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The significance of laboratory diagnostics in animal health in Ethiopia: A review of current practices

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Abstract

Animal health is crucial for Ethiopia's economy and food security, yet it faces disease challenges. Effective control relies on timely laboratory diagnostics. This review examines the role of diagnostics in Ethiopia's animal health, assessing current practices, challenges, and innovative technologies. It evaluates diagnostic infrastructure, human resources, and veterinary lab tests. While traditional methods remain important, there is a shift towards advanced molecular, serological, and point-of-care diagnostics, supported by international partnerships and the One Health approach. The review highlights issues like inadequate funding, outdated equipment, supply chain inefficiencies, and limited access in remote areas. It concludes with recommendations to enhance Ethiopia's animal health diagnostics, focusing on infrastructure investment, human capital development, standardization, technology integration, and improved collaboration for a resilient system.

Keywords: Laboratory diagnostics, animal health, ethiopia, current practices, disease surveillance, one health

1. Introduction

Ethiopia has Africa's largest livestock population, with about 65 million cattle, 39 million sheep, 32 million goats, and many camels, equines, and poultry (CSA, 2021) ^[13]. This vast resource is crucial to the economy, contributing 16.5% to the national GDP and 35.6% to agricultural GDP, while supporting over 80% of the rural population (FAO, 2020a; MoA, 2019) ^[25, 47]. Livestock also play a key role in food security, providing meat, milk, and eggs, as well as draught power, manure, and hides (Ayele *et al.*, 2017) ^[8]. The livestock sector in Ethiopia has great potential but faces serious challenges from infectious and parasitic diseases, leading to production losses, lower fertility, higher mortality rates, and limited market access (Gizaw *et al.*, 2019; Regassa *et al.*, 2013) ^[74, 52]. Endemic diseases like trypanosomiasis, PPR, FMD, anthrax, bovine tuberculosis, and various parasites are significant threats (Aklilu *et al.*, 2018; Teklemariam *et al.*, 2021; Tarekegn (2023)) ^[5, 60, 31]. Moreover, the emergence of zoonotic diseases that can transfer between animals and humans complicates both animal and public health (Duguma *et al.*, 2019) ^[20]. Reliable laboratory diagnostics are essential for animal health, underpinning effective disease prevention and control by enabling accurate pathogen identification and informing treatment and policy decisions (OIE, 2018) ^[50]. Inadequate diagnostics can intensify disease outbreaks, lead to treatment failures, and compromise surveillance.

This review will examine the role of laboratory diagnostics in Ethiopia's animal health, focusing on current practices, infrastructure, human resources, and available tests. It will also assess the integration of innovations such as molecular diagnostics and point-of-care testing. By identifying challenges and opportunities, this review aims to provide a critical evaluation and recommendations to enhance Ethiopia's diagnostic capabilities, ultimately improving animal productivity, food security, and public health in alignment with the One Health approach.

2. Methodology

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This review paper adopted a systematic approach to synthesize existing literature on animal health laboratory diagnostics in Ethiopia. A comprehensive search was conducted across multiple scholarly databases, including PubMed, Web of Science, Scopus, Google Scholar, and institutional repositories of Ethiopian universities and research centers (e.g., Ethiopian Institute of Agricultural Research-EIAR). Keywords used in various combinations included "animal health," "veterinary diagnostics," "laboratory," "Ethiopia," "current practices," "innovations," "molecular diagnostics," "surveillance," "capacity building," "One Health," "challenges," and specific animal diseases prevalent in Ethiopia.

The search encompassed publications from 2000 to 2023 to capture recent developments while retaining historical context. Inclusion criteria focused on peer-reviewed journal articles, conference proceedings, technical reports from national and international organizations (e.g., FAO, OIE, AU-IBAR), and relevant government policy documents specifically addressing animal health diagnostics in Ethiopia or comparable low-income country settings with transferable insights. Exclusion criteria included opinion pieces, non-empirical studies, and documents not directly relevant to the Ethiopian context or animal health diagnostics.

