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A Review on Zoonotic and Economic Importance of Anthrax

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Abstract

Anthrax is a highly contagious disease caused by the bacterium bacillus anthracis, impacting both humans and animals, with a higher prevalence in livestock and economically significant wild animals. Herbivorous animals can contract the disease by inhaling or ingesting spores while grazing, while carnivores may become infected by consuming infected herbivores. In humans, infection typically occurs through contact with the spores via ingestion, inhalation, or direct contact. The disease does not spread directly from person to person; instead, the resilient spores of bacillus anthracis act as the primary source of infection, capable of surviving in the environment for extended periods. Severe outbreaks of anthrax have been observed in regions with tropical and sub-tropical climates and high rainfall. Essential measures for managing the disease include controlling infected animals, preventing contact with them and their products, implementing quarantine on affected properties, vaccinating potentially exposed livestock, disposing of dead animals properly, and disinfecting contaminated areas. Quarantine restrictions should be lifted only after no new cases of anthrax have been reported for at least six weeks following vaccination. Individuals exposed to the disease may receive an anthrax vaccine as a preventive measure. Bacillus anthracis is susceptible to various antibiotics such as penicillin, chloramphenicol, streptomycin, tetracycline, and erythromycin.

Keywords: Animal; Anthrax; Bacillus Anthracis; Human Infection

Abbreviations

°C: Celsius Degrees; CDC: Communicable Diseases Control; CFR: Case Fatality Rate; CO2: Carbon Dioxide; EF: Edema Factor; FAO: Food and Drug Administration Organization; GDP: Gross Domestic Products; LF: Lethal Factor; SNNPR: Southern Nation and Nationalities People Region; USD: United States Dollars; WHO: World Health Organization.

Introduction

Anthrax is a zoonotic illness caused by the gram-positive spore-forming bacterium Bacillus anthracis. It primarily impacts domestic and wild herbivores, such as cattle, sheep, goats, bison, deer, antelope, and hippos, and is typically fatal in these species. The disease is widespread globally and remains endemic in various regions worldwide, notably in sub-Saharan Africa, Asia, and Central and South America (World Health Organization [1].

Anthrax is essentially a disease that affects all warm-blooded creatures, including humans. The term 'anthrax' originates from the Greek word 'anthrakos,' meaning coal, alluding to the characteristic eschar found in the human cutaneous form. The disease has various names in different regions, such as splenic fever, wool sorter disease, Siberian ulcer, Charbon, and Milzbrand [2]. Although anthrax is present on all continents except Antarctica, it is particularly prevalent in parts of Africa, Asia, and the Middle East where animal control measures are inadequate [3].

Herbivorous and wild mammals typically contract anthrax through ingesting or inhaling spores while grazing. Ingestion is believed to be the primary method by which herbivores acquire anthrax. Carnivores sharing the same environment may become infected by consuming contaminated animals [4]. Human cases usually arise from exposure to infected animals and their tissues. Human anthrax is infrequent and sporadic in most countries, primarily affecting veterinarians, agricultural workers, and individuals handling hides, hair, wool, and bone products [5]. There have been no documented instances of human-to-human transmission. In humans, anthrax manifests in three forms: cutaneous, gastrointestinal, and inhalational. The incubation period for humans typically ranges from 1 to 7 days but varies depending on the form of the disease [1].

Anthrax is a disease that is found worldwide, with reported cases on all continents where animals and humans are densely populated. The World Anthrax Data Site, a World Health Organization Collaborating Center for Remote Sensing and Geographic Information Systems, documented animal anthrax outbreaks in nearly 200 countries between 1996 and 1997 [6]. The data collected by this site includes information on the country of origin, anthrax status, vaccination programs, affected species, outbreak years, number of outbreaks per year, cases reported, vaccinated individuals, and total livestock population. Countries are categorized based on their anthrax status, which can be hyperendemic/epidemic, endemic, sporadic, probably free, free, or unknown. For instance, countries like Zimbabwe experienced an anthrax epidemic from 1978 to 1980, resulting in infections in approximately 10,000 humans and 151 deaths. Regions with unknown anthrax status include the polar extremes of the Arctic and Antarctic [7].

