Causal Factors and Epidemiological Analysis of the Main Bovine Zoonoses

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ABSTRACT

Even though cattle farming is a fundamental livestock activity in the production of food and the development of many countries, it is generating adverse effects on the environment and health. The invasion of natural ecosystems to expand breeding sites increases contact with wildlife and its pathogens, causing domestic animals to participate as potential reservoirs, which increases the risks of transmission of zoonotic diseases to humans. This condition highlights the relevance that animals have in both the origin and transmission of these diseases. The identification of causal factors, such as etiological agents, pathogenicity, environmental conditions in which they develop, transmission mechanisms, as well as risk factors for human and animal health, are decisive for generating intervention strategies.

From the epidemiological point of view, imbalances in the ecological triad etiological agent-host-environment are associated with natural changes in the environment, physical and chemical factors and the biological conditions of the pathogens that manifest under certain conditions, initiating the epidemiological chain, so the scope of each zoonosis will depend on environmental conditions, prevalence and incidence.

In the case of cattle, zoonoses can affect both productivity and public health, so adequate health management is essential, which includes primary prevention measures that guarantee the health of the animals by providing them with the necessary conditions of well-being and specific protection. Likewise, at a secondary level, early diagnosis and timely treatment of the disease, to promote the recovery of the animal and thereby reduce the risks of transmission to humans. The problem currently faced is the diversity of diseases and etiological agents that produce zoonotic diseases in cattle, highlighting bacterial, parasitic and viral zoonoses. Many of these diseases have a global distribution, such as brucellosis, anthrax, leptospirosis and tuberculosis, which are present in all five regions of the world. The current challenge, in addition to strengthening prevention and control measures, is to ensure that public, animal and environmental health function comprehensively.

Keywords: Cattle, ecological triad, Natural History of the Disease, epidemiological analysis, etiological agent, zoonoses

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1. INTRODUCTION

Bovine farming is a fundamental activity for food production and development in many countries. As per report by FAO, the availability of beef increases by 5.9%, while its consumption by 20% until 2030 (OECD-FAO 2021). In 2021, the countries with the highest number of cattle were Brazil (224.6 million), India (193.2) and the United States (93.8). However, by 2022, the main producers of beef were the United States, Brazil, and China, with 12.8, 10.3 and 7.1 million metric tons, respectively (Orús 2023).

Although bovine production volumes make an important contribution to global food security, they are also having adverse effects on the environment and health. In addition to the factors inherent to climate change, the demographic explosion, migration, urbanization and the trade in animals increases the incidence of zoonoses that is associated with the modifications introduced to livestock production. The invasion of natural ecosystems to expand breeding sites increases contact with wildlife and its pathogens, causing domestic animals to participate as potential reservoirs and increasing the risks of disease transmission to humans (Morand et al. 2014).

Zoonoses represent important economic losses. Losses in the productivity and development of animals, abortions, premature deaths and disposal of animals unfit for human consumption, add to the expenditure of resources for animal health care. Likewise, they accentuate the risks for public health and animal health, especially when the measures applied are more oriented towards treatment than prevention and control. The importance given to zoonoses highlights the relevance of animals, both in the origin and in the transmission of diseases to humans (Rahman et al. 2020).

2. ZOONOSES FROM THE NATURAL HISTORY OF DISEASE

The growing emergence of zoonotic pathogens underscores the importance of advancing towards a greater understanding of the role of domestic animals as potential sources of disease. In the transmission of diseases, the interrelationships established between the environments, the etiological agent, animals and humans play a determining role. Zoonoses are no exception, as they have a series of characteristics that make their dissemination possible and make their control and eradication complex. The identification of causal factors, such as etiological agents, pathogenicity, environmental conditions, transmission mechanisms, as well as risk factors for human and animal health, are decisive for generating intervention strategies (Acero 2016).

The Natural History of Disease (NHD) allows us to know the natural behavior of a disease, from its origin and its evolution, without man's intervention. The risk factors in the health/disease patterns are those associated with the components of the ecological triad: etiological agent, host, and environment. It includes the periods a) Pre-pathogenic: the disease is not manifested, because the elements of the ecological triad are in balance; b) Pathogenic: there is a trigger that breaks this balance, starting the infection that can present sub clinically or clinically and c) Post-pathogenic: corresponds to the outcome of the disease (recovery, chronic state, sequelae or death) (Fajardo-Gutiérrez 2017).

From the epidemiological point of view, the most relevant period is the pre-pathogenic period. Imbalances in the ecological triad, in addition to being associated with natural changes in the environment (such as precipitation, floods, heat waves, high temperatures), are influenced by the action of chemical agents (pesticides, food additives, drugs). Physical (heat, mechanical force, radiation) and biological conditions of the pathogens that manifest under certain conditions (proliferation, changes in infectivity, degree of pathogenicity, ability to evade the host response), which marks the beginning of the epidemiological chain. The scope of each zoonoses depends on the specific environmental conditions, the prevalence (proportion of sick animals when evaluating the disease in the population) and the incidence (new cases). When these occur constantly in a geographical area, these are endemic. If their manifestation is transitory and affects a large number of animals, it is epizootics. These can even reach to greater magnitudes such as epidemics or pandemics (Rosales 2017; Briones et al. 2018; Baker et al. 2022).

