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A Review of the Historical Perspectives of Contagious Bovine Pleuropneumonia in Africa and Entry into Nigeria

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A B S T R A C T

CBPP is a highly contagious and economically significant respiratory disease of cattle. A systematic search of databases from 1987 to 2024 was conducted. This review assesses the history of CBPP in Africa. CBPP is caused by *Mycoplasma mycoides* subsp. *mycoides*. The disease's spread across the African continent has been facilitated by factors such as colonial trade routes, cattle movements, nomadic pastoralism, and environmental conditions. The introduction of CBPP into Nigeria marked a pivotal moment in the country's agricultural history. This review traces the early documentation of CBPP outbreaks, highlighting the disease's influence on traditional cattle-rearing practices and the subsequent social and economic consequences. It further examines the role of vaccination efforts, disease monitoring, and government policies in controlling the disease. In Nigeria, CBPP has disrupted cattle herd compositions and cattle movement patterns, with financial costs incurred. This review underscores the importance of continued research as a way out of CBPP.

Introduction

Contagious bovine pleuropneumonia (CBPP) is a highly infectious respiratory disease that affects cattle, characterized by severe inflammation of the lungs and pleura [1], (Figure 1).

Figure 1. Contagious Bovine Pleuropneumonia (CBPP) showing severe inflammation of the lungs and pleura (a), hepatization (b) and thickened interlobular septae (c) of cattle [2].

CBPP infected cattle imported from India in the 19th century was the source of this disease in cattle herds in East, Central, and West Africa [3]. CBPP is one of the most dreadful threats to cattle industry in Africa [4]. The occurrence of CBPP was global at some points aside from countries of South America and Madagascar [5]. Despite the fact that CBPP has been eradicated from the US and Great Britain hundreds of years back, still the disease is never out of Africa [6, 7, 8, 9].

The disease is caused by the bacterium *Mycoplasma mycoides* subsp. *mycoides*, which spreads through close contact, often in crowded or mobile herds [10]. Symptoms include coughing, fever, labored breathing, and sometimes death, with significant morbidity and mortality rates in affected herds. CBPP is a major concern for cattle in Africa due to its rapid spread and devastating economic impacts [8,9]. Many African communities depend on cattle for livelihoods, food, and trade, and CBPP outbreaks lead to high losses in productivity, financial strain for farmers, and food insecurity [11]. The disease also hampers cattle trade and movement, necessitating strict control measures that can disrupt traditional cattle-rearing practices. Despite vaccination efforts, challenges in vaccine efficacy, logistics, and disease monitoring make CBPP control difficult, underscoring the need for sustained veterinary and policy interventions [12,13].

The objectives of this review are as follows:

Historical Contextualization: To provide a comprehensive historical overview of Contagious Bovine Pleuropneumonia (CBPP), tracing its origins and documenting its progression across the African continent. This includes examining the factors that facilitated its spread, such as cattle trade routes, colonial influence, and nomadic pastoralism.

Spread Across Africa: To analyze the pathways and methods by which CBPP spread throughout Africa, identifying significant outbreaks and their effects on local cattle-rearing communities. This section will explore how the disease adapted to different environments and livestock practices across the continent.

Entry into Nigeria: To investigate how CBPP entered Nigeria, examining the earliest cases, potential points of entry, and contributing factors such as cross-border cattle movement and trade networks.

Impact on Nigeria’s Cattle Sector: To assess the socioeconomic and agricultural impacts of CBPP on Nigeria’s cattle industry, including economic losses, effects on rural livelihoods, and shifts in livestock management practices.

Evaluation of Control Efforts: To review Nigeria’s historical and ongoing CBPP control measures, such as quarantine, vaccination campaigns, and international collaborations. This includes discussing the successes and challenges encountered in eradicating or managing the disease in the country.

Lessons for Future Disease Management: To draw insights from historical trends and control efforts, highlighting lessons that can inform more effective strategies for CBPP control, prevention, and eradication in Nigeria and other parts of Africa.

This review aims to assess the history of CBPP in Africa, its introduction in Nigeria, socioeconomic impact, disease control, eradication efforts, and challenges in CBPP management and provides insights into transboundary animal diseases, with a focus on informing future policies and interventions.

METHODOLOGY

A systematic search of databasessuch as PubMed, Scopus, Web of Science, Google Scholar, GRIS and African Journals Online (AJOL) were conducted. The search period depended on the available data online because the review was a historical one. The search terms used included specific terms and keywords such as *Mycoplasma mycoides*, Historical perspectives, Bovine pleuropneumonia, CBPP in Africa, CBPP in Nigeria. Articles were included if they (1) were peer-reviewed, (2) were actual research works, (3) focused on CBPP in other African countries, (4) focused on CBPP in Africa and(5) focused on CBPP in Nigeria. Studies were excluded if they (1) were not in English, (2) focused on CBPP outside Africa, or (3) lacked historical or quantitative data. Two authors independently screened titles and abstracts using the predefined criteria. Disagreements were resolved through discussion or consultation with a third reviewer.

Data on study design, population, outcomes, and key findings were extracted using a standardized form. These data were then synthesized to address the objectives of the review.

BACKGROUND ON CONTAGIOUS BOVINE PLEUROPNEUMONIA

1.Pathology and Transmission:

Disease Pathology: Contagious Bovine Pleuropneumonia (CBPP) is a highly infectious respiratory disease caused by the bacterium *Mycoplasma mycoides* subsp. *Mycoides [*14]. This pathogen primarily targets the lungs and pleura (the thin membrane surrounding the lungs) in cattle. Once inside the host, the bacterium adheres ~~to~~ and invades respiratory epithelial cells, causing localized inflammation. This invasion triggers immune responses, leading to the accumulation of fluid, fibrin, and cells in the lungs, resulting in pleuropneumonia. Affected cattle develop lesions in the lungs and pleura that can range from mild to severe, with lung tissue often becoming consolidated and necrotic in advanced cases. This pathology not only hampers the animal's respiratory function but can also lead to systemic illness and further complicating recovery [15].

Transmission of CBPP: CBPP primarily spreads through direct contact between infected and healthy cattle [14]. The bacterium is shed through respiratory secretions, including droplets from coughing or sneezing, which are then inhaled by nearby animals [16]. Transmission is particularly rapid in environments where cattle are closely confined, such as markets, transportation vehicles, and communal grazing areas [17]. While infected animals in the acute phase are the most contagious, asymptomatic carriers can also harbor the bacteria and transmit the disease over prolonged periods, often acting as sources for future outbreaks. The movement of livestock, especially through trade or transboundary pastoralism, plays a significant role in the disease's spread across regions [18].

2. Effects on Cattle: The clinical signs of CBPP can vary but typically include high fever, labored breathing, coughing, nasal discharge, and lethargy [19]. The inflammation and fluid buildup in the lungs severely compromise respiratory function, leading to decreased oxygenation, exhaustion, and often death in severe cases [20]. Chronic cases may exhibit wasting, poor body condition, and persistent cough, reducing the cattle's productivity even if they survive the initial infection [21]. Morbidity and mortality rates in herds can be high, particularly in populations that lack immunity or access to treatment [14]. This results in severe economic consequences for farmers, as cattle are essential for meat, milk production, labor, and income in many African communities. CBPP's combination of high transmissibility, significant morbidity, and long-lasting impacts on cattle health makes it a challenging and devastating disease for cattle-dependent economies, necessitating strict control measures to prevent outbreaks.

HISTORICAL OVERVIEW OF CONTAGIOUS BOVINE PLEUROPNEUMONIA (CBPP) IN AFRICA

Origins of CBPP: Contagious Bovine Pleuropneumonia (CBPP) is believed to have originated in Europe, where the disease was initially identified in the early 18th century [22]. It spread to other parts of the world primarily through the movement of cattle for trade, military activities, and colonization. CBPP's transmission is closely linked to cattle movement, as infected animals carry the disease to new herds, making it especially challenging to control in regions with extensive livestock trade [23].