In Ethiopia, animal anthrax is an endemic disease that typically occurs during the months of May and June, known as the anthrax season, in various farming areas of the country. While suspected cases of livestock anthrax are reported from multiple districts, only a few are officially confirmed [8]. Previous studies have shown that rural communities are familiar with the disease, but there is limited information available regarding its prevalence, epidemiology, and public health implications [9]. In the Ethiopian fiscal year 2003, the Federal Democratic Republic of Ethiopia Ministry of Health surveillance data indicated a total of 1,096 suspected human anthrax cases and 16 deaths with a Case Fatality Rate (CFR) of 1.5% reported from four regions (Tigray, Amhara, Oromia, and SNNPR). The highest number of cases were reported in Tigray (396), followed by SNNPR (340), Amhara (296), and Oromia (64), with the highest number of deaths (9) occurring in SNNPR (56% of total deaths), followed by Oromia (5 deaths – 31%) and Tigray (2 deaths – 13%) (Ministry of Health, 2010/11). In 1993, there were 305 reported cases of anthrax, while none were reported in 1994.

Zoonoses are diseases that can be transmitted between animals (both domestic and wildlife) and humans. It is estimated that around 60% of all human diseases and approximately 75% of emerging infectious diseases are zoonotic. Anthrax is a significant zoonotic disease that can affect a wide range of mammals and various bird species [10].

Therefore, the objectives of this study are to examine anthrax, explore its zoonotic implications, and emphasize its economic importance.

Anthrax

Etiology

Anthrax is a bacterial illness caused by the spore-forming Bacillus anthracis, a gram-positive, rod-shaped bacterium. This bacterium is aerobic, non-motile, and forms centrally located spores. Bacillus anthracis is classified in the family Bacillaceae [11]. The outermost part of the bacterium that interacts with the host when in its spore form is the exosporium primarily composed of protein with lipid and carbohydrate components [12]. Although the exact function of the exosporium is not fully understood, it appears to have pili structures that enhance spore attachment to surfaces [13].

Bacillus anthracis possesses a unique capsule that significantly contributes to its virulence. This capsule improves the bacterium's ability to evade host defenses and can lead to septicemia. The S-layer, which is the outermost layer of the bacterium covering the peptidoglycan, carries a negative charge that hinders macrophages from engulfing and eliminating Bacillus anthracis [14]. Vegetative cells of anthracis impede the host's immune response [15]. These vegetative cells are gram-positive, containing an extensive peptidoglycan layer and S-layer protein. Polysaccharides in the cell wall play a role in attaching the protective S-layer to the cell wall [16].

Epidemiology

Occurrence

The disease is believed to have originated in sub-Saharan Africa and has since spread globally, with varying levels of prevalence depending on factors such as soil, climate, and prevention efforts. B. anthraces can be found in soils worldwide, so isolating them from a specific environment does not guarantee their absence in that habitat [17]. Accidental ingestion of contaminated bone meal or pasture, often due to tannery effluent, is a common source of infection. In these cases, outbreaks are rare, with only a small number of animals affected. The development of an effective live vaccine, along with the use of penicillin and quarantine measures, has significantly reduced the occurrence of anthrax in many countries compared to its historical levels [18].

The primary reservoir for B. anthraces is contaminated soil, where spores can remain viable for long periods. Herbivores, as the main hosts, become infected when grazing in contaminated areas. Since the organism does not rely on an animal reservoir, it is difficult to eradicate from a region, leading to endemic anthrax in many countries [16].

Human infection typically occurs through contact with infected animals or animal products. Nonindustrial anthrax affects those who work closely with animals or carcasses, such as farmers, veterinarians, and butchers, usually manifesting as cutaneous anthrax. Industrial anthrax, acquired from handling contaminated animal products like hair or hides, is more likely to result in pulmonary anthrax from inhaling spore-laden dust [19].

Risk Factors

Host Factor: Anthrax affects all vertebrates, with cattle and sheep being the most susceptible, followed by goats and horses. Humans fall between these groups and more resistant animals like pigs, dogs, and cats. The disease is typically fatal in farm animals, except for pigs, although the fatality rate is still high in this species.

Agent Factor: The virulence of Bacillus anthracis strains is attributed to lethal factor (LF) and edema factor (EF), along with a protective antigen that forms spores. The primary virulence factors are the toxins and capsule of the bacterium, which consist of three protein components: EF, PF (protective factor), and LF. These components work together synergistically, with EF and LF entering target cells by competitively binding with PF. The presence of all three components leads to maximum lethality, and only encapsulated toxigenic strains are virulent [16,20].