From 423 open access research articles, 70 were selected for analysis based on their titles and abstracts. Full-text articles were then reviewed for detailed information on diagnostic practices, infrastructure, human resources, techniques, challenges, and technology integration in Ethiopia. Data included laboratory types, diagnostic methods, targeted diseases, limitations, and proposed solutions. The results were qualitatively analyzed to identify common themes, trends, and gaps, forming the basis for the subsequent sections of this review.

3. The Significance of Laboratory Diagnostics

Laboratory diagnostics are the cornerstone of modern animal health management, providing the scientific basis for control and prevention strategies (OIE, 2018) [50]. Their significance spans various critical areas:

3.1 Accurate Disease Diagnosis and Treatment

The primary function of diagnostic laboratories is to accurately identify the causative agents of animal diseases (e.g., bacteria, viruses, parasites, fungi). This precise identification is crucial for differentiating between diseases with similar clinical signs, guiding appropriate treatment regimens, and preventing the wasteful use of ineffective drugs (Teklemariam *et al.*, 2021) [60]. For instance, differentiating between viral and bacterial respiratory infections in cattle is essential for judicious antibiotic use, combating antimicrobial resistance (AMR) (Shiferaw *et al.*, 2020) [56]. Timely and accurate diagnosis minimizes suffering, reduces mortality, and optimizes the economic viability of livestock operations.

3.2 Epidemiological Surveillance and Early Warning Systems

Laboratory data are vital for epidemiological surveillance, enabling the monitoring of disease incidence, prevalence, and geographical distribution (Ayele *et al.*, 2017) [8]. By collecting and analyzing diagnostic results, veterinary authorities can identify emerging disease threats, track the spread of existing ones, and establish baseline data for endemic diseases. This intelligence is critical for developing early warning systems, allowing for rapid response and containment efforts during outbreaks, thereby preventing widespread economic

devastation (Gizaw *et al.*, 2019) [74]. For example, serological surveys can map the distribution of diseases like FMD or PPR, informing vaccination campaigns (Regassa *et al.*, 2013) [52].

3.3 Antimicrobial Resistance (AMR) Monitoring

The global rise of AMR poses a major threat to both animal and human health (WHO, 2021) [68]. Veterinary diagnostic laboratories play a crucial role in monitoring AMR patterns by conducting antimicrobial susceptibility testing (AST) on bacterial isolates from diseased animals (Shiferaw *et al.*, 2020) [56]. This data informs veterinary practitioners on appropriate antibiotic choices, helps in the development of national guidelines for prudent antimicrobial use, and contributes to global surveillance efforts to mitigate the spread of resistant pathogens (FAO, 2020b) [26]. In Ethiopia, where antibiotic access and prescription can be unregulated, this role is particularly vital (Ketema *et al.*, 2019) [71].

3.4 Trade and Food Safety

Access to international and regional livestock markets often depends on a country's ability to demonstrate freedom from specific animal diseases, or to certify the health status of animals and animal products (OIE, 2018) [50]. Robust diagnostic capacity is essential for issuing health certificates, facilitating safe trade, and ensuring compliance with international sanitary and phytosanitary standards. Furthermore, diagnostics contribute to food safety by identifying pathogens in food animals that could pose a risk to human consumers, such as *Salmonella*, *E. coli* O157:H7, or *Campylobacter* (Duguma *et al.*, 2019) [14, 20]. This protects public health and enhances consumer confidence in animal-derived products.

3.5 Zoonotic Disease Control and One Health

Many animal diseases are zoonotic, meaning they can transmit from animals to humans (e.g., rabies, brucellosis, anthrax, bovine tuberculosis) (Duguma *et al.*, 2019) [20]. Veterinary laboratories are at the forefront of identifying these pathogens in animal reservoirs, providing critical information for public health interventions. This necessitates a "One Health" approach, where veterinary, human health, and environmental sectors collaborate on disease surveillance, diagnosis, and control (Kassa *et al.*, 2020) [38]. By strengthening veterinary diagnostics, Ethiopia can significantly enhance its capacity to detect and respond to zoonotic threats, safeguarding both animal and human populations (Gebreyes *et al.*, 2014) [28].

Overall, these diagnostic instruments are crucial for the prompt identification, efficient management, and prevention of health risks, thereby safeguarding public health and improving global health security.