1. **Introduction and Early Outbreaks in Africa:** The first documented outbreaks of CBPP in Africa are believed to have occurred in the early 19th century, likely brought by European settlers and their imported cattle [24]. These initial cases were recorded in North Africa, where trade routes connected local livestock populations to European cattle [11]. By the mid-19th century, CBPP had spread into West, East, and Southern Africa, aided by established trade routes and the movement of cattle herds along migration paths and trading corridors [25]. In recent years, the spread and distribution of CBPP in Africa is enormous (Figure 2).

2. Spread through Colonial Influence: CBPP spread extensively during the colonial era, when European colonizers introduced large-scale cattle imports to support settlements and military campaigns [26]. This influx of cattle contributed to the spread of

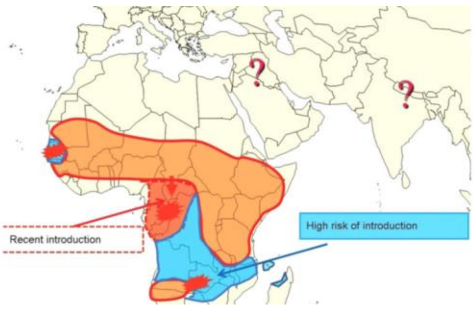

Figure 2. Distribution of CBPP in Africa [11]

CBPP across vast regions in Africa, where native livestock populations were previously unaffected by the disease [27]. Colonial policies also encouraged livestock trade and cattle ranching, which increased inter-regional cattle movement and facilitated CBPP's transmission to new areas [28]. By the late 19th century, CBPP was well established in many

African countries, becoming a major concern for colonial veterinary services [29].

3. Impact on Traditional Pastoral Systems: The disease had a particularly significant impact on traditional African pastoral systems, where cattle are central to both livelihoods and cultural practices [30]. The introduction of CBPP disrupted these systems, as pastoralists faced sudden losses in their herds and the threat of recurring outbreaks [27]. Attempts to control the disease through quarantine and movement restrictions often clashed with nomadic and transhumant practices, creating further challenges for containment [31].

4. CBPP's Entry into Nigeria: CBPP likely entered Nigeria in the late 19th or early 20th century through regional cattle trade, pastoralist movements, and colonial activities [32]. The disease spread rapidly across northern Nigeria, where cattle rearing are integral to the economy and culture, and gradually made its way into other parts of the country. Nigeria's diverse cattle populations and widespread movement of herds made containment challenging, and the disease soon became endemic in many areas. Early efforts by colonial authorities to control CBPP in Nigeria were met with limited success, as veterinary infrastructure was underdeveloped, and enforcement of movement restrictions faced resistance from local communities [11].

5. Establishing CBPP as an Endemic Disease in Africa: By the 20th century, CBPP had become endemic in much of sub-Saharan Africa [8]. This period saw repeated outbreaks across the continent, leading to significant economic losses for cattle owners and widespread disruptions to rural livelihoods. CBPP's persistence in Africa continues to impact cattle populations today, and its long history in the region underscores the need for ongoing control efforts and policy interventions to support disease management [33].

6. Early Introduction and Initial Spread: Contagious Bovine Pleuropneumonia (CBPP) is thought to have arrived in Africa during the early 19th century, likely introduced by European settlers and traders who brought cattle from Europe [34]. The disease first appeared in northern Africa, where connections to European trade routes enabled its spread. As CBPP took hold, it followed existing cattle trade routes, quickly reaching regions where cattle rearing were integral to local economies and cultures [32].

7. Influence of Colonial Trade Routes: The colonial era profoundly influenced CBPP's spread across Africa [35]. European colonial powers relied heavily on cattle for food, labor, and commercial trade, leading to increased cattle imports [36]. Colonial trade routes connected remote regions to major ports, facilitating intercontinental livestock movement and, subsequently, the disease's progression [37]. These routes—particularly those linking North Africa to West and East Africa—served as pathways for CBPP, allowing it to move from coastal entry points into the interior of the continent.

8. Impact of Cattle Movements and Pastoral Practices: Africa's long-standing pastoralist traditions and the seasonal transhumance practices of moving livestock between grazing areas contributed to the spread of CBPP [38]. Pastoral communities often moved their herds in search of fresh grazing land and water sources, especially in arid and semi-arid regions where resources were scarce (Figure 3). In East and West Africa, cattle movements facilitated CBPP's transmission across vast distances, affecting livestock populations in Kenya, Tanzania, Uganda, and Nigeria [39]. The disease's spread was particularly pronounced in areas where multiple herds mingled, such as at watering points or grazing lands, providing ample opportunities for CBPP transmission [40].

9. Role of Environmental Factors: Environmental conditions in Africa played a significant role in CBPP's spread [11]. The disease thrives in densely populated cattle areas and close quarters where respiratory droplets can easily transmit from animal to animal [41]. The semi-arid climate in parts of the Sahel and East Africa often necessitates dense gatherings of cattle around scarce water sources, creating ideal conditions for CBPP outbreaks [42]. Seasonal migrations, coupled with regional droughts and resource scarcity, pushed herds into new areas, increasing the likelihood of contact with infected animals and new outbreaks. [43].

Figure 3. Unrestricted nomadic cattle movement in Ilorin to search for food in the bush instead of the standard practice of intensive husbandry

10. Expansion into West Africa and Nigeria: CBPP reached West Africa by the late 19th century, brought in part by cattle traders and nomadic pastoralists moving along trade routes [44]. As it spread, the disease eventually entered Nigeria, where livestock farming and trade are deeply embedded in the cultural and economic fabric. In Nigeria, CBPP followed traditional cattle trading routes from northern regions to other parts of the country, with infected animals carrying the bacterium into previously unexposed areas [45] The disease soon became endemic, affecting cattle populations nationwide. Colonial attempts to limit CBPP's spread, such as movement restrictions and quarantine measures, were often met with resistance, as these measures clashed with established pastoralist practices and economic needs [46].

11. Colonial Veterinary Responses and Control Efforts: In response to the growing threat, colonial authorities across Africa implemented various veterinary control measures, including quarantine, movement restrictions, and, in some cases, cattle culling [11]. Veterinary departments were established to monitor CBPP, and initial efforts were made to develop vaccines and containment protocols [47]. However, colonial veterinary infrastructure was often under-resourced, and enforcing restrictions in remote regions proved challenging [48]. The combination of pastoral resistance, limited resources, and the highly infectious nature of CBPP made eradication efforts largely unsuccessful [49]. The disease persisted, and outbreaks continued to devastate livestock populations and rural economies throughout the 20th century.

12. Legacy of CBPP's Spread in Africa: CBPP's historical spread throughout Africa reflects a complex interplay of colonial expansion, environmental factors, and traditional cattle movement practices [50]. The disease has become a persistent threat, embedded in the livestock management challenges faced by African governments and communities today [51]. Understanding CBPP's spread provides valuable insights into the disease's current distribution and underscores the need for targeted, collaborative approaches to disease control that account for Africa's diverse pastoral and agricultural practices.

ENTRY OF CBPP INTO NIGERIA

1. Year of First Recorded Outbreak in Nigeria: The first documented cases of CBPP in Nigeria occurred in the late 19th century, with reports indicating that the disease had spread to the country by the 1880s [22].

2. Initial Regions Affected by CBPP in Nigeria: Northern Nigeria was the primary entry point for CBPP, specifically in areas with active cattle trade and movement, such as the Kano and Sokoto regions [52].

3. Early Observations of CBPP in Nigeria: The disease was first noted among local herds in regions where cattle trade routes intersected, suggesting an introduction linked to transboundary cattle movements. [53].

4. Sources of Introduction: Regional Cattle Movements: CBPP likely entered Nigeria through cattle brought in from neighboring regions already affected by the disease, including Sudan and Chad [54]. Seasonal migrations and cross-border trade facilitated the introduction and spread of the disease.