Pathogen Factors: When material containing anthrax bacilli is exposed to air, spores form that can remain infective in the environment for extended periods. These spores are highly resistant to external influences such as temperature, disinfectants, and even salting of hides. Anthrax bacilli can survive for decades in soil, especially in warm climates with organic matter present. Acidic soils reduce the survival of Bacillus anthracis [21].

Environmental Factor: In tropical and sub-tropical regions with high rainfall, anthrax infection persists in the soil, leading to frequent and severe outbreaks. Some African countries experience annual outbreaks during summers with heavy rainfall, causing significant wildlife mortality. Predators may act as carriers of the infection. In temperate climates, sporadic outbreaks occur due to soil-borne infections triggered by specific climatic conditions like heavy rain after drought or dry summers following prolonged rain when the temperature exceeds 15°C. The relationship with climate allows for predicting anthrax longevity in soil based on environmental conditions [22].

Transmission

Infections can enter the body through ingestion, inhalation, or skin contact. The organism can spread within an area through various means such as streams, insects, dogs, wild birds, and fecal contamination from infected animals. Introducing infection to a new area often occurs through contaminated animal products like bone meal, fertilizers, hides, wool, or contaminated concentrates and forage. Inhalation infection is generally considered less significant in animals, although the risk of infection through contaminated dust should always be taken into account. Wool sorter's disease in humans is caused by inhaling anthrax spores in the wool and hair industries, but cutaneous anthrax is more prevalent even in these industries [19].

Pathogenesis

When inhaled, B.anthracis spores require a lesion to enter the body. Once inside, the spores may start to germinate and travel to the lymphatic system where they multiply. Initially, during the incubation period, the bacteria are filtered by the spleen and other parts of the reticulo-endothelial system. However, the system eventually breaks down due to toxin action, leading to internal bleeding in the final hours of life. The Anthrax toxin is thought to play a role in two stages of infection. In the early stages, it manipulates the immune response to ensure survival in the host and aid in spreading. In systemic disease, the toxin targets tissues and causes lethality [23].

When ingested, infection can occur through intact mucous membranes, epithelial defects around erupting teeth, or scratches from tough food materials. The organism is resistant to phagocytosis, partly due to the presence of the body-D-glutamic acid capsule. It multiplies in regional lymph nodes and spreads through lymphatic vessels into the bloodstream, leading to septicemia with widespread invasion of body tissues. Bacillus anthracis produces a lethal toxin that causes edema, tissue damage, shock, acute renal failure, and ultimately anoxia. In pigs, the infection localizes in throat lymph nodes after invading through the upper digestive tract, often resulting in fatal septicemia from local lesions [19].

Clinical Finding

In Animals

Cattle are more commonly affected by anthrax compared to other herbivores due to their feeding behavior. Unlike sheep or goats, which bite plants off at ground level or browse on shrubs, cattle tend to pull pasture out of the ground with roots. This behavior increases their likelihood of ingesting high doses of the bacterium from potentially contaminated soil [24]. In Wales, bovine anthrax outbreaks are more frequent than in sheep [25]. With significantly higher mortality rates. The disease in ruminants typically progresses rapidly, with death occurring within 3-5 days depending on the ingested dose [26]. Clinical signs of anthrax in cattle include staggering, excitation/somnolence, convulsions, recumbences, spasms, dyspnea, colic, and swellings around the neck, chest, and abdomen. Animals may be found dead near water sources or grazing fields where previous cases were reported. Ulcers in the oral cavity and bleeding from the nose and anus are common in dying animals. Herbivore blood at death contains high levels of bacilli that can speculate upon exposure to air. Acute forms of the disease may present with fever, congested mucous membranes, muscle spasms, labored breathing, and eventual death [27]. Additionally, abortions and blood-stained or yellowish milk have been reported in dairy cattle affected by anthrax [24].

Horses exhibit a severe form of infection characterized by symptoms such as fever, abdominal pain, diarrhea, difficulty breathing, swellings with dead tissue at the center, and bloody discharge from the nose and anus [27]. Pigs have a moderate level of resistance to the infection but can sometimes develop asymptomatic infections that are occasionally detected during slaughter or post-mortem examinations. Symptoms in pigs may include inflammation of the throat, painful neck swellings, and skin lesions. In cases where the gastrointestinal tract is affected, signs like vomiting, jaundice, and diarrhea may be observed. Pathological changes seen during post-mortem examinations are primarily located in the throat and intestines [28].