Because bovine zoonoses can affect public health (due to the morbidity caused by the disease), as well as livestock productivity, proper sanitary management of bovines is essential through the application of preventive measures (Espejel 2020). In the pre-pathogenic period, primary prevention is oriented towards promoting animal health, including welfare conditions (adequate conditions of the facilities, access to water, adequate feeding, and adequate herd management), and specific protection (vaccination, deworming, pest control, and biosecurity measures) (Rosales 2017).

In the pathogenic period, the secondary level of prevention includes early diagnosis, in order to timely detect the infection and stop the chain of pathogen transmission before it spreads in the herd. The second measure is timely treatment, providing it from the beginning of the infection to increase its effectiveness; likewise, limit the damage to the animal as much as possible, to prevent it from becoming incapacitated or dying. Depending on the degree of progress, the bovine can recover from the infection; however, as a convalescent host it can remain as a carrier, for a determined or indefinite time. In the post-pathogenic period, tertiary level measures apply actions to seek the restoration of the animal, which depends on the disease, type of damage and purpose of production, which can conclude with the sacrifice of sick animals (Rosales 2017).

3. MAIN BOVINE ZOONOSES

During the pathogenic period of NHD, various etiological agents participate in the main bovine zoonoses. The majority (42%) are bacterial zoonoses, such as Anthrax, Tuberculosis, Brucellosis, Leptospirosis and *Escherichia coli* infections. Those caused by other agents include parasitic zoonoses (Cryptosporidiosis, Dermatophilosis), viral (Rabies), rickettsial (Q-Fever), protozoal (Giardiasis) and non-viral acellular pathogens (Bovine Spongiform Encephalopathy) (McDaniel et al. 2014; Rahman et al. 2020).

In recent decades, these zoonoses have shown a wide distribution in different regions of the world. Brucellosis, anthrax, leptospirosis and tuberculosis are present in the five regions of the world. Bovine Spongiform Encephalopathy in the Americas, Asia and Europe. Rabies and Q fever, in all regions except Oceania, while Vesicular Stomatitis only in the Americas. According to the data registered from 2005-2022 in the World Animal Health Information System (WAHIS), of the World Organization for Animal Health (WHO, created as OIE), the most important bovine zoonoses are Brucellosis (with 1,883,028 confirmed cases), Leptospirosis (923,236) and Tuberculosis (525,698), and Anthrax due to its level of lethality (20,054,380 dead animals) (WOAH 2023).

4. BOVINE BRUCELLOSIS

It is a highly virulent, chronic, infectious, and contagious bacterial zoonoses caused by *Brucella abortus*. It mainly affects reproduction. In females, it can cause abortions towards the last third of pregnancy and signs such as infertility, subclinical mastitis, anorexia, fever and depression. In males it produces epididymitis, testicular fibrosis, vesiculitis, orchitis and in some cases, permanent infertility (de Figueiredo et al. 2015). Infected pregnant females that do not miscarry remain with the calves as asymptomatic carriers (vertical transmission). Transmission in the herd occurs horizontally, through the conjunctival, oral, nasal, or genital routes, through direct contact with infected animals, and indirectly through contaminated materials, water, feed, and pasture. Between different herds, transmission usually occurs through the entry of infected animals, the use of shared pastures and water sources, especially in free-traffic breeding, and even by personnel working in different production units who do not observe control measures (Adesokan et al. 2013).

Humans can contract the disease through the digestive tract, by consuming contaminated milk and its unpasteurized derivatives, or raw or poorly cooked meat (Negrón et al. 2019). The greatest risks are associated with occupational and professional work, as for farm staff and veterinarians. Contagion can

occur by conjunctival inoculation, respiratory route by inhalation of aerosols during the cleaning of the stables or the movement of livestock, or by direct contact with infected animals blood, urine, aborted products, or contaminated dust (Molineri et al. 2014).

5. LEPTOSPIROSIS

It is the second most important zoonosis transmitted by bovines and always present in breeding sites. Disease caused by the *Leptospira* bacterium. The *hardjo* and *pomona* serovars of *Leptospira interrogans* are the most frequent in cattle. Rodents are the reservoirs, while livestock and humans are incidental hosts. In times of heavy rain, its epidemic potential is high. The routes of entry to the animal are multiple, including the ocular, nasal, oral, genital mucous membranes or skin wounds. Upon entering, they move into the bloodstream from where they reach the tissues and organs. They multiply significantly in the convoluted tubules of the kidneys. Urine containing the bacteria contaminates water sources, feed, and pasture. Vaginal fluids and semen can present a bacterial load. In humid and warm conditions, they manage to survive outside the host for up to six months. In infected animals, it can cause infertility, abortion, nephritis, mastitis, anemia, hemoglobinuria, low weight of calves at birth and even cause the death of calves (Torres et al. 2018; Valverde-Latorre et al. 2021).
Humans can acquire the disease by direct contact, fomites, or environments contaminated with the urine of infected animals in contaminated lagoons or lakes. It usually develops asymptomatically. However, in severe cases multi-organ failure increases the mortality rates (Ramírez-García et al. 2019).