5, Colonial Trade Routes and Cattle Imports: The establishment of colonial trade routes intensified livestock trade, making it easier for infected animals from neighboring countries to enter Nigeria [55]. These routes also increased the frequency of cattle exchanges between communities, inadvertently spreading CBPP.

6. Spread and Documentation Through the Early 20th Century: Impact on Northern Cattle Herds: The disease spread rapidly among herds in the northern regions, with documented reports from veterinary services in the early 1900s indicating widespread infection [14]. The high density of cattle herds in northern Nigeria created ideal conditions for the disease's spread.

7. Further Regional Spread: As cattle movement continued along trade routes from the north to other parts of Nigeria, CBPP spread to the central and southern regions [56]. By the 1920s, the disease had become endemic in many parts of the country[8].

8. Colonial Veterinary Response and Early Control Efforts: First Veterinary Documentation: Colonial veterinary authorities documented CBPP cases extensively during the early 1900s, recognizing its impact on livestock and rural economies [54]. Initial reports underscored the need for containment and control, although resources were limited.

9. Movement Restrictions and Quarantine Efforts: In response to the outbreak, colonial authorities attempted to control the disease by imposing movement restrictions and quarantine measures, particularly in affected northern regions [11]. However, enforcement challenges and pastoral resistance hindered containment efforts.

10. Legacy of Early Outbreaks:

A. Endemic Status: By the mid-20th century, CBPP had become a persistent problem in Nigeria, affecting cattle-rearing practices and leading to economic losses for pastoral communities [57].

B. Significance of Historical Spread: Understanding the initial spread of CBPP in Nigeria provides insight into the disease's current distribution and the challenges faced in eradicating it. Early outbreaks shaped national veterinary strategies, highlighting the importance of monitoring transboundary livestock movement and implementing sustainable disease control measures. This early historical spread and initial documentation of CBPP in Nigeria underscore the importance of regional cooperation in managing animal diseases and the ongoing need for effective veterinary infrastructure to combat endemic diseases like CBPP.

EARLY INTERVENTIONS BY NIGERIAN AUTHORITIES AND VETERINARY SERVICES TO CONTROL CBPP

Contagious Bovine Pleuropneumonia (CBPP) has long been a significant threat to cattle health and the livestock economy in Nigeria [56]. From the early days of the disease's entry into the country, Nigerian authorities and veterinary services began implementing interventions to control its spread. However, these efforts were initially challenged by limited resources, inadequate infrastructure, and a lack of understanding of the disease. Below is an examination of the key early interventions that were undertaken to combat CBPP in Nigeria, including quarantine measures and vaccination attempts.

1. **Quarantine Measures and Movement Restrictions**

Initial Quarantine Responses: Upon the recognition of CBPP as a major threat, Nigerian authorities implemented quarantine measures to limit the movement of infected cattle [11]. Quarantining affected regions and isolating sick animals were some of the first steps taken to prevent the further spread of the disease. For instance, the affected herds in the northern regions, where the disease was first identified, were placed under quarantine in an attempt to contain the outbreaks.

Border Controls: In the early stages, there were limited efforts to control cross-border movement of cattle, which facilitated the spread of CBPP from neighboring countries where the disease was already endemic. Eventually, Nigerian authorities began implementing some border control measures to restrict the importation of cattle from CBPP-affected regions [54]. This was particularly important given the high level of cross-border cattle trade in the Sahel region and West Africa.

Cattle Herd Monitoring: The authorities also initiated efforts to monitor cattle herds more closely in the regions where CBPP was most prevalent. This included the establishment of veterinary checkpoints and the requirement for health certificates to allow movement of cattle within the country, though enforcement remained inconsistent in some areas.

2. **Vaccination Attempts**

Introduction of Vaccination: Vaccination was one of the most promising interventions for controlling CBPP in the early 20th century. Early attempts at controlling the disease through vaccination faced challenges due to the limited availability of effective vaccines, and a lack of coordinated national strategies. The first major effort to combat CBPP through vaccination occurred in the 1930s, after the discovery of a vaccine derived from *Mycoplasma mycoides* [58].

Challenges in Vaccine Efficacy and Availability: The development and use of vaccines in Nigeria were hindered by a lack of infrastructure for vaccine production and distribution [59].The initial vaccines were not always reliable, and their administration was limited in many regions due to logistical difficulties and the lack of a comprehensive vaccination campaign.

Imported Vaccines: In some cases, Nigeria relied on vaccines imported from European countries, such as those developed in the UK [60]. However, the cost and limited supply of these vaccines meant that they were not always available to reach every affected region. Furthermore, the vaccines that were used were often not well-suited to the local environmental conditions or strains of the bacteria present in Nigeria, leading to suboptimal results.

Dissemination Issues: The success of vaccination campaigns was often undermined by inadequate knowledge of proper vaccination techniques, difficulties in reaching remote cattle herders, and a lack of coordination between veterinary authorities and local communities [61]. In many areas, cattle herders were either unaware of vaccination efforts or reluctant to participate due to a lack of trust in government initiatives.

3. **Surveillance and Diagnosis**

Establishment of Diagnostic Systems: Early control efforts were also focused on improving the diagnosis of CBPP [11]. In the initial phases, the Nigerian Veterinary Services worked to establish systems for diagnosing the disease, including laboratory-based tests. However, due to limited diagnostic facilities and trained personnel, these efforts were often delayed or ineffective.

Outbreak Reporting and Data Collection: The lack of a formal reporting system for outbreaks of CBPP contributed to delays in response and poor coordination between regional authorities. However, over time, Nigerian veterinary services established a network for reporting and monitoring disease outbreaks, which helped provide better information for controlling CBPP.

4. **Collaboration with International Organizations**

Assistance from Colonial Authorities: During the colonial period, the British colonial government in Nigeria worked with international agencies, such as the World Health Organization (WHO) and the Food and Agriculture Organization (FAO), to introduce CBPP control measures [62]. These included veterinary training programs, the development of diagnostic tools, and the establishment of quarantine and vaccination protocols.

Technical Support and Expertise: The Nigerian Veterinary Services received support from international experts in the field of animal diseases [63]. This collaboration provided access to international research on CBPP, allowing the country to benefit from advancements in disease control practices and vaccine development. However, this support was often sporadic and came with challenges in terms of sustainability and adaptation to local conditions.

5. **Public Awareness and Education**

Raising Awareness Among Herdsmen: One of the key strategies that Nigerian authorities employed was to raise awareness among pastoralists and cattle herders about the nature of CBPP and the importance of reporting sick animals [64]. Efforts Have been made to educate herders about quarantine practices, the benefits of vaccination, and the need to reduce cattle movement during outbreaks.

Challenges in Communication: Communication with rural communities, particularly nomadic herders, was a major challenge. Many herders were not familiar with veterinary terminology, and local languages were often barriers to conveying important disease control messages [65]. Additionally, the social structures in rural areas often meant that decisions were made by traditional leaders or local elders, who needed to be involved in any disease control campaigns to ensure compliance.

6. **Institutional and Structural Issues**

Limited Veterinary Infrastructure: The Nigerian Veterinary Service was often underfunded and lacked the resources to implement comprehensive disease control strategies across the country [66]. Many regions lacked veterinary clinics, diagnostic laboratories, and skilled veterinary personnel, which hindered efforts to control CBPP.

Inadequate Research and Development: In the early years, there was insufficient local research on CBPP, and Nigeria relied heavily on external sources for vaccine production and disease control knowledge [67]. This dependence on external expertise created challenges in terms of understanding the specific epidemiology of the disease in the Nigerian context.