Carnivores can become infected by consuming carcasses contaminated with anthrax, although they generally have some resistance to the disease. Cheetahs and mink are more vulnerable to anthrax compared to other carnivores, with a variety of carnivores reported to have been affected over time [29]. Domestic dogs have also been unintentionally exposed to anthrax spores in bioterrorism attacks. Following an incubation period of approximately 3-5 days, infected dogs may exhibit symptoms such as high fever (>40°C), lethargy, loss of appetite, and the development of swollen, edematous lesions on various body parts, ultimately leading to death with the presence of bloody discharge from bodily openings. Mink experience a rapid incubation period of less than 20 hours, resulting in a mortality rate of 50-100% with significant pathological changes including enlarged spleens and pulmonary edema. In dogs, the oropharynx and upper gastrointestinal tract serve as primary entry points for the bacterium, causing swelling in the head, neck, and mediastinal structures. Symptoms in dogs may include excessive drooling, diarrhea, and swollen forelimbs, with reports of shock and toxemia leading to death in cases where dogs consumed contaminated carcasses [29].

Except for ostriches, anthrax infections have only been documented in birds kept in captivity, such as poultry, pigeons, and eagles. Nevertheless, these occurrences are infrequent, and when they do happen, affected birds typically exhibit symptoms of septicemia and succumb to sudden death. From a pathological perspective, observable signs include darkened skin coloration, swollen and congested lungs, and hemorrhagic inflammation of the intestines [30].

In Humans

Anthrax infection in humans is divided into two main categories: Agricultural and Industrial. Agricultural cases occur when individuals come into contact with tissues from infected or deceased animals, excluding ostriches. In captive birds like poultry, pigeons, and eagles, anthrax infections are rare but can lead to symptoms of septicemia and sudden death. Pathologically, affected birds may show darkened skin, swollen lungs, and hemorrhagic inflammation in the intestines [30]. These cases typically involve individuals such as veterinarians, butchers, slaughterhouse workers, and ranchers who handle or process infected animal products. Industrial cases, which accounted for 65% of cases reported between 1955-1999, occur during the cleaning and processing of contaminated animal materials like hair, wool, hides, and skins [31].

In humans, anthrax can manifest in three primary forms depending on the route of infection. Cutaneous anthrax is the most common form, representing up to 90% of cases. It is characterized by a black skin lesion with a necrotic center surrounded by a fluid-filled vesicle that eventually forms a painless black scab. Gastrointestinal anthrax is the second most common form and results from consuming contaminated meat, leading to ulcerative lesions in the intestines. Inhalational anthrax, the most fatal and rare form, occurs through inhaling anthrax spores in the environment and is often associated with industrial exposure. Meningeal anthrax is a rare complication that can develop from any of the other forms and involves the spread of bacteria or exotoxins to the brain and meninges [29,32-34].

Diagnosis

To confirm a diagnosis on an unopened carcass, it is recommended to collect peripheral blood or local edema fluid through needle puncture. If blood is difficult to obtain, sampling from the jugular vein may be necessary. Careful collection of blood from an ear vein can also be done to prevent contamination and sporulation. The smears should be prepared and analyzed by a microbiologist with experience and qualifications. It is important to note that there is a high risk of zoonotic transmission when handling carcasses and submitting specimens [19].

In Direct Microscopy, Bacillus anthracis forms a capsule in vivo, and either Giemsa or polychrome methylene blue stains can be used to visualize the capsule, which is diagnostically significant. The capsule material is more prominent in blood smears taken from recently deceased animals. Smears stained with polychrome methylene blue show square-ended, blue rods arranged in short chains surrounded by pink capsule material. In Giemsa-stained smears, the capsule appears reddish [35].

Isolating and cultivating Bacillus species within the Bacillus cereus group typically involves their growth on sheep or ox blood agar aerobically at 37°C, with visible growth occurring within 24-48 hours. To ensure the purity of the culture, a MacConkey agar plate can be used as a secondary measure to detect any gram-negative contaminants present in the specimen. In cases where the specimen is contaminated with substances like hair, bone meal, or animal feeds, it is recommended to finely grind the material, soak it in saline solution, and then heats it at 65°C for 10 minutes. Following this, the cooled suspension is filtered through gauze and centrifuged to obtain a deposit that can be utilized for either further culture or animal inoculation [35].

