionary insight for Brucella typing. However, it is labor-intensive, requires standardized protocols and databases, and may not reflect the true phylogeny of Brucella [36].

The Current Knowledge and Challenges of Molecular Epidemiology of Bovine Brucellosis

Bovine brucellosis is a zoonotic infection caused by bacteria of the genus Brucella, mainly Brucella abortus, that affects cattle and other domestic and wild animals. It is a major public health problem and a cause of economic losses in many countries, especially in developing regions [20]. Molecular epidemiology of bovine brucellosis is the study of the genetic diversity, evolution, transmission, and population structure of Brucella strains isolated from cattle and other hosts. It can provide insights into the origin, spread, and control of the disease [37].

Molecular typing methods, such as multilocus variable-number tandem-repeat analysis (MLVA), multilocus sequence analysis (MLSA), single nucleotide polymorphism (SNP) typing, and whole genome sequencing (WGS), have been used to characterize Brucella strains from different geographic regions, animal species, and sources of infection [30]. These methods have revealed a high genetic diversity and variability of Brucella strains within and between countries, reflecting the complex epidemiology and ecology of the disease [38].

Molecular epidemiology has also identified the emergence and dissemination of new Brucella variants, such as biovars 5b and 6 in Europe, biovar 3b in Africa, and biovar 1 in Asia, that pose new challenges for diagnosis and control; and has also contributed to the understanding of the transmission dynamics and risk factors of bovine brucellosis, such as animal movement, trade, husbandry practices, wildlife reservoirs, and human activities [39,18].

However, molecular epidemiology of bovine brucellosis also faces some limitations and difficulties, such as the lack of standardized and harmonized typing methods and databases, the limited availability and accessibility of molecular data from endemic areas, the need for more representative and comprehensive sampling strategies, and the integration of molecular data with epidemiological, clinical, and environmental information [40]. Therefore, molecular epidemiology of bovine brucellosis is a valuable tool for improving the surveillance, prevention, and control of the disease, but it requires further development and application in different settings and contexts.

Bovine Brucellosis in Ethiopian Perspective

Bovine brucellosis a major public health problem and a constraint to livestock production in Ethiopia. The epidemiological situation and trends of bovine brucellosis in Ethiopia are influenced by various factors, such as the management system, the breed of cattle, the diagnostic methods, the geographical location, and the environmental conditions. According to the prevalence of bovine brucellosis in Ethiopia ranges from 1.2% to 22.5% at the individual level, and from 3.3% to 68.6% at the herd level [6]. The disease is more common in pastoral and mixed farming systems, where cattle are kept in close contact with humans and other animals. The exotic and cross-bred cattle are more susceptible to brucellosis than the local breeds, because they have lower immunity and higher reproductive performance [27]. The disease causes abortion, infertility, reduced milk production, and decreased weight gain in cattle, resulting in significant economic losses [41].

The diagnosis of bovine brucellosis is challenging, because the clinical signs are not specific and the laboratory tests are not standardized or widely available. The most commonly used diagnostic methods in Ethiopia are the Rose Bengal Plate Test (RBPT) and the Complement Fixation Test (CFT), which have different sensitivities and specificities [42]. Molecular techniques, such as polymerase chain reaction (PCR), are more accurate and reliable, but they require sophisticated equipment and trained personnel [24]. Therefore, there is a need for rapid, simple, and cost-effective diagnostic tools that can be applied in field settings.

The distribution of bovine brucellosis in Ethiopia varies according to the geographical regions and climatic conditions. The disease is more prevalent in lowland areas than in highland areas, because of the higher temperature and humidity that favor the survival of Brucella organisms [43]. The disease is also influenced by seasonal factors, such as rainfall, drought, and migration of animals [44]. The risk factors for bovine brucellosis include the herd size, the sex and age of cattle, the history of abortion, the contact with wildlife, and the consumption of raw milk or milk products [45].

The public health implications of bovine brucellosis in Ethiopia are serious, because humans can acquire the infection through direct or indirect contact with infected cattle or their products. The symptoms of human brucellosis include fever, headache, joint pain, fatigue, and enlarged spleen or liver [18]. The disease can also cause chronic complications, such as endocarditis, arthritis, osteomyelitis, meningitis, or orchitis [46]. The treatment of human brucellosis requires prolonged antibiotic therapy, which can be expensive and have adverse effects. The prevention and control of human brucellosis depends on the control of bovine brucellosis [47]. Therefore, based on this analysis, it can be concluded that there is a need for further research on the seroprevalence, molecular characterization, and risk factors for bovine brucellosis in different regions of Ethiopia.