CBPP Control Efforts and Challenges in Nigeria Past and Current Vaccination Strategies for Contagious Bovine Pleuropneumonia (CBPP) in Africa and Nigeria

Vaccination has been one of the primary strategies used to control Contagious Bovine Pleuropneumonia (CBPP) in both Africa and Nigeria [4]. Over the years, efforts have been made to develop and deploy vaccines to reduce the incidence of the disease and to provide herd immunity. However, several challenges have hindered the effectiveness of vaccination campaigns, including issues with vaccine efficacy, cold chain logistics, and farmer compliance. This section examines the evolution of vaccination strategies, the successes and setbacks faced, and the challenges that continue to affect the control of CBPP in Nigeria and across the African continent.

1**. Past Vaccination Strategies**

Early Efforts and Development of Vaccines: In the early stages of CBPP control, vaccine development faced significant challenges due to limited understanding of the disease and its causative agent, *Mycoplasma mycoides subsp. Mycoides* [68]. The first vaccines for CBPP were based on inactivated or live attenuated strains of the pathogen [69]. In many African countries, including Nigeria, the introduction of these vaccines was a significant step forward, as they helped reduce the spread of the disease in localized areas. However, the vaccines were not widely available, and distribution was often inconsistent, particularly in remote rural areas.

Use of the T1/44 Vaccine: One of the more commonly used vaccines in Africa and Nigeria was the T1/44 strain, an inactivated vaccine that was introduced in the 1970s [70]. While it offered some protection against CBPP, its effectiveness varied based on factors such as the dosage, the health status of the animals, and the environmental conditions under which the vaccine was administered. The T1/44 vaccine was successful in reducing outbreaks in some regions but could not provide long-term immunity, which led to recurring outbreaks and the need for frequent revaccination [69].

Challenges with Vaccine Efficacy: The efficacy of early CBPP vaccines was inconsistent due to the lack of a universal vaccine for all strains of *Mycoplasma mycoides* [57]. Different regions experienced varying levels of effectiveness, and the problem of incomplete immunity remained an obstacle to disease eradication efforts. The disease’s tendency to mutate and adapt to vaccine-induced immunity also played a role in diminishing the overall success of early vaccination program [57].

2. Current Vaccination Strategies

Introduction of Improved Vaccines: In recent years, there has been progress in developing more effective vaccines for CBPP. The T1/44 vaccine has been improved with the development of newer vaccines like the *Mycoplasma mycoides* subsp. mycoides and *M. mycoides* subsp. capri-based vaccines [71]. These newer vaccines have shown improved protection and are being deployed in some regions. Additionally, there has been greater emphasis on vaccines that provide longer-lasting immunity, which is crucial for reducing the frequency of outbreaks [72].

Vaccination Campaigns and Government Initiatives: Vaccination campaigns, often led by national veterinary services and supported by international organizations like the World Organisationfor Animal Health (OIE) and the Food and Agriculture Organization (FAO), have become more coordinated in recent years [73]. In Nigeria, authorities have initiated widespread vaccination programs in regions where CBPP outbreaks have been most frequent [74]. These efforts have been bolstered by improved surveillance and monitoring systems to track outbreaks and vaccination coverage. In addition to mass vaccination, some strategies include targeted vaccination of high-risk areas and the use of mobile veterinary units to vaccinate remote pastoralist communities.

Reinforcement of Surveillance and Monitoring: Modern vaccination strategies often involve the use of better surveillance and diagnostic tools to assess the effectiveness of vaccination programs. These tools help authorities identify regions with low vaccination coverage and ensure that resources are targeted where they are needed most. Surveillance data also help to identify emerging trends in CBPP outbreaks, which can guide vaccination campaigns and allow for timely intervention.

3. Challenges with Vaccine Efficacy

Limited Long-Term Immunity: One of the major challenges with current and past CBPP vaccines is the limited duration of immunity they provide [75]. While vaccines like the T1/44 strain can offer protection for several months, they do not confer lifelong immunity, requiring animals to be revaccinated regularly [76]. This presents a logistical challenge, especially in remote areas where access to veterinary services and vaccines may be limited.

Vaccine Strain Differences: CBPP is caused by *Mycoplasma mycoides* subsp. *mycoides*, but different strains of this pathogen exist, and the vaccines developed may not provide protection against all of them [75]. This strain variability (Figure 4) complicates the development of a "one-size-fits-all" vaccine [77]. Colony immunostaining using *M. mycoides* SC strain B17 MAb 5G1 reveals that the surface protein Vmm is expressed differently in each colony. The population includes sectored colonies (S), where growth-induced mutations have caused ON/OFF switching of the Vmm expression, negative colonies (N), and colonies that express the Vmm protein and are positive for MAb 5G1. A single colony that was cultivated in broth, filtered, and plated on agar is the source of all the colonies.

The efficacy of vaccines is often compromised in regions where the prevalent strain differs from the vaccine strain, making the disease more difficult to control across different regions of Nigeria and Africa.

Vaccine-Induced Resistance: As CBPP persists in certain regions, there is a possibility of the development of strains that are resistant to the vaccines being used [11]. This could be due to the pathogen's ability to mutate and evolve in response to selective pressure from vaccination programs. While this

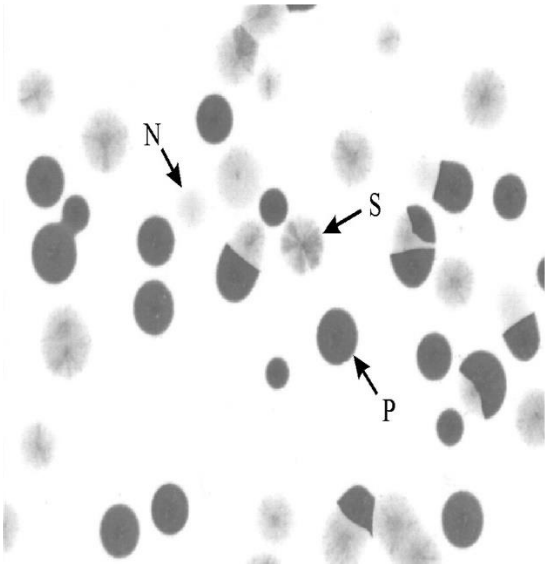

Figure 4. *Mycoplasma mycoides* subspecies *mycoides* colonies derived from a single colony that was cultured in broth, filtered, and plated on agar. The plate is composed of colonies that are positive for MAb 5G1 and express the Vmm protein (P), negative colonies (N), and sectored colonies (S) where mutations during growth have induced ON/OFF switching of the Vmm expression. Colony immunostaining with MAb 5G1 of *M. mycoides* SC strain B17, demonstrating variable expression of the surface protein Vmm among and within colonies [78].

phenomenon has not been fully documented, it is a concern in the long-term management of CBPP.

4. Cold Chain Logistics and Vaccine Storage

Challenges with Cold Chain Storage: One of the most significant logistical challenges in CBPP vaccination programs in Africa, particularly in Nigeria, is maintaining an effective cold chain [60]. Vaccines, especially those that are live attenuated, require strict temperature control from the production site to the point of administration to remain effective [79]. However, in many rural areas, especially in remote and nomadic communities, inadequate refrigeration and transportation infrastructure make it difficult to store and transport vaccines at the required temperatures. This results in reduced vaccine efficacy and limited access to immunization in hard-to-reach areas.

Impact of Poor Infrastructure: In addition to the challenges related to cold chain management, poor road infrastructure and limited access to veterinary clinics in rural areas exacerbate the problem of vaccine delivery [80]. Farmers in isolated areas may not have access to timely vaccinations for their cattle, which increases the likelihood of CBPP outbreaks. The lack of infrastructure also means that some farmers are unable to participate in vaccination campaigns, leaving their animals unprotected.

5. Farmer Compliance and Community Engagement

Farmer Awareness and Participation: While vaccination is an essential tool in CBPP control, farmer compliance remains a major issue. Many farmers are not always fully aware of the importance of vaccination or may be skeptical about the vaccines' effectiveness [60]. In some cases, there is resistance to vaccination due to cultural practices, mistrust of government interventions, or past experiences with ineffective vaccines.