When virulent strains of bacteria are cultured in a medium containing serum or bicarbonate, they develop capsules, and colonies become visible within 24 hours. These colonies typically appear flat, gray in color, and are usually non-hemolytic, ranging from smooth to mucoid. In contrast, if serum or bicarbonate is absent from the culture medium, the bacteria do not form capsules, resulting in rough colonies [36].

The Identification of Bacillus anthracis based on colonial morphology in a hospital microbiology laboratory involves examining a direct Gram's stained smear of skin lesions, blood, or cerebrospinal fluid. This method reveals encapsulated, large Gram-positive bacilli arranged in short chains. Following an incubation period of 18-24 hours, growth is observed on blood agar plates, characterized by grey/white colonies measuring 2-5 mm in diameter with irregular edges. Blood cultures typically yield positive results within six to 24 hours [16].

Confirmation of the diagnosis often involves animal testing, as Bacillus anthracis is more pathogenic to guinea pigs and mice compared to other Bacillus species, leading to death within 24 hours. Spleen and blood smears from infected animals reveal large encapsulated rods, further confirming the presence of the pathogen [16].

Bacillus anthracis exhibits a unique liquefaction pattern resembling an inverted fir tree with side shoots extending from the stab line, contrasting with other species that rapidly liquefy nutrient gelatin. Typically, Bacillus anthracis and most other Bacillus species do not form capsules on laboratory media, presenting with dry colonies. However, the production of capsules by Bacillus anthracis can be induced by cultivating it on nutrient agar supplemented with 0.7% sodium bicarbonate under 10% CO_2, resulting in noticeably mucoid colonies [28].

Differential Diagnosis

Depending on the clinical presentation or symptoms, the disease can be distinguished from various other conditions. Glanders is characterized by fever and inflamed lymph nodes, but does not involve bloody diarrhea, and there is no presence of tarry blood after death. Plague presents with fever, skin bleeding, and swollen lymph nodes, but lacks painless lymph node swelling and does not involve loss of clotted blood from natural openings [37]. Typhoid fever is characterized by high fever and edema in the chest and abdomen, but does not involve swelling of lymph nodes. Q fever presents with symptoms similar to influenza and pneumonia. In cases of black leg, there is edema of skeletal and cardiac muscle. The ulcerative eschar of cutaneous anthrax must be differentiated from other popular lesions that present regional lymphadenopathy. If the lesion is purulent and the regional lymph nodes are palpable, staphylococcal lymphadenitis is the most likely cause, although cutaneous anthrax lesions can be superinfected with pyogenic bacteria [38].

Treatment

Bacillus anthracis is susceptible to several antibiotics, including penicillin, chloramphenicol, streptomycin, tetracycline, and erythromycin. Treatment should be continued for at least five days. However, in cases of acute anthrax, antimicrobial treatment is often ineffective [38].

Initiating treatment with any of these antibiotics within 24 hours of infection protected animals during treatment, but many animals succumbed to anthrax after treatment cessation, with varying levels of protection ranging from 10-90 percent. When antibiotic treatment was combined with a protective antigen vaccine, all animals remained fully protected even after treatment cessation. Animals whose treatment was delayed beyond 24 hours post-infection experienced differing levels of bacteremia and toxemia [39].

Control and Prevention

Effective control of anthrax hinges on thorough monitoring of the disease, which involves actively investigating outbreaks and utilizing historical data, implementing sustainable livestock vaccination programs, and appropriately disposing of infected carcasses. Understanding the bacterial characteristics, eco-epidemiological niche, and risk factors for natural occurrences is crucial in identifying potential anthrax hotspots. This knowledge can help predict outbreaks and facilitate the implementation of preventive measures to mitigate the spread of the disease. Timely identification and reporting of anthrax outbreaks enable preparedness and early intervention efforts to contain further transmission and prevent human infections [30].

In endemic regions, proactive and strategic deployment of vaccines and personnel before natural risk factors manifest is essential in reducing the prevalence of anthrax. Proper disposal of infected carcasses and decontamination of contaminated materials are key measures in decreasing the number of spores. Effective disposal methods include incineration, rendering, deep burial, or allowing the carcass to decompose undisturbed. Incineration is the most reliable method as it ensures complete destruction of the bacteria, eliminating spores from the environment [30].