The Socio-Economic Impact and Public Health Implications

The socio-economic impact and public health implications of bovine brucellosis in Ethiopia can be evaluated based on the prevalence and distribution of the disease in different regions, agro-ecological zones, and livestock production systems [12]. This can help to estimate the burden of the disease on the livestock sector and identify the high-risk areas for transmission and control interventions. The molecular characterization and genetic diversity of Brucella strains can help to understand the epidemiology, evolution, and transmission dynamics of the disease, as well as to develop appropriate diagnostic tools and vaccines. The risk factors associated with the disease in cattle and humans can help to identify the main sources and routes of exposure, as well as the potential risk groups and behaviors that facilitate the spread of the disease [48].

The clinical manifestations, diagnosis, treatment, and prevention of bovine brucellosis in cattle and humans can help to assess the health impact of the disease on both animal and human populations, as well as to evaluate the effectiveness and feasibility of existing or novel control strategies [49]. The economic losses and social consequences can also help to quantify the direct and indirect costs of the disease on the livestock industry, human health, food security, and livelihoods of affected communities [34].

The Existing Policies and Programs for Control and Eradication
The goal of bovine brucellosis control and eradication is to prevent or eliminate the disease from domestic cattle and other susceptible animals. Different countries have different policies and programs for achieving this goal, depending on the prevalence, distribution, and impact of the disease in their regions. Some of the common strategies include, surveillance and reporting, vaccination, diagnostic testing and laboratory services, test-and-slaughter policy, education and awareness, and the socio-cultural and economic factors [41].

Surveillance and reporting involve testing animals for brucellosis infection, tracing the source and contacts of infected animals, reporting the results to the authorities, and maintaining a database of the disease situation [50]. Surveillance and reporting are essential tools for monitoring the progress of control and eradication efforts, identifying high-risk areas, and implementing appropriate interventions in Brucella infection [51].

Vaccination involves immunizing animals with a vaccine that protects them from brucellosis infection or reduces the severity of the disease. Vaccination can be compulsory or voluntary, depending on the level of risk and the availability of resources which can reduce the incidence and transmission of bovine brucellosis, but it cannot eliminate the disease completely [52]. Vaccinated animals should be identified with a tag or a mark to distinguish them from unvaccinated ones.

Diagnostic testing is necessary for confirming the diagnosis of suspected cases, screening animals for trade or movement, evaluating the effectiveness of vaccination programs, and verifying the absence of infection in eradication areas [53]. Test-and-slaughter policy involves culling animals that test positive for brucellosis infection, as well as their contacts or offspring. It is aimed at removing the source of infection from the population and preventing further spread of the disease [54]. Test-and-slaughter policy should be accompanied by compensation for the owners of culled animals, as well as disinfection of contaminated premises.

Education and awareness involve informing and educating farmers, consumers, health workers, and other stakeholders about bovine brucellosis, its causes, symptoms, transmission, prevention, control, and eradication. This can increase the knowledge and understanding of the disease, improve the compliance and cooperation with control and eradication measures, reduce the risk behaviors and practices that facilitate the spread of the disease, and promote the adoption of good animal husbandry and hygiene practices [55].

Socio-cultural and economic factors involve considering the social, cultural, economic, and environmental factors that influence the behavior and practices of livestock owners and consumers regarding bovine brucellosis. These factors can affect the acceptance, feasibility, sustainability, and effectiveness of control and eradication programs [2]. Low awareness and knowledge of the disease among farmers and consumers, lack of access to diagnostic tests and laboratories, high cost and low availability of vaccines; inadequate compensation for culled animals, poor enforcement of quarantine and movement restrictions; traditional customs such as raw milk consumption or animal sharing, poverty and food insecurity that limit the adoption of preventive measures, plus weak coordination and collaboration among different sectors involved in animal health are among some of the factors that may hinder bovine brucellosis control and eradication in Ethiopia [4].

Conclusion and Recommendations

Bovine brucellosis is a serious zoonotic disease that affects cattle and other animals, as well as humans. It has a global and regional distribution, and it can cause significant economic losses and public health risks in Ethiopia. The disease is transmitted by various routes, such as consumption of unpasteurized dairy products, direct contact, venereal transmission, breast-feeding, and sexual contact. The diagnosis can be done by different methods, such as bacteriological culture, molecular techniques, and serological tests. The treatment is not recommended due to its ineffectiveness, costliness, and risk of creating antibiotic-resistant strains of Brucella abortus. Therefore, prevention and control measures are essential to eradicate the disease from Ethiopia. Based on the above conclusion, we can recommend the following actions to address the problem:

- Strengthening the surveillance systems for bovine brucellosis at national and local levels.
- Implementing effective vaccination programs for cattle and other animals at risk.
- Improving the identification and testing of infected animals through test-and-slaughter schemes.
- Enhancing the quarantine and biosecurity measures to prevent the spread of the disease within and between farms.
- Raising public awareness about the signs, symptoms, transmission modes, prevention strategies, and treatment options of bovine brucellosis.
- Developing policies and programs for bovine brucellosis control and eradication in Ethiopia.