4. Current Practices in Animal Health Laboratory Diagnostics in Ethiopia

Ethiopia's animal health diagnostic network is structured hierarchically, encompassing national, regional, and district-level laboratories. However, the operational capacity and capabilities vary significantly across these tiers.

4.1 Infrastructure and Facilities

At the apex of the diagnostic network are the National Animal Health Diagnostic and Investigation Center (NAHDIC), located in Sebeta. NAHDIC serves as the national reference

laboratory, responsible for confirmatory testing, specialized diagnostics, quality assurance, and training (MoA, 2019) [47]. It houses relatively more advanced equipment and expertise compared to lower-tier laboratories. Below NAHDIC, several regional veterinary laboratories (e.g., in Mekelle, Bahir Dar, Kombolcha, Gondar, Jimma, Hawassa) provide diagnostic services for their respective regions, often serving as referral centers for district-level facilities (Aklilu *et al.*, 2018) [5]. At the grassroots level, numerous district veterinary clinics or diagnostic posts exist, but their diagnostic capabilities are often rudimentary, limited to basic microscopy and clinical examinations (Gizaw *et al.*, 2019) [74]. A consistent challenge across all levels is the age and maintenance of equipment. Many laboratories operate with outdated machinery, frequently experiencing breakdowns due to a lack of spare parts, technical expertise for repair, and irregular maintenance schedules (Regassa *et al.*, 2013; Teklemariam *et al.*, 2021) [52, 60]. Similarly, infrastructure often suffers from inadequate laboratory space, unreliable power supply, and insufficient biosafety levels, particularly for handling highly pathogenic agents (Shiferaw *et al.*, 2020) [56]. Cold chain integrity, crucial for sample preservation and reagent storage, is often compromised, especially in remote areas (Ketema *et al.*, 2019) [71].

4.2 Human Resources and Capacity

The availability of trained and experienced personnel is a critical determinant of diagnostic capacity. While Ethiopia produces a steady stream of veterinary professionals, the number of specialized laboratory technicians, microbiologists, virologists, and pathologists is insufficient, particularly at regional and district levels (Ayele *et al.*, 2017) [8]. There is a significant brain drain, with skilled professionals often seeking opportunities in urban centers or abroad (Gebreyes *et al.*, 2014) [28]. Furthermore, continuous professional development and specialized training are often lacking. Many laboratory staff receives initial training but have limited opportunities for refresher courses on new techniques, quality management systems, or biosafety protocols (Kassa *et al.*, 2020) [38]. This leads to reliance on traditional methods and difficulties in adopting modern diagnostic innovations. Staff motivation can also be low due to inadequate remuneration, poor working conditions, and limited career progression opportunities (FAO, 2020a) [25].

4.3 Diagnostic Capabilities and Range of Tests

The diagnostic repertoire in Ethiopian veterinary laboratories primarily relies on conventional methods:

- a) **Parasitology:** Light microscopy is widely used for direct examination of fecal, blood, and skin samples to identify helminth eggs, protozoa, and ectoparasites (Abebe *et al.*, 2018) [2]. Though foundational, this method requires skilled technicians and can be labor-intensive.
- b) **Bacteriology:** Culture and isolation techniques are employed for bacterial identification, followed by biochemical tests and antibiotic susceptibility testing (AST) (Shiferaw *et al.*, 2020) [56]. These methods are time-consuming, taking days to weeks for results, which can delay treatment decisions during outbreaks.
- c) **Serology:** Enzyme-Linked Immunosorbent Assays (ELISA) and Agar Gel Immunodiffusion (AGID) tests are used for detecting antibodies or antigens for diseases like Brucellosis, FMD, and PPR (Regassa *et al.*, 2013) [52]. While faster than culture, these tests require specific

reagents and equipment.

- d) **Virology:** Direct observation of clinical signs, post-mortem pathology, and sometimes haemagglutination/haemagglutination inhibition tests are used for viral diseases (Teklemariam *et al.*, 2021) [60]. Advanced viral diagnostics are largely confined to NAHDIC.
- e) **Pathology:** Basic histopathology and gross pathology are conducted, primarily at NAHDIC and some university veterinary faculties (Gizaw *et al.*, 2019) [74].