6. BOVINE TUBERCULOSIS

The etiological agent is the bacterium *Mycobacterium bovis*, with bovines being the definitive host. Other wild and domestic mammals may serve as incidental hosts. Infected animals shed the bacteria in milk, feces, respiratory secretions, and even in semen and vaginal fluids. Transmission can be through the air (aerosols), through skin wounds, or through the ingestion of contaminated milk (calves). Asymptomatic carrier animals contribute to the spread of the disease. The high tolerance of the pathogen to low temperatures and humid places increases the risks of contagion. The infection can remain dormant for years, entering its active form under stressful conditions or in physically compromised animals. Signs can take months to develop. When they manifest, the animal show weakness, fluctuating low fever, progressive emaciation and wet cough. In severe cases, the animal dies from acute respiratory complications (Olea-Polpeka et al. 2017; Hernández-Solís et al. 2019).
Zoonotic tuberculosis in humans can occur from exposure to aerosols, secretions, and primarily from the consumption of unpasteurized milk or dairy products and raw or undercooked meat (Scott et al. 2016).

7. ANTHRAX

It is a highly contagious infectious disease caused by *Bacillus anthracis*. This bacterium form spores that resist extreme environmental conditions, which allows them to remain viable and infective in the soil (reservoir) for a long time, as well as to survive pasteurization. A greater proliferation is associated in calcareous or alkaline soils. It mainly affects herbivorous wild animals, and to a lesser degree to domestic animals and humans. The bacteria capsule produces lethal toxins. The presence of spores in pastures and contaminated water sources are the main source of infection in cattle. In the super-acute course, the animals do not show obvious signs for days, but when they appear, death occurs within a few hours. The acute or fulminant form manifests itself two days after infection. The animal shows signs of depression, elevated temperature, heart and respiratory rate, and congested and hemorrhagic mucous membranes.

In both cases, bloody discharge from the nose, mouth, anus, and vulva is evident in the dead animal (Laverde et al. 2008; Shadomi et al. 2016).
It is a high-risk occupational disease for those who perform slaughtering, leather tanning, or handling contaminated wool. In humans, the disease can develop in the lungs by inhaling the spores (the most lethal form), through the skin, through a wound, or gastrointestinal by consuming raw or semi-raw meat from an infected animal (Guzmán-Terán et al. 2017).

8. Q-FEVER

The etiological agent is *Coxiella burnetii*, one of the most infectious agents known. The main reservoirs are domestic ruminants. The disease is seasonal, and occurs in females during the calving season. The bacterium has a selective tropism for the uterus and mammary glands. During pregnancy, it can cause abortion in some cases. The placenta, fetal membranes and fetuses (in abortions) from infected cows present a high infective load (Roca 2007). The main route of transmission is respiratory, through the inhalation of aerosols from calving waste (primary aerosols) or contaminated materials such as manure, bedding and other fomites (secondary). To a lesser degree, transmission can also occur orally through the consumption of contaminated food (de Rooij et al. 2016).
In humans, the highest risk is occupational, in people who carry out livestock activities and veterinarians by aerogenous route. The disease can also develop in humans from the consumption of contaminated milk. It presents a wide range of manifestations, ranging from mild infections that can be asymptomatic, to chronic and disabling clinical pictures, which can cause death in severe cases (Rabaza et al. 2022).

9. BOVINE SPONGIFORM ENCEPHALOPATHY

Until now, it is the only bovine zoonoses produced by prions (infectious abnormal proteins). It is a neurodegenerative disease, which is incurable and deadly. Animals acquire it in the first six months of life, by consuming feed formulated with contaminated meat and bone meal. The incubation period is long, generally more than 4 to 5 years. Specific risk materials (SRM) such as nervous tissues (brain, spinal cord) are responsible for transmission. The signs associated with the disease appear in cows of 5-6 years of age. These include weight loss, behavior changes, weakness, and progressive neurological deterioration. Prevention and control measures require the elimination of animals that show signs of the disease, as well as the confirmation of diagnosis with laboratory tests (Hernández et al. 2002).
In humans, the BSE variant is Juvenile Creutzfeldt-Jakob disease. It has its origin in the consumption of meat from infected cattle or that had contact with sick animals. It causes progressive neurological and psychiatric disorders, until death occurs due to cerebral or respiratory complications (García-Ortega et al. 2019).