Incentives for Compliance: Encouraging farmer participation in vaccination campaigns requires education and awareness-building efforts. Farmers need to be convinced of the value of vaccination, not just for the individual health of their cattle, but also for the wider benefits of herd immunity. Offering incentives, such as free or subsidized vaccines, can also improve compliance. In some cases, community engagement strategies have proven effective in increasing vaccination rates, particularly when pastoralist communities are involved in the planning and delivery of vaccination programs.

Barriers to Compliance: Financial constraints, lack of access to veterinary services, and fear of side effects from vaccination all contribute to low farmer compliance in certain areas. These factors need to be addressed in the design and implementation of future vaccination strategies.

The Role of Partnerships in Nigeria’s Contagious Bovine Pleuropneumonia (CBPP) Control Efforts: Collaboration with the African Union and the World Organization for Animal Health (OIE)

The control and eventual eradication of Contagious Bovine Pleuropneumonia (CBPP) in Nigeria has been significantly influenced by international partnerships with organizations like the African Union (AU) and the World Organization for Animal Health (OIE) [81]. These collaborations have provided technical expertise, funding, and regional coordination necessary to combat CBPP effectively, given its transboundary nature and the challenges posed by the disease. This section highlights the key roles that these organizations have played in Nigeria’s CBPP control efforts, including their support for surveillance, vaccination programs, capacity-building initiatives, and policy development.

1. African Union (AU) and Its Role in CBPP Control

The African Union, through its specialized agency the African Union Inter-African Bureau for Animal Resources (AU-IBAR), has been instrumental in addressing animal diseases, including CBPP, across the continent. The AU-IBAR’s role in Nigeria’s CBPP control efforts has been multifaceted, focusing on the following key areas:

Regional Coordination and Policy Development: The African Union has played a pivotal role in facilitating regional collaboration and policy harmonization among African countries affected by CBPP [82]. By working through the African Union Pan-African Program for the Control of Epizootics (PACE), the AU has helped Nigeria align its CBPP control strategies with regional efforts. This coordination ensures that countries share information, resources, and strategies, creating a unified approach to managing CBPP outbreaks and reducing the risk of cross-border transmission.

Capacity Building and Technical Assistance: The AU-IBAR has supported Nigeria by providing training for veterinary staff, improving diagnostic capabilities, and enhancing surveillance systems [83].

Financial Support and Vaccine Distribution: Through its partnerships with various international donors and financial institutions, the AU has facilitated the provision of funding for CBPP control activities in Nigeria [11]. This has included financing for vaccination campaigns, particularly in regions where the disease is endemic. The AU has also helped to coordinate the distribution of vaccines, ensuring that they reach remote areas where CBPP is most prevalent.

Cross-Border Cooperation: Since CBPP is a transboundary animal disease (TAD), the AU has been essential in promoting cross-border cooperation. For example, Nigeria’s neighboring countries, such as Chad, Niger, and Cameroon, have collaborated in joint surveillance and vaccination efforts [84], which has helped to contain the spread of CBPP and limit outbreaks along shared borders.

2. World Organization for Animal Health (OIE) and Its Impact on CBPP Control

The OIE, an intergovernmental organization that provides leadership in the development of international standards for animal health and veterinary care, has also been a key partner in Nigeria’s efforts to control CBPP. The OIE’s involvement can be categorized into the following areas:

Setting International Standards: The OIE plays a crucial role in setting global standards for the diagnosis, surveillance, and control of animal diseases [85], including CBPP. Through its Terrestrial Animal Health Code, the OIE establishes protocols for CBPP control, providing countries like Nigeria with a clear framework for managing the disease. These standards help ensure that control measures align with international best practices, which enhances the credibility of Nigeria’s CBPP control efforts in the global community.

Technical Expertise and Guidance: The OIE has provided Nigeria with expert advice on CBPP control, including recommendations on vaccination strategies [86]. disease surveillance, and biosecurity measures. The organization has also facilitated workshops, conferences, and seminars that bring together veterinary professionals, government officials, and researchers from Nigeria and across the region to share knowledge and experiences in the fight against CBPP.

Monitoring and Reporting: As part of its role in the global animal health governance structure, the OIE monitors and reports on the status of animal diseases worldwide [87], including CBPP. Nigeria, as a member state of the OIE, regularly reports its CBPP surveillance data to the organization, which helps ensure transparency and provides an opportunity for technical support and intervention when necessary. The OIE also helps Nigeria analyze outbreak trends, which can inform future control measures.

Collaboration on Vaccination and Diagnostic Research: The OIE has supported research into new vaccines and diagnostic tests for CBPP [88]. For Nigeria, which has faced challenges with vaccine efficacy and cold chain logistics, OIE's efforts to promote the development and distribution of more effective vaccines are invaluable. Additionally, the OIE has facilitated Nigeria's access to cutting-edge diagnostic tools, which has improved the country's ability to detect and monitor CBPP more accurately.

Emergency Response and Funding: The OIE, through partnerships with other international organizations like the World Bank and the Food and Agriculture Organization (FAO), has provided funding and emergency support during major CBPP outbreaks [89]. This financial assistance has helped Nigeria implement swift response measures, including culling infected animals, enforcing quarantine zones, and conducting mass vaccination campaigns in high-risk regions.

3. **Synergistic Impact of AU and OIE Partnership on Nigeria's CBPP Control**

The partnership between the African Union and the OIE has had a synergistic effect on Nigeria's CBPP control efforts, resulting in several successful interventions:

Joint Vaccination Campaigns: Both the AU and OIE have supported large-scale vaccination programs aimed at reducing CBPP transmission in Nigeria [45]. The coordination between these organizations has ensured the availability of vaccines and vaccination teams in regions with the highest incidence of CBPP, thus improving vaccination coverage and reducing outbreaks.

Strengthened Regional Veterinary Networks: Through collaborations facilitated by the AU and OIE, Nigeria has become an active participant in regional veterinary networks [90]. These networks enable the sharing of information, resources, and expertise across borders, which has been critical for controlling CBPP outbreaks that affect multiple countries.

Data Sharing and Surveillance Systems: The AU and OIE have helped Nigeria improve its animal health data collection and reporting systems, making it easier for authorities to track CBPP outbreaks and respond promptly [11]. The establishment of a more robust surveillance system has been essential for detecting new outbreaks early and containing them before they spread.

4. Challenges and Future Directions

While partnerships with organizations like the AU and OIE have significantly contributed to Nigeria's efforts to control CBPP, challenges remain, such as dealing with many strains of *Mycoplasma mycoides* subspecies *mycoides* (Figure 4):

Sustainability of Interventions: Long-term sustainability of CBPP control efforts remains a challenge, especially in terms of financing, continuity of vaccination programs, and maintaining a skilled veterinary workforce in rural areas.

Cold Chain and Vaccine Distribution: Despite the support from AU and OIE, challenges such as maintaining the cold chain for vaccine distribution and ensuring that vaccines reach remote areas continue to hinder effective vaccination campaigns.

Increased Collaboration with Other Stakeholders: Strengthening partnerships with local farmers, community organizations, and non-governmental organizations (NGOs) is essential for improving the acceptance and success of CBPP control measures. Engaging local communities in monitoring and disease prevention is critical to ensuring sustainable outcomes.

CONCLUSION

Contagious Bovine Pleuropneumonia (CBPP) has had a significant impact on cattle populations across Africa, with its historical spread and persistence shaped by a variety of factors, both natural and anthropogenic. The disease's entry and widespread impact in Nigeria can be traced through several key historical elements:

Understanding the historical spread and impact of Contagious Bovine Pleuropneumonia (CBPP) in Africa, particularly its entry into Nigeria, provides valuable insights for shaping future strategies for disease prevention, control, and eradication. By learning from past experiences, both successes and failures, modern CBPP control strategies can be optimized to be more effective, sustainable, and contextually relevant.