The range of diseases that can be reliably diagnosed is often limited by the available technology and expertise (Aklilu *et al.*, 2018) [5]. While common diseases like anthrax, rabies (via fluorescent antibody test), and specific parasites are routinely diagnosed, complex or emerging pathogens may go undetected or require external referral.

4.4 Disease Surveillance Programs

Laboratory diagnostics are vital for managing zoonotic diseases, ensuring food safety, monitoring antimicrobial resistance (AMR), and enabling accurate disease diagnosis and treatment. Ethiopia has made progress by establishing national disease surveillance systems for priority diseases, often with support from organizations like FAO and OIE (MoA, 2019) [47]. These systems depend on laboratory data to track outbreaks, but challenges remain, such as inconsistent data collection and reporting across the health system (Kassa *et al.*, 2020) [38]. Many positive cases from regional labs go unreported in national databases, leading to data gaps and an incomplete understanding of the national disease burden. Additionally, slow laboratory result turnaround times impede effective epidemiological surveillance and outbreak management (Gebreyes *et al.*, 2014) [28]. To improve disease monitoring and control in Ethiopia, enhancing laboratory infrastructure, data integration, and communication between regional and national levels is essential. Integrating laboratory diagnostics into the One Health framework fosters collaboration among human, animal, and environmental health sectors, crucial for tackling complex zoonotic challenges. Moreover, accurate laboratory diagnostics are key to monitoring AMR and guiding appropriate antimicrobial use, which is critical in addressing the global AMR crisis (Tadesse *et al.*, 2017) [57]. Overall, enhancing laboratory capacity and data systems will support more accurate disease detection, timely interventions, and better health outcomes both locally and globally (Nuradin Yusuf Ame *et al.*, 2022) [72].

4.5 Challenges in Current Practices

Several main challenges impede the effectiveness of animal health diagnostics in Ethiopia:

- a) **Limited Funding:** Insufficient government allocation for veterinary services, leading to perennial shortages of reagents, consumables, and maintenance budgets (FAO, 2020a) [25].
- b) **Supply Chain Issues:** Irregular and unreliable supply chains for essential reagents, kits, and equipment spare parts, exacerbated by import complexities and a lack of local manufacturing (Shiferaw *et al.*, 2020) [56].
- c) **Quality Assurance (QA) and Quality Control (QC):** Lack of standardized protocols, internal and external quality assurance programs, and accreditation processes compromises the reliability and comparability of diagnostic results across different laboratories (OIE,

2018)^[50].

- d) **Geographical Accessibility:** The vast and often rugged terrain of Ethiopia makes it challenging for farmers to access distant diagnostic centers, and for specimens to be transported to laboratories under appropriate conditions (Ketema *et al.*, 2019)^[41, 71].
- e) **Data Management and Sharing:** Inadequate digital infrastructure and standardized data management systems hinder efficient data collection, analysis, and sharing among different levels of the veterinary system and with human health counterparts (Kassa *et al.*, 2020)^[38].
- f) **Lack of Integration:** Poor integration of diagnostic services with field epidemiology and clinical veterinary practices means that laboratory results are not always effectively used to guide disease control efforts (Duguma *et al.*, 2019)^[20].

5. Innovations and Emerging Technologies in Ethiopian Animal Health Diagnostics

Despite the challenges, Ethiopia's animal health sector is gradually adopting and exploring innovative diagnostic technologies, often driven by international collaborations and a recognized need for more efficient and accurate tools.

5.1 Molecular Diagnostics

Molecular techniques like PCR and its variants (RT-PCR, qPCR) represent a significant advancement (Teklemariam *et al.*, 2021)^[60], offering greater sensitivity, specificity, and faster results than traditional methods. NAHDIC, in partnership with veterinary faculties such as Addis Ababa and Haramaya Universities, has established PCR capabilities for detecting diseases like PPR, FMD, rabies, and avian influenza (Aklilu *et al.*, 2018; Shiferaw *et al.*, 2020)^[5, 56]. This has improved diagnostic accuracy during outbreaks and enabled rapid strain differentiation. Additionally, Loop-mediated Isothermal Amplification (LAMP) is being explored for its simpler equipment, making it suitable for field use (Ketema *et al.*, 2019)^[71]. The widespread use of molecular diagnostics could revolutionize disease surveillance by enabling early and accurate detection of infections, aiding targeted interventions and eradication monitoring (Gizaw *et al.*, 2019)^[74]. However, access to these diagnostics remains limited in many animal health labs, necessitating support from donors and government agencies.