10. PARALYTIC RABIES

It is a type of encephalitis caused by the RNA virus of the genus Lyssavirus. The disease is progressive and deadly, affecting all mammals. It attacks the host's central nervous system, causing brain death. The virus loses its infectious potential on exposure to light. Transmission occurs mainly in cattle through the bite of the hematophagous bat *Desmodus rotundus* (reservoir), or through contact of infected saliva with wounds, or the mucous membranes of the eyes, nose, and mouth. Neck flexion, hind limb paralysis and excessive salivation are unequivocal signs of the disease (Bárcenas-Reyes et al. 2015).

Transmission to people includes bites from sick animals or getting saliva into the eyes, nose, mouth, or wounds. The occupational risk is latent, especially in the traces when manipulating the brain. Consumption of unpasteurized infected milk can be another route of infection (NCEZID 2019).

11. GIARDIA INFECTIONS

It is a disease caused by the protozoan parasite of the genus *Giardia*, present in all vertebrates. Considered as the causal agent of a large number of cases of gastrointestinal diseases in animals and humans. In animals, it alters the functioning of the gastrointestinal tract, decreases the absorption of nutrients, and causes emaciation due to diarrhea, mainly in young animals. The flies of the Muscidae family that abound in manure heaps are the vectors of this protozoan (Abeywardena 2015). Dissemination is by cysts excreted in the feces, which contaminate food and water sources. Both animals with evidence of the disease and asymptomatic animals participate in an important way in this process. Once in the stomach, they disengage, releasing the trophozoites that multiply actively. As they descend towards the terminal portion of the digestive tract, they encyst again. After three days of infection, it is possible to observe the presence of cysts in the feces (Otero-Negrete et al. 2011).
In public health, these zoonoses is of great relevance throughout the world. Transmission is through fecal-oral route. The ingestion of the cyst with consuming water or food, or by putting contaminated fomites in the mouth. The highest prevalence and incidence occurs in unhealthy areas or with contaminated water. People who contract the infection have diarrheal symptoms of different intensity and their evolution usually depends on medical care. In severe cases, it can even lead to death (AMSE 2016).

12. CRYPTOSPORIDIOSIS

Infection caused by the protozoan parasite of the genus *Cryptosporidium*. It occurs ubiquitously with Giardia in diarrheal infections in animals. Despite the taxonomic differences, the form of transmission and mechanisms of action are very similar in animals. In *Cryptosporidium* the infective form are the oocysts. The joint action of these parasites represents a major public health problem, due to the high infectious potential and exposure. In livestock production, they cause significant losses due to the cost of treatments, the delay in the development of animals, and the deaths of newborn animals (Santin 2020).

13. *ESCHERICHIA COLI* INFECTIONS

This bacterium is part of microbiota of the digestive tract of ruminants and other mammals, including humans. However, there are serotypes that cause diarrheal-type diseases in calves. 15-20% of neonatal deaths are due to infections caused by this bacterium. *Escherichia coli* serotype O157:H7 is a zoonotic Shiga toxin-producing pathogen (STEC). It is located in the lymphoid tissue that joins the rectum with the anus, where it colonizes in cattle. This location allows a wide spread of the pathogen, through bovine feces (Lara-Duran et al. 2019).
STEC bacteria are included in the Verocytotoxin-producing *E. coli* (VTEC), responsible for hemolytic-uremic syndrome (HUS) in humans (Etcheverria et al. 2013). They are highly relevant foodborne pathogens in Foodborne Diseases. The sources of infection are diverse, including fruits and vegetables that have been in contact with contaminated feces; and contaminated raw or undercooked meat. Infections caused by STEC/VTEC include watery diarrhea, hemorrhagic colitis, renal failure, Thrombotic Thrombocytopenic Purpura (TTP) and Hemolytic Uremic Syndrome (HUS) (Rípodas et al. 2017).

14. EPIDEMIOLOGICAL ANALYSIS OF THE MAIN BOVINE ZOONOSES

Epidemiological information is crucial to understand the behavior of zoonoses, their effects on animal production and health and the possible risks to human health. Its indicators are the basis for defining intervention processes to prevent, control or eradicate them. Despite being the same livestock species, the scope of each zoonoses depends on the characteristics of the etiological agent, environmental conditions, contexts, and methods of breeding. Based on the information compiled by the WHOA, the analysis addresses different aspects related to the main bovine zoonoses (WOAH 2023).

Bovine brucellosis is the most prevalent zoonoses worldwide (Table 1). The Americas registers the highest number of susceptible animals with 49.2 million animals (Ma), which is 42.6% of the total cases reported worldwide. It corresponds to immunologically compromised animals, which have the necessary characteristics to develop the disease, when exposed to the etiological agent (Vargas and Galindo 2015).

As observed, there is no correspondence between the number of positive, eliminated, euthanized and dead cases. In addition to the subtotals by period, the analysis by region shows this condition more precisely: For Asia, the total number of positive cases is 405,943. If the eliminated (244,315), sacrificed (195,029) and dead (1,137,027) are added, the total amount goes to 1,576,371 (a difference of 1,170,428 compared to the positive cases). More than data errors, these differences show that the problem is much more complex in terms of prevalence and incidence. Likewise, in epidemiology, unless it is a follow-up, the data analysis cannot be linear. It is important to consider that, depending on the interaction with the etiological agent, the conditions of the animal and the environment, the course of the disease may be different in each animal (Rojas et al. 2021).