Rendering or sterilization processes may not always eradicate all bacteria, potentially leaving rendered material as a source of infection for animals. Deep burial, when combined with disinfection, can be an alternative method, with recommendations to bury carcasses at least six feet deep and cover them with lime-mixed soil to prevent spore exposure. However, disturbances to burial sites can lead to spores resurfacing and causing new outbreaks. Leaving an anthrax-infected carcass untouched, fenced off, and isolated from scavengers and humans for natural decomposition is considered the least preferred option. While this method minimizes spore dissemination, there is still a risk of environmental contamination from bloody discharges during putrefaction. Scorching the site post-decomposition can help reduce this risk.

Zoonotic Importance

Anthrax primarily impacts herbivorous animals, with humans typically contracting the disease through contact with infected animals or their byproducts. Occupational exposure to anthrax is common among individuals handling processed hides, goat hair, bone products, wool, and infected wildlife. Workers in abattoirs who handle infected meat are also at risk of contracting the disease. The introduction of animal feed containing bone meal can lead to new outbreaks of anthrax in livestock. Cutaneous infections may occur in knackery workers and individuals handling pet meat. Additionally, anthrax can be utilized as a biological weapon, often spread as an aerosol, prompting consideration of this possibility when assessing new cases, particularly in instances of pulmonary anthrax [40].

Anthrax remains a significant threat in certain regions, with occasional outbreaks in humans. In Africa, it is estimated that one cow with anthrax can lead to up to ten human cases. However, the incidence of anthrax has significantly decreased in developed countries. For instance, in the United States, while around 130 human cases occurred annually in the early 1900s, only one or two cases of cutaneous anthrax are typically reported each year now. In many countries, anthrax cases are rare and sporadic, primarily affecting veterinarians, agricultural workers, and those involved in processing hides, hair, wool, and bone products as an occupational hazard. The cutaneous form of anthrax accounts for the majority (90-95%) of natural infections, while the gastrointestinal form is less common but can occur during outbreaks linked to contaminated meat. Natural cases of inhalational anthrax are uncommon, but it is expected to be more prevalent if used as a biological weapon. In 2001, a bioterrorist attack involving anthrax-contaminated mail resulted in 11 cases of inhalational anthrax and 11 cases of cutaneous anthrax. The mortality rates vary depending on the form of the disease, with untreated cutaneous anthrax having a fatality rate of 5-20% and less than 1% with antibiotic treatment. Inhalational anthrax has a high mortality rate even with appropriate treatment, with earlier estimates suggesting a rate of 90-100%, but newer treatments may reduce this. In the 2001 attack, six out of eleven patients with inhalational anthrax recovered with treatment (a case fatality rate of 45%), but once the fulminant stage is reached, mortality is high at 97% regardless of treatment. Anthrax meningoencephalitis is also deadly, with an estimated case fatality rate of 95-100%. Limited information exists for gastrointestinal anthrax, with estimates of a case fatality rate ranging from 25% to 60-75%. Some outbreaks have shown asymptomatic or mild infections in adults, but higher mortality rates in [40].

Economic Significance

The impact of anthrax disease results in a decrease in productivity by hindering the efficient conversion of resources into output or products. In many developing nations, the vaccination of vulnerable animals in areas endemic to the disease has significantly decreased its prevalence to almost negligible levels on a national scale. Nonetheless, individual herds may still face substantial losses. These losses stem from both mortality and the temporary cessation of milk production in infected dairy herds. Additionally, following vaccination, issues may arise due to animal deaths, diminished animal product output, complete disposal of carcasses and by-products, and the closure of slaughterhouses.

The mortality rates for anthrax vary across different animal species. While clinical infections in ruminants and horses typically lead to fatality, pigs often manage to recover. Carnivores also exhibit relatively low mortality rates, although this data is not widely available for wild animals (Table 1) [40].