5.2 Advanced Serological Assays and Rapid Diagnostic Tests (RDTs)

In addition to conventional ELISA, the latest generations of serological assays demonstrate enhanced performance. More importantly, Rapid Diagnostic Tests (RDTs) are becoming increasingly popular. The implementation of Lateral flow assays (LFAs) for diseases such as PPR, Rift Valley Fever, and Brucellosis is being initiated, especially in remote regions (Regassa *et al.*, 2013)^[52]. These tests are designed to be user-friendly, necessitate minimal equipment, can be conducted in the field, and yield results in a matter of minutes. The impact of RDTs enables field veterinarians to make swift, informed decisions, particularly in situations where access to laboratories is restricted (Ayele *et al.*, 2017)^[8]. They are especially useful for preliminary screening during outbreaks and for monitoring in isolated pastoralist communities. Nevertheless, their accuracy may vary, and positive results frequently necessitate laboratory verification.

5.3 Digital Technologies and Data Management

The incorporation of digital tools is crucial for modernizing Ethiopia's diagnostic system. Laboratory Information Management Systems (LIMS) at NAHDIC, along with various regional laboratories, are implementing LIMS to manage sample tracking, test results, and inventory control (MoA, 2019)^[47]. This results in improved efficiency, reduces errors, and enhances data accessibility. Mobile-based Reporting Applications are being explored for the real-time reporting of clinical cases and diagnostic results from the field, facilitating faster information sharing with central authorities (FAO, 2020a)^[25]. Telemedicine/Tele-diagnostics, which allows for remote consultations and diagnostic assessments through digital imaging of microscopic slides or clinical photographs, can extend the reach of specialists (Aklilu *et al.*, 2018)^[5].

5.4 The One Health Approach and Inter-sectoral Collaboration

The acknowledgment of the interdependence among animal, human, and environmental health has led to the emergence of One Health initiatives in Ethiopia. Joint surveillance programs for zoonotic diseases, such as rabies and brucellosis, are promoting collaboration between veterinary and public health laboratories (Kassa *et al.*, 2020)^[38]. This collaboration includes the exchange of protocols, expertise, and possibly even equipment. International partnerships with organizations like the FAO, OIE, World Bank, and various research institutions, including ILRI and Washington State University, are vital for providing funding, capacity building, technical assistance, and the introduction of innovative technologies (Gebreyes *et al.*, 2014; Shiferaw *et al.*, 2020)^[28, 56]. These collaborations are essential for transferring knowledge and advanced diagnostic tools to Ethiopia.

6. Discussion

The review of animal health laboratory diagnostics in Ethiopia reveals a dynamic landscape characterized by both foundational challenges and promising advancements. While the significance of robust diagnostic services is unequivocally recognized, the practical realization of this potential is hindered by systemic weaknesses.

Current practices, heavily reliant on conventional methods, face pervasive issues of inadequate infrastructure, outdated equipment, and recurrent shortages of essential reagents (Regassa *et al.*, 2013; Teklemariam *et al.*, 2021)^[52, 60]. These limitations directly impact the accuracy, timeliness, and scope of diagnostic services, leading to delayed disease control responses, suboptimal treatment outcomes, and an incomplete picture of the national animal disease burden. The human resource deficit, coupled with insufficient continuous professional development, further exacerbates these problems, limiting the capacity to effectively utilize existing technologies and adapt to new ones (Ayele *et al.*, 2017)^[8]. Moreover, the lack of standardized quality assurance systems compromises the reliability and comparability of diagnostic results across various laboratories, impeding evidence-based policy formulation and effective disease surveillance (OIE, 2018)^[50].