The highest frequencies registered by country show these differences at the regional level. In the number of susceptible animals, the highest value corresponds to Venezuela, for positive cases to Mexico and for dead animals to Turkey (Table 2).

In practice, unless there is systematic surveillance, in many cases when the cow miscarries in the last third of gestation, brucellosis appears as a probable cause. The disease is confirmed when laboratory tests are performed. There are infected, asymptomatic cows that do not abort, which contribute to the spread of the disease. In addition to the possible direct exposure to the placenta, which has a significant load of pathogen, bacteria contained in the milk increase the risk of contagion to humans. The undetected cases, the chronic carriers and the ignorance of the cause of death aggravate the real problem. In many places, the entities responsible for epidemiological surveillance violate the processes by leaving sick animals in free transit that spread the disease among herds, or by slaughtering without prior verification (McDaniel et al. 2014).

As part of these strategies, some countries have achieved excellent results by identifying and eliminating sick animals and receiving compensation to replace the animals. Although this measure has proven its effectiveness, the lack of economic resources is usually a determining factor, which is why it is applicable only in places of low prevalence. For this reason, many animals are destined for the sale of meat. Given the transmission mechanism of brucellosis, inadequate cooking of meat increases the risk of contagion in humans (Adesokan et al. 2013; Negrón et al. 2019).

In primary prevention, vaccination is the key to reduce the susceptibility of animals to contracting the disease. In the comparison of sub-periods, the increasing decrease in the number of immunized cattle in Africa is associated with the increase in susceptible animals. In the Americas, in the last sub-period, the significant increase in the number of vaccinated animals from 320,258 to 6.6 Ma reduced those susceptible from 22.1 to 3.2 Ma, showing the efficacy of immunization as a preventive measure (WOAH 2023).

Table 1: Epidemiological data on Brucellosis by world region (2005-2022)

Period	Region	New outbreaks	Animals Susceptible	Positive cases	Eliminated	Slaughtered for commercial purposes	Dead	Vaccinated
2005-2010	Africa	740	553,596	43,405	2,602	10,815	223	480,302
	Americas	8,259	23,899,771	588,022	5,704	121,257	806	424,500
	Asia	2,756	17,721,708	168,882	73,937	57,165	296,332	295,763
	Europe	2,271	12,271,959	128,543	57,085	97,846	837	373,921
	Oceania	4	12,127	123	0	116	7	0
	Subtotal	14,031	54,459,161	928,975	139,328	287,199	298,205	1,574,486
2011-2016	Africa	900	1,054,609	40,208	3,384	11,528	424	269,565
	Americas	5,362	22,117,982	224,766	4,986	70,985	12,182	320,258
	Asia	4,069	20,958,095	106,547	76,782	65,979	409,890	409,255
	Europe	1,140	5,817,708	100,564	20,861	76,273	114	377
	Oceania	20	84,003	1,291	0	920	1	521
	Subtotal	11,491	50,032,397	473,376	106,013	225,685	422,611	999,976
2017-2022	Africa	663	1,325,865	33,127	899	11,087	388	61,085
	Americas	5,907	3,223,236	252,530	10,593	57,702	1,051	6,616,890
	Asia	2,499	5,802,659	130,514	93,596	71,885	430,805	430,513
	Europe	707	787,949	64,425	1,429	62,152	203	1
	Oceania	7	41,780	81	0	75	0	0
	Subtotal	9,783	11,181,489	480,677	106,517	202,901	432,447	7,108,489
	Total	35,305	115,673,047	1,883,028	351,858	715,785	1,153,263	9,682,951

Susceptible animals: Animals that do not have specific immunity to the etiological agent.
Eliminated: Sick animals euthanized for elimination and replacement, as control measure.
Slaughtered for commercial purposes: Sick animals brought to the slaughterhouse for the sale of meat and offal.
Deaths: Animals reported to have died from the disease.
Source: Own elaboration based on the processing of data reported in WOAH (2023).

Table 2: Countries by region with the highest number of Brucellosis cases reported by indicator

Region	AC	ANIMALS SUSCEPTIBLE			POSITIVE CASES			DEAD ANIMALS		
Africa	37	Esuatini (506,916)	Uganda (501,755)	Mozambique (358,621)	South Africa (67,929)	Algeria (23,043)	Eritrea (5,755)	South Africa (538)	Zambia (187)	Mozambique (69)
Americas	21	Venezuela (22'100,445)	Mexico (14'085,318)	Bolivia (5'788,314)	Mexico (409,379)	Brazil (213,548)	Argentina (145,713)	Mexico (12,152)	Colombia (595)	Bolivia (430)
Asia	31	Azerbaijan (15'612,204)	Kyrgyzstan (9'637,809)	Armenia (7'546,538)	Korea (81,983)	Turkey (62,787)	Kyrgyzstan (59,269)	Turkey (276,004)	Syria (178,325)	Tajikistan (170,778)
Europe	17	Spain (16'649,591)	Italy (6'153,111)	Macedonia (1'151,028)	Russia (151,005)	Italy (73,705)	Spain (34,301)	Russia (770)	Greece (201)	Italy (169)
Oceania	1	Fiji (137,910)			Fiji (1,495)			Fiji (8)		

AC=Affected Countries (by region).
Source: Own elaboration based on the processing of data reported in WOAH (2023).