References

1. Franc K A, Krecek R C, Häsler B N, Arenas-Gamboa A M (2018) Brucellosis remains a neglected disease in the developing world: a call for interdisciplinary action. BMC public health 18: 1-9.
2. Mersha T T, Mekonnen Wolde B, Shumuye N A, Hailu A B, Mohammed A H, et al. (2021) Prioritization of neglected tropical zoonotic diseases: A one health perspective from Tigray region, Northern Ethiopia. PLoS One 16: e0254071.
3. Endale Y, Nibo B, Million T, Ulfina G, Lemma F, et al. (2021) Current Status of Artificial Insemination Delivery Services at Smallholder Dairy Farmers in Ethiopia. Livestock Research Results 297.
4. Kumsa T Z, Borena B M, Derib B T, Gichile A G, Marami L M (2023) Bovine brucellosis: seroprevalence, risk factors and assessment of knowledge, attitude, and practice of cattle owners in Lare and Jikawo districts of Gambella region, Ethiopia. bioRxiv doi: https://doi.org/10.1101/2023.01.26.525782.
5. Mitiku H, Jimma W, Diriba C (2016) Managing Indigenous Knowledge for Corrective and Preventive Cares: The Case of Horro Guduru Wollega Zone, Oromia, Ethiopia. Universal Journal of Public Health 4: 212-217.
6. Erkyihun G A, Gari F R, Kassa G M (2022) Bovine brucellosis and its public health significance in Ethiopia. Zoonoses 2.
7. Zelalem Z (2021) Worsening violence in western Ethiopia forcing civilians to flee. Al Jazeera.
8. Abubakar M, Mansoor M, Arshed M J (2012) Bovine Brucellosis: Old and New Concepts with Pakistan Perspective. Pakistan Veterinary Journal 32: 499-502.
9. Legesse A, Mekuriaw A, Gelaye E, Abayneh T, Getachew B, et al. (2023) Comparative evaluation of RBPT, I-ELISA, and CFT for the diagnosis of brucellosis and PCR detection of Brucella species from Ethiopian sheep, goats, and cattle sera. BMC microbiology 23: 1-8.
10. Pal M, Gizaw F, Fekadu G, Alemayehu G, Kandi V (2017). Public health and economic importance of bovine Brucellosis: an overview. Am J Epidemiol 5: 27-34.
11. Jamil T, Khan A U, Saqib M, Hussain M H, Melzer F, et al. (2021) Animal and human brucellosis in Pakistan. Frontiers in public health 9: 660508.
12. Tulu D (2022) Bovine brucellosis: epidemiology, public health implications, and status of brucellosis in Ethiopia. Veterinary Medicine: Research and Reports 13: 21-30.
13. Zinsstag J, Kaiser-Grolimund A, Heitz-Tokpa K, Sreedharan R, Lubroth J, et al. (2023) Advancing One human–animal–environment Health for global health security: what does the evidence say? The Lancet 401: 591-604.
14. Qiu Y, Guitian J, Webster J P, Musallam I, Haider N, et al. (2023) Global prioritization of endemic zoonotic diseases for conducting surveillance in domestic animals to protect public health. Philosophical Transactions of the Royal Society B 378: 20220407.
15. Megersa B, Biffa D, Niguse F, Rufael T, Asmare K, et al. (2011) Cattle brucellosis in traditional livestock husbandry practice in Southern and Eastern Ethiopia, and its zoonotic implication. Acta Veterinaria Scandinavica 53: 1-8.
16. Majzobi M M, Karami P, Khodavirdipour A, Alikhani M Y (2022) Brucellosis in humans with the approach of brucella species contamination in unpasteurized milk and dairy products from Hamadan, Iran. Iranian Journal of Medical Microbiology 16: 282-287.
17. Adeniyi P O, Anam B E (2023) Bacterial Zoonotic Diseases: A Public Health Nutrition Perspective and Policy Implication in Nigeria. World Journal of Public Health 8: 220.
18. Berhanu G, Pal M (2020) Brucellosis: A highly infectious zoonosis of public health and economic importance. Journal of Emerging Environmental Technologies and Health Protection 3: 5-9.
19. Hussen A H, Nigussie Z, Agonafir A (2020) Review on Bovine Brucellosis and its Current Status in Ethiopia. J Vet Marine Sci 3: 164-172.
20. Khan A U, Melzer F, Hendam A, Sayour A E, Khan I, et al. (2020a) Seroprevalence and Molecular Identification of Brucella spp. in Bovines in Pakistan—Investigating Association with Risk Factors Using Machine Learning. Frontiers in Veterinary Science 7: 594498.
21. Vinueza R L, Durand B, Ortega F, Salas F, Ferreira Vicente A, et al. (2023) Farm Prevalence of Bovine Brucellosis, Farmer Awareness, and Local Practices in Small-and Medium-Scale Cattle Farms in a Tropical Region of Ecuador. Transboundary and Emerging Diseases https://doi.org/10.1155/2023/6242561.
22. Robi D T (2020) Epidemiology, economic and public health importance of small ruminant Brucella infection in Ethiopia. World J Vet Sci 2: 1007.
23. Mengele I J, Shirima G M, Bronsvoort B M, Hernandez-Castro L E, Cook E A (2023) Diagnostic challenges of brucellosis in humans and livestock in Tanzania: A thematic review. CABIOneHealthohcs20230001. file:///C:/Users/slv/Desktop/Diagnostic_challenges_of_brucellosis_in_humans_and.pdf
24. ur Rahman M, Ullah A, Haroon H, Bilal M, Khan F M, et al. (2019) Serological and Molecular Techniques for the Diagnostic of Brucellosis. VNUHCM Journal of Science and