However, the landscape is not without hope. The gradual integration of innovations such as molecular diagnostics (PCR, LAMP), rapid diagnostic tests (RDTs), and exploration of digital technologies demonstrates a clear understanding of the need to modernize (Aklilu *et al.*, 2018; Shiferaw *et al.*, 2020)^[5, 56]. NAHDIC, supported by international partners, plays a crucial role in spearheading these advancements,

serving as a hub for training and technology transfer. The increasing emphasis on the One Health approach is particularly commendable, fostering inter-sectoral collaboration for zoonotic disease surveillance and control (Kassa *et al.*, 2020) [38]. This holistic perspective is vital for a country like Ethiopia, where the interface between humans, animals, and the environment is highly active, facilitating pathogen spillover (Duguma *et al.*, 2019) [20].

The gap between the potential of innovative diagnostics and their widespread implementation remains substantial. While NAHDIC might boast advanced PCR capabilities, these are often not effectively cascaded down to regional and district levels where the majority of animal health issues are encountered (Gizaw *et al.*, 2019) [74]. This disparity highlights the need for a more equitable distribution of resources and expertise. The challenges of geographical accessibility, unreliable supply chains, and funding scarcity are formidable barriers that must be addressed strategically. Relying solely on external funding for advanced technologies is unsustainable; there is a critical need for increased domestic investment and the development of local capacity for reagent production and equipment maintenance (FAO, 2020b) [26].

The implications of these diagnostic shortcomings extend beyond animal health. Suboptimal disease control burdens the national economy, perpetuates poverty among livestock-dependent communities, and threatens food security (MoA, 2019) [47]. The inability to accurately diagnose and monitor zoonotic diseases puts public health at risk, underlining the urgency of strengthening veterinary diagnostics as a cornerstone of national biosecurity (Gebreyes *et al.*, 2014) [28]. Ultimately, transforming Ethiopia's animal health diagnostic landscape requires a multi-pronged approach that balances the adoption of cutting-edge technologies with the strengthening of foundational capacities. It necessitates a strategic investment in infrastructure, human capital, and robust quality management systems, alongside fostering strong collaborations across sectors and with international partners.

7. Conclusion and Recommendations

Laboratory diagnostics are vital for animal health, livelihoods, food security, and public health in Ethiopia. Despite advancements in molecular and rapid diagnostic technologies, challenges like underfunding, poor infrastructure, human resource shortages, and logistical issues hinder progress. The full benefits of these innovations remain untapped in the country's livestock systems. By addressing these challenges, Ethiopia can transform its animal health diagnostic system into a proactive and reliable resource for managing diseases, enhancing livestock productivity, and safeguarding human health under a One Health strategy.

To strengthen Ethiopia's animal health diagnostic landscape and build a resilient system capable of addressing current and future disease threats, the following recommendations and future directions are crucial:

- Increase budget allocations for veterinary laboratories by the Ethiopian government and development partners. Modernize outdated equipment, ensure regular maintenance, and establish reliable cold chain systems in regional and district labs. Enhance biosafety and biosecurity protocols to safely manage pathogens.
- Ongoing training for lab staff in advanced diagnostics, quality assurance, and biosafety is essential for human resource development and retention. To attract and keep talent in veterinary diagnostics, implement competitive salaries, career advancement opportunities, and

recognition policies. Enhance collaboration between veterinary schools and diagnostic labs to align curricula with practical training for students.

- Establish a national accreditation body for veterinary labs to help them meet international standards and develop standardized SOPs for diagnostic tests, ensuring consistent and reliable results. Actively participate in international EQA programs and create national inter-laboratory proficiency testing initiatives.
- Inter-sectoral Coordination: Improve collaboration among animal health, public health, and environmental sectors for integrated disease surveillance and data sharing on zoonotic diseases.
- National and International Partnerships: Leverage existing partnerships and form new alliances with organizations like OIE, FAO, and WHO to gain technical support and resources.
- Implement comprehensive Laboratory Information Management Systems (LIMS) across the diagnostic network for improved data handling; Ensure integration of veterinary LIMS with national surveillance databases for better disease intelligence; Strengthen epidemiological analysis of diagnostic data to inform evidence-based policy, targeted interventions, and resource allocation.

8. Conflict of Interest

Not available

9. Financial Support

Not available

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