According to the data registered by the WOAH (2023), the second most prevalent zoonoses is Leptospirosis with 959,792 fewer cases than Brucellosis. It is noteworthy that for the period considered in the comparison (2005-2022), the records only include information up to 2011. Even so, they are greater than for those of Tuberculosis (Table 3).

The absence of data from 2012-2022 (even for 2023) cannot be interpreted as the disappearance of the disease. The main reason is that only in 2011 (without integrating Africa and Oceania), all the indicators increased with respect to the accumulated frequency registered for the previous 6-year period. The bias introduced by the lack of records in monitoring the behavior of the disease is important, especially considering the prevalence and impact it can have on human and animal health.

The report also includes birds, buffaloes, goats, deer, rabbits, equids, wildlife (unspecified species), cats, sheep, goats, dogs and pigs. In addition to showing the diversity of affected species, the global totals are useful to measure the impact of the disease. Suffice it to point out that the total number of outbreaks registered for bovines (2,402) represents only 12.74% of the 18,884. The same happens with the other indicators, when considering the different animal species affected by the disease. Of the total number of susceptible animals 47.53% and of the positive cases 85.52% correspond to bovines. This indicates that the spread of the disease can occur through contact with domestic and wild species, which increases the risks for humans (WOAH 2023). The diversity of wild and domestic species, for which the disease is registered, at least allow us to infer that it is zoonoses of great proportions.

Following the order of prevalence, despite of the fact that in public health tuberculosis before the SARS-CoV-2 (COVID-19) pandemic was the disease that caused the most deaths from a single infectious agent (*Mycobacterium*) worldwide, the WOAH records start from 2019 (Table 4).

This organization places the disease under control, although in 2018 it recognizes its presence in 82 countries. It is noted that although there have been important advances in the control of the disease; its persistence is associated with infection caused by wild animals. The registry integrates 39 animal species including 3 domestic (cattle, sheep and goats) and 36 wild animal species (WOAH 2023).

Alternative measures can contribute to the eradication of the disease in cattle. In Mexico, the control guide is the Official Mexican Standard NOM-031-ZOO-1995, which is the basis for the National Campaign against Bovine Tuberculosis (*Mycobacterium bovis*). This standard contemplates the tuberculin test for diagnosis. As a control measure, the positive reactors are eliminated (sacrifice). (Rojas et al. 2021). Different studies have suggested BCG vaccination as an alternative for the control of bovine tuberculosis (Buddle et al. 2018; Chandran et al. 2019; Marais et al. 2019). The difficulty is that immunization can lead to the identification of false positives in intradermal tuberculin tests. Its confirmation requires *M. bovis* antigens not expressed by BCG, which are not yet available (WOAH 2019).

Anthrax is the zoonoses with the highest levels of mortality. Despite of the fact that the prevalence is not comparable to that of brucellosis, the lethality of the etiological agent, together with the prevailing socio-economic conditions in each region are determining factors. According to the data, there are clear differences between the sub-periods. Between the first and second, all indicators are reduced (even vaccination). Africa is the region with the highest number of positive cases and dead animals, despite of the fact that it is also the region with the highest number of vaccinated animals (almost 100% of susceptible animals). The inferred effect is the reduction in the number of positive cases for the second period (78.2% reduction in prevalence). However, in the case of Asia, where the proportion of vaccinated animals is ten times higher than the reported susceptible animals, it is logical to assume a significant reduction in the number of positive cases for the following period. According to the data, the positive cases of the second period are equivalent to 88.4% of the previous period (reduction of 11.6%) (Table 5).

These comparisons show that care for zoonoses requires a comprehensive vision, which contemplates that, although it is the same etiological agent and the same species of host, the behavior of the disease depends on the condition of each animal, the environmental conditions and not only physical in which it is found, but also contextual (ecological triad). Despite the high lethality of *Bacillus anthracis*, the administration of timely treatment can prevent the death of the animal. In regions with insufficient budget, in addition to the inability to maintain vaccination schemes as preventive measures, there is also a lack of resources to provide the treatments, which increases the number of deaths, without neglecting the fact that the number of cattle heads is usually variable. Worldwide, the largest number of susceptible

animals is recorded by Ethiopia (15.9 Ma), the positive cases in the Ivory Coast (41,297) and the dead animals by Ethiopia (7.96 Ma) (WOAH 2023).