Technology Development 22: 400-408.
25. Khan U D, Khan A, Gul S T, Saleemi M K, Du X X (2020b) Seroprevalence of brucellosis in cattle (Bos taurus) kept in peri urban areas of Pakistan. Agrobiological Records 1: 6-10.
26. Gemechu R (2017). Brucellosis and its control through One Health approaches in Ethiopia. Journal of Veterinary Medical Research 4: 1080.
27. Nyokabi N S, Berg S, Mihret A, Almaw G, Worku G G, et al. (2023a) Adoption of Biosecurity Practices in Smallholder Dairy Farms in Ethiopia. Transboundary and Emerging Diseases https://doi.org/10.1155/2023/2277409.
28. Tevdoradze E, Farlow J, Kotorashvili A, Skhirtladze N, Antadze I, et al. (2015) Whole genome sequence comparison of ten diagnostic Brucella phages propagated on two Brucella abortus hosts. Virology journal 12: 1-11.
29. Cloeckaert A, Zygmunt M S, Scholz H C, Vizcaino N, Whatmore A M (2021) Pathogenomics of the genus Brucella and beyond. Frontiers in Microbiology 12: 700734.
30. Pisarenko S V, Kovalev D A, Volynkina A S, Ponomarenko D G, Rusanova D V, et al. (2018) Global evolution and phylogeography of Brucella melitensis strains. BMC genomics 19: 1-10.
31. Tekle M, Legesse M, Edao B M, Ameni G, Mamo G (2019). Isolation and identification of Brucella melitensis using bacteriological and molecular tools from aborted goats in the Afar region of north-eastern Ethiopia. BMC microbiology 19: 1-6.
32. Ashford R T, Muchowski J, Koylass M, Scholz H C, Whatmore A M (2020) Application of whole genome sequencing and pan-family multi-locus sequence analysis to characterize relationships within the family Brucellaceae. Frontiers in Microbiology 11: 1329.
33. Katsiolis A, Papadopoulos D K, Giantsis I A, Papageorgiou K, Zdragas A, et al. (2022). Brucella spp. distribution, hosting ruminants from Greece, applying various molecular identification techniques. BMC Veterinary Research 18: 1-9.
34. Edao B M (2020) Brucellosis in Ethiopia: Epidemiology and public health significance (Doctoral dissertation, University of Cambridge) https://www.frontiersin.org/articles/10.3389/fmicb.2023.1128966/full.
35. Amoupour M, Nezamzadeh F, Bialvaei A Z, Sedighi M, Jazi F M, et al. (2019). Differentiation of Brucella abortus and B. melitensis biovars using PCR-RFLP and REP-PCR. New microbes and new infections 32: 100589.
36. Saavedra M J, Fernandes C, Queiroga C (2019) Laboratory diagnosis of brucellosis. Brucellosis in Goats and Sheep: an endemic and re-emerging old zoonosis in the 21st century 151-180.
37. Dadar M, Brangsch H, Alamian S, Neubauer H, Wareth G (2023) Whole-genome sequencing for genetic diversity analysis of Iranian Brucella spp. isolated from humans and livestock. One Health 16: 100483.
38. Ali S, Akhter S, Khan I, Ahmed H, Maalik A, et al. (2019) Molecular Typing of Brucella abortus Strains Isolated from cattle in different districts of Pakistan based on Bruce-Ladder-PCR and MLVA-16 Assays. Pak Vet J 39: 463-465.
39. Whatmore A M, Foster J T (2021) Emerging diversity and ongoing expansion of the genus Brucella. Infection, Genetics and Evolution 92: 104865.
40. Edao B M, Ameni G, Berg S, Tekle M, Whatmore A M, et al. (2023) Whole genome sequencing of Ethiopian Brucella abortus isolates expands the known diversity of an early branching sub-Saharan African lineage. Frontiers in Microbiology 14: 1128966.