Despite significant progress in understanding and managing Contagious Bovine Pleuropneumonia (CBPP) over the years, the disease remains a serious threat to cattle farming, livelihoods, and economies, particularly in Africa and Nigeria with continuous outbreaks and pathological lesions picked at postmortem examinations (Figure 5). To fully address the challenges posed by CBPP, continued research, adequate funding, and sustained policy support are essential.

Figure 5. Recently encountered cases of CBPP outbreak in Ilorin, Nigeria: showing an emaciated Cow with typical signs of CBPP on the field with respiratory distress, weakness, grunting with ocular and nasal discharges. Postmortem examination carried out showed a very hard to touch lung tissue, hepatization with thickened interlobular septae.

Ethical Considerations

There were no ethical considerations to be considered in this review.

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Conflict of interest

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REFERENCES

[1] Di Teodoro, G., Marruchella, G., Di Provvido, A., D'Angelo, A.R., Orsini, G., Di Giuseppe, P., Sacchini, F. and Scacchia, M. (2020). Contagious bovine pleuropneumonia: a comprehensive overview. Veterinary pathology, 57(4), 476-489

[2] Musa, J. A., Bale, J. O., Kazeem, H. M., Nwankpa, N. D., Di Provvido, A., Sacchini, F., Zilli, K., Abass, A., Scacchia, M.& Pini, A. (2016). Molecular detection of Nigerian field isolates of Mycoplasma mycoides subsp. mycoides as causative agents of contagious bovine pleuropneumonia. International Journal of Veterinary Science and Medicine, 4(2), 46-53.

[3] Provost A, Perreau P, Beard A, Le Goff C, Martel JL, Cottew G.S.(1987). Contagious bovine pleuropneumonia. Revue scientifique et technique. 6:625–679.

[4] Masiga, W. N., Domenech, J., & Windsor, R. S. (1996). Manifestation and epidemiology of contagious bovine pleuropneumonia in Africa. Revue Scientifique et Technique-Office International des Epizooties, 15(4), 1283-1308.

[5] Thiaucourt F, Yaya A, Wesonga H, Manso-Silvan L, Blanchard A. (2004). Contagious bovine pleuropneumonia vaccines and control strategies: recent data. Developmental Biology.119:99–111.

[6] Radostits, O.M., Gay, C.C., Hinchcliff, K.W., Constable, P.D. (2007). Veterinary Medicine. A Text Book of Diseases of Cattle, Sheep, Pigs, Goats and Horses. 10th ed. London: W.B. Saunders Elsevier; 1125–1131.

[7] Nicholas R, Ayling R, McAuliffe L.(2008) Contagious Bovine Pleuropneumonia. Mycoplasma Diseases of Ruminants. UK: CABI, Publishing; 2008:69–97.

[8] Olorunshola, I. D., Peters, A. R., Scacchia, M., & Nicholas, R. A. (2017). Contagious bovine pleuropneumonia-never out of Africa?. *CABI Reviews*, (2017), 1-7.

[9] Ahmad, K. H., Mamman, P. H., Adamu, J., Bello, M., Olorunshola, I. D., Umar, B. N., Dalis J. S., Salawudeen, M. T. and Sada, A. (2024). Seroprevalence of Contagious Bovine Pleuropneumonia in Cattle Slaughtered from Sokoto and Zamfara States, North-western Nigeria. Sahel Journal of Veterinary Sciences. Vol. 21, No. 4, Pp 20-26.https://doi.org/10.54058/x8v68t59

[10] Mwirigi, M. K. (2016). Determination of Mycoplasma Mycoides Subsp. Mycoides Components That Confer Protection Against Contagious Bovine Pleuropneumonia and Understanding of Immunological Responses (Doctoral dissertation, University of Nairobi).

[11] Olorunshola, I. D., Daodu, B. O., Omoregie, S., Folahan, F. F., Ogah, I. J., Nicholas, R., Adegboye, D.& Peters, D. (2023). Recent trends and updates of Contagious Bovine Pleuropneumonia (CBPP) and Contagious Caprine Pleuropneumonia (CCPP) in Nigeria. Savannah Veterinary Journal, 6(1), 1-18.

[12] Alhaji, N. B., Ankeli, P. I., Ikpa, L. T., & Babalobi, O. O. (2020). Contagious bovine pleuropneumonia: challenges and prospects regarding diagnosis and control strategies in Africa. Veterinary Medicine: Research and Reports, 71-85.

[13] Ilemobade, A. A., Adegboye, D. S., Onoviran, O., & Chima, J. C. (1982). Immunodepressive effects of trypanosomal infection in cattle immunized against contagious bovine pleuropneumonia. Parasite immunology, 4(4), 273-282

[14] Nuvey, F. S., Mensah, G. I., Zinsstag, J., Hattendorf, J., Fink, G., Bonfoh, B., & Addo, K. K. (2023). Management of diseases in a ruminant livestock production system: a participatory appraisal of the performance of veterinary services delivery, and utilization in Ghana. BMC Veterinary Research, 19(1), 237.

[15] Nicholas, R. A. (2023). Contagious Bovine Pleuropneumonia: A Passage to India. Animals, 13(13), 2151.

[16]Abbott, K. A. (2024). Diseases of the respiratory system. In Sheep Veterinary Practice (pp. 483-508). CRC Press.

[17] Siankwilimba, E. (2024). Development of a sustainable cattle farming business model for small scale cattle farmers: the case of Namwala district of Zambia (Doctoral dissertation, The University of Zambia).

[18] Mulugeta, Y., Hordofa, D., & Elias, D. (2023). Participatory Epidemiology of Endemic Bovine Diseases amongest Dasanech and Nyangatom Pastoralists, South Omo Zone, Ethiopia.

[19] Lugonzo, G. O. (2023). Peste Des Petits Ruminants in Goats in Kwale County: Co-infection With Contagious Caprine Pleuropneumonia and Residents' Knowledge, Perception, and Socio-economic Aspect of the Two Diseases (Doctoral dissertation, University of Nairobi).

[20] Rocha, N. N., Silva, P. L., Battaglini, D., & Rocco, P. R. (2024). Heart-lung crosstalk in acute respiratory distress syndrome. Frontiers in Physiology, 15, 1478514.

[21] Surve, A. A., Hwang, J. Y., Manian, S., Onono, J. O., & Yoder, J. (2023). Economics of East Coast fever: a literature review. Frontiers in Veterinary Science, 10, 1-16.

[22] Thiaucourt, F. (1999). Contagious bovine pleuropneumonia and contagious caprine pleuropneumonia: historical review and actual threat for European cattle. Mycoplasmas of ruminants: pathogenicity, diagnostics, epidemiology and molecular genetics, 3, 5-13.

[23] Tweyongyere, R., Nkamwesiga, J., Etiang, P., 85. Mugezi, I., Wamala, H., Wasswa, A. T., Kamusiime, M., Ainebyoona, S., Abizera, H., Mwiine, F.N.& Muhanguzi, D. (2024). Seroprevalence of contagious bovine pleuropneumonia (CBPP) in cattle from Karamoja region, North-eastern

[24] Yalew, S. A. (2023). Historical analysis of animal diseases: Nagana in Southwestern Ethiopia, Gambella. Ethiopian Veterinary Journal, 27(1), 55-71. Uganda. BMC Veterinary Research, 20(1), 97

[25]. Penrith, M. L., & Thomson, G. (2012). Analysis of the status of transboundary animal diseases and their control in the SADC region during the period 2005-2011, focusing on the five countries that contribute land to the Kavango Zambezi (KAZA) Transfrontier Conservation Area (TFCA). Technical Report.

[26] Van Wolputte, S. (2015). "The natives are clever enough": contagious bovine pleuropneumonia and the politics of ambiguity in north-west Namibia. Social Dynamics, 41(1), 166-183.

[27] Muindi, P. W. (2014). A qualitative assessment of the gendered effects of contagious bovine pleuroneumonia (CBPP) outbreaks and control among the Somali Pastoralists of Ijara Sub-County, Garissa County, Northeastern Kenya (Doctoral dissertation, University of Nairobi).