Livestock keepers		Consumers	Total
Years of life lost due to mortality (YLL)	187595.65	6045.37	193641.02
Years lost due to morbidity (YLD)	0.93	0.2	1.13
Disability-Adjusted Life Years DALYs (YLL+YLD)	187596.58	6045.57	193642.15
Willingness to pay for one year of healthy life (USDPPP)	2100	2100	2100
Total social cost (USDPPP)	393952817	12695693	406648510
Total social cost as percent of GDP (USDPPP)	0.22	0.01	0.23

Table 1: Estimates of the annual public health costs of anthrax in Ethiopia.
Source: FAO [41]

The economic impact of anthrax is significant, considering both the value of animals lost and the productivity lost within the production systems. Even though expert opinions suggest a generally low prevalence of anthrax, the total economic cost of the disease amounts to USD 162.86 million (PPP), with two-thirds of this cost originating from the mixed-crop livestock system. The majority of this loss (~90 percent) stems from the immediate death of affected animals. These losses account for 0.85 percent of the contribution of livestock to GDP and 0.09 percent of total GDP, per anthrax case and as a percentage of the farm-gate price of healthy animals [41].

In intensive/semi-intensive systems, the occurrence of anthrax results in the complete loss of value for infected animals. Some value can be recuperated through salvage slaughtering among livestock keepers in mixed crop-livestock and pastoral/agro-pastoral production systems. The social costs of anthrax, measured in Disability-Adjusted Life Years (DALYs), reach 187,596.58 and 6,045.57 among livestock keepers and consumers, respectively. The corresponding monetary costs (USD PPP) amount to 393,952,817 and 12,695,693 USD within these two risk groups, respectively. In total, the social cost of anthrax stands at 406,648,510 USD (PPP), equivalent to 0.23 percent of GDP (PPP).Comparatively, the total public health and livestock-related monetary costs (USD PPP) stemming from anthrax showcase the highest social costs within the mixed crop-livestock system, followed by the pastoral/agro-pastoral system. When contrasting the total public health costs (for both livestock keepers and consumers) with the value lost in animals, it becomes evident that over two-thirds of the economic impact of anthrax affects the public (Table 2) [41].

	Dairy C.	Feedlot	U/P-U	Mixed	P/A-P	TOTAL
Estimated prevalence	0.10%	0.1%.	0.20%	0.50%	0.50%	0.47%
Value of animals lost (million USD PPP	8.19	0.11	28.5	91.52	16.51	144.85
Value of production lost (million USD PPP)	-	-	-	15.25	2.75	18
TOTAL (million USD PPP)	8.19	0.11	28.5	106.78	19.27	162.86
Total loss, percent of livestock share in GDP	0.04	0.001	0.15	0.56	0.1	0.85
Total loss, percent of GDP	0.005	0	0.02	0.06	0.01	0.09

Table 2: Prevalence of anthrax and estimates of its economic costs In Ethiopia.
Dairy C. = Commercial Dairy; Feedlot = Beef Feedlot; U/P-U = Urban/Peri-urban; Mixed = Mixed Crop Livestock; P/A-P = Pastoral/Agro-pastoral.

Shows the economic impact of anthrax is significant, with a total cost of USD 162.86 million (PPP) attributed to the disease. The majority of this cost, two-thirds, comes from the mixed-crop livestock system. The main factor contributing to this cost is the immediate death of affected animals, accounting for around 90 percent of the losses. In terms of the overall economy, the losses represent 0.85 percent of the contribution of livestock to GDP and 0.09 percent of total GDP. Despite the low overall prevalence of anthrax, the financial impact on both animals and production systems is substantial (FAO, 2017) [41].

Conclusion and Recommendations

Anthrax, caused by the bacteria bacillus anthracis, is a contagious disease affecting both animals and humans. It poses significant challenges through animal deaths, decreased animal product availability, condemnation of carcasses, and closure of abattoirs. In humans, it can manifest as pulmonary, intestinal, or cutaneous anthrax. Controlling the spread of anthrax in meat and milk-producing animals is crucial to prevent risks to human health. During outbreaks, measures such as quarantining affected farms, disposing of infected animals and carcasses, and vaccinating surviving animals are essential components of disease control efforts that indirectly reduce human exposure.

To mitigate the impact of anthrax, specific recommendations include:

- Avoiding consumption of raw meat
- Prompt diagnosis and treatment of sick animals with effective antibiotics
- Quarantining affected properties and vaccinating potentially exposed livestock in confirmed cases
- Implementing strict control measures for infected animals and preventing contact with contaminated animals and products
- Practicing environmental and personal hygiene, including disinfection with formaldehyde
- Providing health education on industrial hygiene precautions for farmers, butchers, tanners, and other workers
- Establishing vaccination schedules for individuals at risk.

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