41. Etefa M, Kabeta T, Merga D, Debelo M (2022) Cross-sectional study of seroprevalence and associated risk factors of bovine brucellosis in selected districts of Jimma zone, south western Oromia, Ethiopia. BioMed Research International 9549942. DOI: 10.1155/2022/9549942
42. Robi D T, Gelalcha B D (2020) Epidemiological investigation of brucellosis in breeding female cattle under the traditional production system of Jimma zone in Ethiopia. Veterinary and animal science 9: 100117.
43. Deresa B, Tulu D, Deressa F B (2020) Epidemiological investigation of cattle abortion and its association with brucellosis in Jimma zone, Ethiopia. Veterinary Medicine: Research and Reports 87-98.
44. Gizaw S, Desta H, Alemu B, Tegegne A, Wieland B (2020) Importance of livestock diseases identified using participatory epidemiology in the highlands of Ethiopia. Tropical Animal Health and Production 52: 1745-1757.
45. Chaka H, Aboset G, Garoma A, Gumi B, Thys E (2018) Cross-sectional survey of brucellosis and associated risk factors in the livestock–wildlife interface area of Nechisar National Park, Ethiopia. Tropical animal health and production 50: 1041-1049.
46. Kung'u M M (2021) Factors associated with brucellosis among patients attending selected hospitals in Kajiado County, Kenya (Doctoral dissertation, JKUAT-COHES) http://ir.jkuat.ac.ke/bitstream/handle/123456789/5437/Muturi%2c%20M.%20MSc%20Applied%20epidemiology%202020.pdf?sequence=1&isAllowed=y
47. Ducrotoy M, Bertu W J, Matope G, Cadmus S, Conde-Álvarez R, et al. (2017). Brucellosis in Sub-Saharan Africa: Current challenges for management, diagnosis and control. Acta tropica 165: 179-193.
48. Govindasamy K, Etter E M, Harris B N, Rossouw J, Abernethy D A, et al. (2021) Knowledge of brucellosis, health-seeking behaviour, and risk factors for Brucella infection amongst workers on cattle farms in Gauteng, South Africa. Pathogens 10: 1484.
49. Mligo B J, Sindato C, Yapi R B, Mathew C, Mkupasi E M, et al. (2022) Knowledge, attitude and practices of frontline health workers in relation to detection of brucellosis in rural settings of Tanzania: a cross-sectional study. One health outlook 4: 1.
50. Nyokabi N S, Moore H, Berg S, Lindahl J, Phelan L, et al. (2023b) Implementing a one health approach to strengthen the management of zoonoses in Ethiopia. One Health 16: 100521.
51. Moriyón Uria I, Blasco Martínez J M, Letesson J J, De Massis F, Moreno E (2023) Brucellosis and One Health: Inherited and Future Challenges 11: 2070. doi: 10.3390/microorganisms11082070.

52. Carpenter A, Waltenburg M A, Hall A, Kile J, Killerby M, et al . (2022)Vaccine Preventable Zoonotic Disease Working Group. Vaccine preventable zoonotic diseases: challenges and opportunities for public health progress. Vaccines 10: 993.
53. Mequanent A (2022) Advancing for diagnoses of brucellosis and therapeutic approach in Ethiopia. Life Science Journal 19.
54. Fekadu Gutema Wegi, Kebede Amenu, Adugna Chalchisa, Gezahegne Mamo (2020) Brucellosis in cattle, camel and human: seroprevalence and associated risk factors in Amibara district of Afar Region, Ethiopia (Doctoral dissertation, Addis Ababa University) 5482725. doi: 10.1155/2021/5482725.
55. Getahun T K, Urge B, Mamo G (2022) Seroprevalence of human brucellosis in selected sites of Central Oromia, Ethiopia. PLoS One 17: e0269929.