[28] Mashinagu, M. M., Wambura, P. N., King, D. P., Paton, D. J., Maree, F., Kimera, S. I., Rweyemamu, M.M.& Kasanga, C. J. (2024). Challenges of Controlling Foot-and-Mouth Disease in Pastoral Settings in Africa. Transboundary and Emerging Diseases, 2024, 1-14.

[29] Amanfu, W. (2009). Contagious bovine pleuropneumonia (lungsickness) in Africa: historical overview: Onderstepoort and veterinary research in Africa. Onderstepoort Journal of Veterinary Research, *76*(1), 13-17.

[30] Ekwem, D., Morrison, T.A., Reeve, R., Enright, J., Buza, J., Shirima, G., Mwajombe, J.K., Lembo, T. and Hopcraft, J.G.C. (2021). Livestock movement informs the risk of disease spread in traditional production systems in East Africa. Scientific Reports, 11(1), 16375.

[31] Mohamud, H. (2010). Famine, displacement, and destitution among pastoralist communities in Northeastern Kenya (Doctoral dissertation, University of Alberta, Edmonton, AB, CA).

[32] Solazzo, D., Moretti, M. V., Tchamba, J. J., Rafael, M. F. F., Tonini, M., Fico, G., Basterrecea, T., Levi, S., Marini, L.& Bruschi, P. (2024). Preserving Ethnoveterinary Medicine (EVM) along the Transhumance Routes in Southwestern Angola: Synergies between International Cooperation and Academic Research. Plants, 13(5), 670.

[33] Ng'ang'a, C. M. (2022). Cultural Drivers of Brucellosis and Treatment Pathways for Febrile Illnesses Among Agro Pastoralists in Kilombero District, Tanzania (Doctoral dissertation, University of Nairobi).

[34] Akyeampong, E. (2020). An Unusual Kind of Town: Cattle Disease, Zoonosis, and Public Health in Colonial Salaga (Northern Ghana). The International Journal of African Historical Studies, 151-172.

[35] Nuvey, F. S., Arkoazi, J., Hattendorf, J., Mensah, G. I., Addo, K. K., Fink, G., Zinsstag, J.& Bonfoh, B. (2022). Effectiveness and profitability of preventive veterinary interventions in controlling infectious diseases of ruminant livestock in sub-Saharan Africa: a scoping review. BMC Veterinary Research, 18(1), 332.

[36] Friedmann, H., & McMichael, P. (1989). Agriculture and the state system. Sociologia ruralis, 29(2).

[37] Gansane, A. K. (2023). The global goods and their impact on society, economy, and environment:

Analysing the phenomenon from the Early Modern Age to the Contemporary Age.

[38] Blench, R. (2000). Extensive pastoral livestock systems: Issues and options for the future. London: ODI.

[39] Kimaro, E. (2018). Cattle vector-borne disease occurrence and management and climate change experiences in pastoral communities in Northern Tanzania (Doctoral dissertation).

[40] Chavwanga, V. (2014). The Department of Veterinary Services and Control of contagious Cattle Diseases in Zambia,1907-1990 (Doctoral dissertation).

[41] Wilhite, B. A. (2019). Current challenges in controlling ruminant diseases associated with *Mycoplasma bovis*, *mycoides*, and *ovipneumoniae*.

[42] Presicce, G. A. (2020). Food Security in Cameroon and Nigeria: Animal Production and Animal Health. Cameroon-Nigeria-Italy scientific cooperation: veterinary public health and sustainable food safety to promote "one health/one prevention", 12, 122.

[43] Osman, A. M. K., Olesambu, E., & Balfroid, C. (2018). Pastoralism in Africa's drylands: reducing risks, addressing vulnerability and enhancing resilience. Rome. 52pp.

[44] Weiss, H. (1998). " Dying Cattle": Some Remarks on the Impact of Cattle Epizootics in the Central Sudan during the Nineteenth Century. African Economic History, (26), 173-199.

[45] Grace, D., Dessie, T., Dione, M., Kiara, H., Liljander, A., Mariner, J.,Naessens, J., Okoth, E., Patel, E., Stienna, L., Toye, P.& Wieland, B. (2020). Transboundary animal diseases. In The Impact of the International Livestock Research Institute (pp. 274-301). Wallingford UK: CABI.

[46] Waller, R., & Homewood, K. (2017). Elders and experts: contesting veterinary knowledge in a pastoral community. In Western medicine as contested knowledge (pp. 69-93). Manchester University Press.

[47] Sharma, B., Parul, S., Goswami, M., & Basak, G. (2020). Animal disease surveillance and control: the Indian perspective. Acta Scientific Veterinary Sciences, 2(3), 1-8

[48] Bjornlund, V., Bjornlund, H., & van Rooyen, A. (2022). Why food insecurity persists in sub-Saharan Africa: A review of existing evidence. Food Security, 14(4), 845-864.

[49] Ssekibaala, G., Ilukor, J., & Walusimbi, S. (2024). Opportunities and challenges of a community-based bull breeding programme: a case of the regional pastoral livelihood resilience project in Uganda. Pastoralism: Research, Policy and Practice, 14, 13274.

[50] Mariner, J. C. (2005). Participatory approaches to the mathematical modelling of rinderpest and contagious bovine pleuropneumonia (Doctoral dissertation, University of Guelph).

[51] Beinart, W., & Brown, K. (2013). African Local Knowledge & Livestock Health: Diseases & Treatments in South Africa. Boydell & Brewer Ltd.

[52] Presicce, G. A. (2020). Food Security in Cameroon and Nigeria: Animal Production and Animal Health. Cameroon-Nigeria-Italy scientific cooperation: veterinary public health and sustainable food safety to promote "one health/one prevention", 12, 122.

[53] Sinkala, Y. (2015). Epidemiology of foot and mouth disease in Zambia (Doctoral dissertation, The University of Zambia).

[54] Egwu, G. O., Nicholas, R. A. J., Ameh, J. A., & Bashiruddin, J. B. (1996). Contagious bovine pleuropneumonia: an update. Veterinary Bulletin, 66(9), 877-888.

[55] Ogundipe, G. A. T. (2002). The roles of veterinary quarantine services in monitoring the movements of animals and disease prevention in Nigeria. Nigerian Veterinary Journal, 23(1), 1-15.

[56] Alhaji, N. B., & Babalobi, O. O. (2016). Sero-positivity and associated risk factors for contagious bovine pleuropneumonia under two cattle production systems in North Central Nigeria. Tropical animal health and production, 48, 3 11-320.

[57] Ackerman, D., Roden, L., & Robinson, L. 2023 Veterinary Mycoplasmas Research Report.

[58] Mariner, J. C., & Catley, A. (2003). The dynamics of CBPP endemism and development of effective control strategies. In Proceedings of the Third Meeting of the Consultative Group on Contagious Bovine Pleuropneumonia, Rome (pp. 76-80).

[59] Adesanya, O. S. (2021). Limitations Impacting Local Manufacturing of Vaccines: A Nigeria Case Study (Doctoral dissertation, Innopharma).

[60] Sinumvayo, J. P., Munezero, P. C., Tope, A. T., Adeyemo, R. O., Bale, M. I., Nyandwi, J. B., Vetja, H., Mutesa, L.& Adedeji, A. A. (2024). Advancing vaccinology capacity: education and efforts in vaccine development and manufacturing across Africa. Vaccines, 12(7), 1-9.

[61] de Haan, C. (Ed.). (2001). Livestock development: implications for rural poverty, the environment, and global food security. World Bank Publications.

[62] Olatunde, I. M. I. (2022). Production and Security of Food in Global Circle: An Exploration of its Challenges in Nigeria Since 1970. Wukari International Studies Journal, 6(2), 22-22.