In the case of bovine rabies (Table 6), the Americas registers the highest number of vaccinated animals and it also reports the highest numbers of susceptible animals, positive cases, and dead animals. The world's main cattle producers i.e., Brazil and the United States are located in this region. The disease is present in 34 countries in Africa, 31 in Asia, 24 in the Americas and 21 in Europe. Oceania is a rabies free region. The largest number of susceptible animals is recorded by Paraguay (9.3 Ma) followed by the Philippines (5.1 Ma). For the positive and dead animals, Brazil (22.4 Ma and 22.3 Ma) and Russia (7.01 Ma and 7.01 Ma) have reported the highest number of cases (WOAH 2023).

Table 3: Epidemiological data on Leptospirosis by world region (2005-2011)

Period	Region	New outbreaks	Animals Susceptible	Positive cases	Eliminated	Slaughtered for commercial purposes	Dead	Vaccinated
2005-2010	Africa	2	35,018	28	0	0	1	0
	Americas	1,196	271,420	26,132	1	3	673	450
	Asia	238	1,001,787	858,880	16	14	915	105,024
	Europe	457	333,702	29,468	4,886	12	121	4,289
	Oceania	14	0	162	0	0	0	0
	Subtotal	1,907	1,641,927	914,670	4,903	29	1,710	109,763
2011	Americes	217	32,417	5,793	0	1	57	426
	Asia	19	14,258	44	0	0	12	0
	Europe	259	3,732	2,729	0	160	6	0
	Subtotal	495	50,407	8,566	0	161	75	426
	Total	2,402	1,692,334	923,236	4,903	190	1,785	110,189

Source: Own elaboration based on the processing of data reported in WOAH (2023).

Table 4: Epidemiological data on Bovine Tuberculosis by world region. (2019-2022)

Period	Region	New outbreaks	Animals Susceptible	Positive cases	Eliminated	Slaughtered for commercial purposes	Dead	Vaccinated
2019-2022	Africa	158	243,414	65,286	1,005	65,947	335	0
	Americas	1,508	715,879	129,210	3,614	120,417	123	0
	Asia	4,202	2,861,382	75,935	16,034	52,283	173	0
	Europe	2,544	10,723,412	254,326	20,511	264,171	39	0
	Oceania	34	300,644	941	0	2,097	0	0
	Total	8,446	14,844,731	525,698	41,164	504,915	670	0

Source: Own elaboration based on the processing of data reported in WOAH (2023).

15. IMPACT OF BOVINE ZOONOSES ON HUMAN HEALTH

Unlike the information available for animals, the information on human cases associated with human zoonoses is limited. In each region and country, the indicators are oriented towards the aspects that mostly affect the population as a basis for defining care and prevention strategies.

Table 8 shows the data registered by the European Center for Disease Control (ECDC) on bovine zoonoses of public health importance for the countries of the European Union (EU) and 3 countries (Iceland, Liechtenstein and Norway) of the European Economic Area (AEE). The accumulated data is from 2008 to 2021 and the incidences for 2020 for each disease (WOAH 2023).

The accumulated data show that the most prevalent zoonoses and the highest incidence is of Tuberculosis, with 9.72/100,000 population (9.50 according to World Bank figures). This data underlines the importance of this disease at global public health level.

Table 5: Anthrax epidemiological data by world region (2005-2022)

Period	Region	New outbreaks	Animals Susceptible	Positive cases	Eliminated	Slaughtered for commercial purposes	Dead	Vaccinated
2005-2010	Africa	314	7,202,734	71,192	12,146	24,576	7,212,517	7,199,819
	Americas	94	168,721	2,902	138	2,528	138,961	136,435
	Asia	163	376,714	6,246	538	4,238	3,869,334	3,865,098
	Europe	24	262,376	844	146	511	2,055,455	2,054,945
	Oceania	18	10,258	175	0	173	12,571	12,398
	Subtotal	612	8,020,803	81,359	12,968	32,026	13,288,838	13,268,695
2011-2016	Africa	178	6,461,533	15,573	923	12,250	2,665,645	2,653,900
	Americas	38	151,916	1,560	262	1,110	85,211	84,101
	Asia	200	414,504	5,524	1,396	4,551	1,213,357	1,209,418
	Europe	21	20,322	350	28	298	78,771	78,473
	Oceania	5	3,272	126	0	126	3,732	3,606
	Subtotal	443	7,051,547	23,133	2,609	18,335	4,046,716	4,029,498
2017-2022	Africa	72	6,194,779	9,036	370	8,066	1,498,498	1,490,476
	Americas	19	61,485	1,053	103	835	13,729	12,897
	Asia	106	476,284	5,439	477	4,993	1,238,832	1,233,938
	Europe	10	8,045	269	12	252	14,636	14,389
	Oceania	6	5,202	173	2	173	4,660	4,487
	Subtotal	213	6,745,795	15,970	964	14,319	2,770,355	2,756,187
	Totales	1,268	21,818,145	120,462	16,541	64,680	20,105,909	20,054,380

Source: Own elaboration based on the processing of data reported in WOAH (2023).

