Zoonoses in Sheep and Risk Factors

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ABSTRACT

The progressive growth of sheep farming on a global scale, although it has an important contribution to development, subsistence and food security, also implies risks for human health. The high propensity of sheep to suffer from diseases associated with a variety of etiological agents underlines the importance of recognizing and addressing the risk factors of zoonotic diseases associated with this livestock species. The emergence and re-emergence of zoonotic diseases and the expansion of their distribution worldwide highlights that in addition to the biological risk factors, related to the susceptibility of sheep, as carriers or reservoirs of different diseases, the rapid evolution and diversification of some etiological agents, changes in the environment and various anthropogenic factors are being determining factors. The current climatic conditions associated with climate change tend to generate variations that favor the adaptation and diversification of pathogens, as well as the multiplication of vectors, which accentuates the problem. Aspects such as the type and size of the herd, the production and grazing system, the coexistence of different livestock and domestic species such as dogs and cats, the introduction of non-certified animals, overcrowding, the sanitary conditions associated with the accumulation of feces and fomites, are contributing to the spread of zoonotic diseases. In the case of humans, interaction with domestic and wild animals, non-compliance with biosafety measures in the management of animals and their waste, as well as sanitary deficiencies in food consumption, increase the risks of dissemination of zoonoses. The geographical distribution of zoonoses is expanding in different regions of the world; in addition to climatic variations, socioeconomic conditions, productive breeding practices and sheep production volumes are being determining factors. The behavior of each zoonosis in each region is variable, since it depends on the convergence of various factors. The fact that for the same zoonosis there are different definitive and incidental hosts is increasing the risk of transmission of these diseases. In addition to this, deficiencies in epidemiological surveillance, animal health controls and prevention measures tend to exacerbate this problem.

Keywords: Sheep, Zoonotic diseases, Risk factors, Production practices, Transmission routes

CITATION

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1. INTRODUCTION

For many populations in the world, sheep farming represents a livestock activity that benefits communities by contributing to subsistence and food security. The progressive growth of sheep farming on a global scale, although it supports these essential aspects for the development and well-being of societies, also highlights the importance of promoting production processes that reduce the associated negative effects. One of the most important is to guarantee the health of the animals, in order to minimize the development of zoonotic diseases that affect the health of humans. The high propensity of sheep to suffer various diseases, associated with a diversity of etiological agents that include viruses, bacteria, rickettsia, protozoa and different types of parasites, underlines the importance of recognizing and addressing the risk factors associated with this type of disease (Ojeda et al. 2022).

The alterations produced by these diseases in animals have serious economic repercussions due to the decrease in productivity. The delay in growth, weight loss, the presentation of abortions and death, generate important losses in production. In health, the ease and speed with which they spread tends to affect the health of the herd, extending their effects to human health, given the diversity of transmission routes to which they are associated (Vega-Pla et al. 2022).

The emergence and re-emergence of zoonotic diseases and the expansion of their distribution in different regions of the world, from originally endemic areas, is part of the current problem. In addition to the biological risk factors, related to the susceptibility of sheep, as carriers or reservoirs of different diseases, the rapid evolution and diversification of some etiological agents (especially viruses), the changes generated in the environment are being decisive. In addition to this, anthropogenic factors such as the population explosion, the increase in interactions with wild animals, the increase in the global mobilization of people, the trafficking of exotic species and commercial diversification, which includes animals, frozen and processed foods, are making important contributions in this regard (PAHO/WHO 2018).

2. WORLD SHEEP POPULATION

Worldwide, the raising of small ruminants is becoming a livestock activity of great importance both economically, as well as for food security and the development of countries. From 2005 to 2020 (Table 1), the highest growth rate is reported in goats among livestock species such as sheep, goats, cattle and pigs. The second place corresponds to sheep, which reach a percentage growth of 14.38% for this period.

Table 1: Percentage growth from 2005 to 2020 by livestock species

	Number of heads		Growth rate	Percentage of growth
Species	2005	2020		
Sheep	110,707,630	126,613,454	0.0014	14.38
Goats	85,057,090	112,810,624	0.0033	32.63
Cattle	908,669,878	982,004,053	0.0008	8.07
Pigs	223,856,534	235,113,946	0.0005	5.03

Source: World data. Elaboration based on data obtained from FAOSTAT (2022)

For sheep, despite the global growth in this period, only Africa (46.01%) and Asia (22.05%) report an increase in their populations at the regional level (Table 2; Fig. 1). For the Americas, Europe and Oceania, the number of sheep has decreased, more significantly in Oceania (-36.46%).

At the sub regional level (Table 3) in 2020, East Asia reported the highest number of sheep heads (20,333,148). For this sub-region, the largest volume is for China, with 17.31 Million head of

sheep, followed by Mongolia (3,004) and Korea (17,100). In the second place, West Africa is located with 12,583,753 Million head of sheep (Mhs), placing Nigeria (4.77 Mhs), Mali (2.01) and Niger (1.37) as the contributing countries. In the Americas, of the total value (8,573,865), 76.15% corresponds to South America, with contributions from Brazil (2.06 Mhs), Argentina (1.45) and Peru (1.19). In the case of Europe, according to the total number of heads, it is located in Northern Europe. The largest contributors to this sub region are Norway (22,466), Sweden (50,115) and Iceland (40,072). However, at the regional level, the countries with the highest number of sheep heads are the United Kingdom (6,879 Mhs) from Western Europe, the Russian Federation (2,065) from Eastern Europe and Spain (1,543) from Southern Europe.