[63] Salman, M. D. (2009). The role of veterinary epidemiology in combating infectious animal diseases on a global scale: The impact of training and outreach programs. Preventive veterinary medicine, 92(4), 284-287.

[64] Suleiman, A., Jackson, E. L., & Rushton, J. (2015). Challenges of pastoral cattle production in a sub-humid zone of Nigeria. Tropical animal health and production, 47, 1177-1185

[65] Azeez, A. (2021). Community Involvement in the Prevention of Bovine Tuberculosis among Nomadic Fulani and their Host Communities in Oyo State, Nigeria (Doctoral dissertation).

[66] Kuye, A., Dauda, M., Ameh, A. O., Danladi, M. I., Atuman, Y. J., Kia, G. S. N., & Häsler, B. (2024). An assessment of the operationality and factors influencing the effectiveness of rabies surveillance in Gombe State, Nigeria. PLOS Neglected Tropical Diseases, 18(5), e0012154.

[67] Suleiman, A., Jackson, E., & Rushton, J. (2018). Perceptions, circumstances and motivators affecting the implementation of contagious bovine pleuropneumonia control programmes in Nigerian Fulani pastoral herds. Preventive veterinary medicine, 149, 67-74.

[68] Soomro, M. A., Soomro, H., Hassan, M. F., Rajput, Z. I., Khanzada, M., & Meghwar, M. (2023). Mycoplasmosis: A Zoonotic Threat-Epidemiology, Pathogenesis and Economic Impact. Zoonosis, Unique Scientific Publishers, Faisalabad, Pakistan, 4, 17-28.

[69] Bamouh, Z., Elarkam, A., Elmejdoub, S., Hamdi, J., Boumart, Z., Smith, G., Suderman, M., Teffera, M., Wesonga, H., Wilson, S., Watts, D. M., Babiuk, S., Pickering, B., & Elharrak, M. (2024). Evaluation of a Combined Live Attenuated Vaccine against Lumpy Skin Disease, Contagious Bovine Pleuropneumonia and Rift Valley Fever. Vaccines, 12(3), 302.

[70] Thiaucourt, F., Exbrayat, A., Loire, E., Boissiere, A., Nwankpa, N., & Manso-Silván, L. (2024). Deep sequencing and variant frequency analysis for the quality control of a live bacterial vaccine against contagious bovine pleuropneumonia, strain T1. Vaccine, 42(8), 1868-1872.

[71] Faburay, B., & McVey, D. S. (2022). Mollicutes. Veterinary Microbiology, 364-376.

[72] Vashishtha, V. M., & Kumar, P. (2024). The durability of vaccine-induced protection: An overview. Expert Review of Vaccines, 23(1), 389-408.

[73] Tounkara, K., Nwankpa, N., Elsken, L., & Eloit, M. (2021). Role of the Regional and International Organizations in Vaccine International Standards. Veterinary Vaccines: Principles and Applications, 25-36.

[74] Onono, J. O., Wieland, B., Suleiman, A., & Rushton, J. (2017). Policy analysis for delivery of contagious bovine pleuropneumonia control strategies in sub-Saharan Africa. Revue scientifique et technique. 36(1), 195-205.

[75] Jores, J., Baldwin, C., Blanchard, A., Browning, G.F., Colston, A., Gerdts, V., Goovaerts, D., Heller, M., Juleff, N., Labroussaa, F., Liljander, A., Muuka, G., Nene, V., Nir-Paz, R., Sacchini, F., Summerfield, A., Thiaucourt, F., Unger, H., Vashee, S., Wang, X.& Salt, J. (2020). Contagious Bovine and Caprine Pleuropneumonia: a research community's recommendations for the development of better vaccines. NPJ vaccines, 5(1), 66.

[76] Mwacalimba, K., Kimeli, P., Tiernan, R., Mijten, E., Miroshnychenko, T., & Poulsen Nautrup, B. (2025). Diseases of Economic Importance in Feedlot Cattle in Sub-Saharan Africa: A Review with a Focus on Existing and Potential Options for Control. Animals, 15(1), 97.

[77] Saletti, G., Gerlach, T., & Rimmelzwaan, G. F. (2018). Influenza vaccines:'tailor-made'or 'one fits all'. Current Opinion in Immunology, 53, 102-110.

[78] Persson, A., Jacobsson, K., Frykberg, L., Johansson, K. E., & Poumarat, F. (2002). Variable surface protein Vmm of Mycoplasma mycoides subsp. mycoides small colony type. Journal of bacteriology, 184(13), 3712-3722.

[79] Gomez, P. L., Robinson, J. M., & Rogalewicz, J. A. (2013). Vaccine manufacturing. Vaccines, 44.

[80] Adesola, R. O., Opuni, E., Idris, I., Okesanya, O. J., Igwe, O., Abdulazeez, M. D., & Lucero-Prisno III, D. E. (2024). Navigating Nigeria's Health Landscape: Population Growth and Its Health Implications. Environmental Health Insights, *18*, 11786302241250211.

[81] Mouiche-Mouliom, M. M., Wafo, E. E. N., Mpouam, S. E., Moffo, F., Feussom, J. M. K., Ngapagna, A. N., Mfopit, Y.& Abdoulmoumini, M. (2024). Zoo-sanitary situation assessment, a preliminary step for country disease prioritization approach? Systematic review and meta-analysis from 2000 to 2020 in Cameroon. Authorea Preprints.

[82] Rosen, L. E., Amuthenu, N. S., Atkinson, S. A., Babayani, N. D., Elago, S. A. T., Hikufe, E., Mafonko, B.R., Mbeha, B., Mokopasetso, M., Motshegwa, K. & Osofsky, S. A. (2024). Veterinary Fences in the KAZA TFCA: Assessment of Livestock Disease Risks of Potential Removal of Specific Fence Sections, with an Emphasis on the Botswana-Namibia Border. AHEAD Programme, Cornell University on behalf of the KAZA Animal Health Sub Working Group.

[83] Magona, J. W., Oppong-Otoo, J., Boussini, H., Isyagi, N., Sidibé, C. A., Wabacha, J. K., & Huyam, S. (2024). Current trends on antimicrobial use and emergence of resistance in the animal health sector in Africa: A review covering the period 2013-2023.

[84] Molnar, G., & Godefroy, S. B. (2020). Review of mechanisms for food safety-related SPS measures within African regional Economic Communities (RECs): Paving the way for a continent-wide food safety coordination effort. Food Control, 115, 107206.

[85] Rahman, H., Hiremath, J. B., Vijayalakshmy, K., & Bujarbaruah, K. M. (2024). Transforming Animal Health Sector. In Transformation of Agri-Food Systems (pp. 33-43). Singapore: Springer Nature Singapore.

[86]Tolesa, A., Jaleta, D., Merdasa, D., & Neggasa, T. (2024). Seroprevalence and associated risk factors of contagious bovine pleuropneumonia in three districts of Ilu Ababor Zone, Oromia, Ethiopia. Ethiopian Veterinary Journal, 28(2), 86-102.

[87] Thompson, L., Cayol, C., Awada, L., Muset, S., Shetty, D., Wang, J., & Tizzani, P. (2024). Role of the World Organisation for Animal Health in global wildlife disease surveillance. Frontiers in Veterinary Science, 11, 1-8.

[88] Teshome, D., Tessema, T., Kumsa, S., Muluneh, B., Sacchini, F., & Kumbe, A. (2024). Sero-prevalence of contagious bovine pleuropneumonia in dryland of Borana, southern Oromia, Ethiopia. Research in Veterinary Science, 166, 105100.

[89] Patil, C. B., & Chinmayi, S. (2024). Agroterrorism: Assessing the Growing Threat to Global Food Security and Economic Stability. International Journal of Biochemistry Research & Review, 33(6), 207-214.

[90] Jaime, G., Hobeika, A., & Figuié, M. (2022). Access to veterinary drugs in sub-saharan Africa: Roadblocks and current solutions. Frontiers in Veterinary Science, 8, 558973.