Table 6: Epidemiological data on Bovine Rabies by world region (Accumulated data 2005-2022)

Region	New outbreaks	Animals Susceptible	Positive cases	Eliminated	Slaughtered for commercial purposes	Dead	Vaccinated
Africa	854	2,224,074	12,387	3,757	318	8,019	256,241
Americas	795	11,366,676	41,773	1,294	266	40,151	180,464,692
Asia	1,309	13,404,954	19,375	3,499	165	15,615	824,997
Europe	8,817	9,803	12,566	812	23	11,711	182,863
Total	11,775	27,005,507	86,101	9,362	772	75,496	181,728,793

Source: Own elaboration based on the processing of data reported in WOAH (2023).

Table 7 shows the grouped data for Bovine Spongiform Encephalopathy and Q fever. In both cases, the largest positive cases correspond to Europe (WOAH 2023).

Based on the incidence report/100,000 people from the World Bank, for 2020 the worldwide incidence was 198.68. At the regional level, the incidence for Africa, Americas, Asia, Europe and Oceania was 192.07, 31.34, 124.52, 13.97 and 134.69, respectively (WB 2021). These figures show the differences that exist between regions, with the African region being the most affected. In many African countries, the low availability of economic resources means that factors such as poverty, inadequate nutrition, lack of water, overcrowding, lack of medical care, as well as drought conditions and other extreme weather events contribute to increase the problem of this disease. Despite the surveillance and implementation of coordinated strategies from different levels, it continues to be the zoonoses with the greatest global affectation.

16. CONCLUSIONS

It is undeniable that cattle raising has important contributions to food security, but it also brings negative effects. Its role in the transmission of zoonoses stands out, with worldwide effects on public and animal health. The available data on its incidence and prevalence are far from showing its real

dimension. The data is partial, since it does not report the actual cases over the total population of each region. There are also deficiencies in notifications (mandatory for many of the zoonoses). In many cases,

Table 7: Epidemiological data on Bovine Spongiform Encephalopathy and Q fever by world region (Accumulated data 2005-2022)

Zoonoses	Region	New outbreaks	Animals Susceptible	Positive cases	Eliminated	Slaughtered for commercial purposes	Dead	Vaccinated
Bovine Spongiform Encephalopathy	Americas	26	27,101	28	540	277	10	0
	Asia	37	8	17	16	0	2	0
	Europe	165	1,838,577	1,320	20,137	1,125	157	0
	Total	228	1,865,686	1,365	20,693	1,402	169	0
Q-Fiver	Africa	9	8	8	0	0	0	0
	Americas	13	3,111	51	0	0	8	0
	Asia	942	8,353	196	0	0	14	0
	Europe	3,537	3,141,981	14,399	508	118	37	421
	Total	4,501	3,153,453	14,654	508	118	59	421

Source: Own elaboration based on the processing of data reported in WOAH (2023).

Table 8: Prevalence and incidence of zoonotic diseases in humans for the EU/EEA

			2008-2021			2020	
Zoonoses	NC_A (WAHIS)	NC_H (ECDC)	RC/C	HOSP	Deaths	RC/C	Incidence (N/100 000)
Anthrax	14	13	101	*	*	3	0.00
Brucellosis	10	26	6,052	1,384	12	134	0.03
Creutzfeldt-Jakob	19	5	24	*	*	0	0.00
Cryptosporidiosis	0	25	124,751	6,884	35	4,167	1.68
E. coli STEC/VTEC	*	31	106,941	32,928	237	4,824	1.59
Q-Fiber	17	26	13,951	*	*	528	0.12
Giardiasis	0	25	238,748	4,965	49	6,559	2.55
Leptospirosis	13	27	9,816	3,929	160	569	0.14
Rabies	1	9	22	*	*	0	0.00
Tuberculosis	14	31	826,039	*	*	5,032	9.72

NC=Number of Countries Affected (A_ Animals; H _ Humans); CR/C= Reported/Confirmed Cases; HOSP= Hospitalized
* No data Source: Own elaboration based on the processing of data reported by ECDC (2023) and WOAH (2023).

the epidemiological surveillance systems present deficiencies, which increases the risks. Control and prevention mechanisms should consider undiagnosed cases that are subclinical. In qualitative terms, the traditional view that zoonoses were typical problem of underdeveloped countries is unsustainable. The current worldwide distribution of bovine zoonoses and their effects on livestock productivity, public and animal health confirms this. Even though, it is in these countries where the impacts tend to be greater due to the lack of resources to face epidemiological surveillance, improve the health infrastructure and implement effective prevention programs. Countries with greater resources and infrastructure are not exempt from this problem. The distribution of etiological agents and the changing conditions associated with climate change are causing them to face new paths, due to the emergence of new diseases. The pending task is not only aimed at strengthening prevention and control measures, but also at seeking to ensure that public, animal and environmental health work in an integral manner.

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