Table 2: Five-year growth of the sheep population (Comparison of the Rate and Percentage of growth between 2005 and 2020)

	Number of heads				2005-2020	
Region	2005	2010	2015	2020	Growth rate	Percentage of growth
Africa	28,648,543	32,293,630	36,195,455	41,830,381	0.0046	46.01
Americas	9,349,045	9,161,025	8,475,230	8,573,865	-0.0008	-8.29
Asia	44,853,746	45,610,887	50,761,802	54,742,389	0.0022	22.05
Europe	13,754,353	13,013,244	13,084,305	12,506,887	-0.0009	-9.07
Oceania	14,101,944	10,066,912	10,006,193	8,959,933	-0.0036	-36.46
	110,707,630	110,145,698	118,522,984	126,613,454	0.0014	14.38

Source: Own elaboration based on data obtained from FAOSTAT (2022)

Table 3: Sheep population by sub region (2018-2020)

Sub region	2018	2019	2020
East Africa	9,283,456	10,981,046	11,154,784
Central Africa	3,971,187	4,238,062	4,525,771
North Africa	10,830,676	10,770,075	11,069,863
Southern Africa	2,603,487	2,538,006	2,496,210
West Africa	11,920,836	12,325,190	12,583,753
Regional total	38,609,641	40,852,378	41,830,381
North America	914,160	908,670	899,370
Central America	932,610	935,655	938,085
Caribbean	206,173	210,604	207,301
South America	6,317,921	6,519,417	6,529,109
Regional total	8,370,863	8,574,346	8,573,865
Central Asia	5,719,572	5,828,712	5,987,514
Eastern Asia	19,212,546	19,594,146	20,333,148
South Asia	15,917,093	15,976,052	16,262,849
Southeast Asia	1,917,832	1,943,631	1,959,068
Western Asia	9,283,478	9,617,458	10,199,811
Regional total	52,050,521	52,959,998	54,742,389
Eastern Europe	3,732,344	3,603,849	3,557,181
Northern Europe	4,171,816	4,133,509	4,035,855
Southern Europe	3,992,947	3,918,717	3,877,686
Western Europe	1,033,736	1,029,174	1,036,165
Regional total	12,930,843	12,685,249	12,506,887
Australia	7,006,732	6,575,541	6,352,937
Fiji	2,770	3,165	3,074
New Zealand	2,729,575	2,682,185	2,602,894
Papua New Guinea	754	758	763
Regional total	9,739,830	9,261,649	8,959,667

Source: Own elaboration based on data obtained from FAOSTAT (2022)

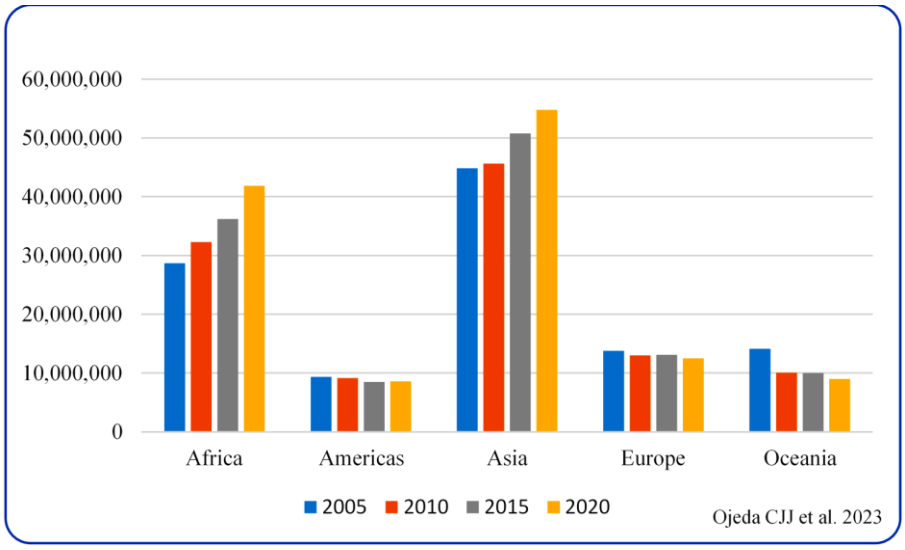


Fig. 1: Five-year growth of the sheep population by regions of the world: **Source:** Own elaboration based on data obtained from FAOSTAT (2022).

3. ZOONOTIC DISEASES IN SHEEP

From the productive point of view, sheep have great advantages for their rearing. Its great adaptability to different environments, the ease of its extensive production, the high level of use of food resources and its efficient forage transformation capacity to produce a greater amount of meat, among other aspects, stand out. However, it is also one of the species most susceptible to various diseases (Moreno and Grajales 2017). This is due to the variety of etiological agents that affect this species.

Among the main zoonotic diseases in sheep, 19 are of bacterial origin, 15 parasitic and 5 viral. Of the bacterial zoonoses, due to their prevalence, distribution and effects, Chlamydiosis (enzootic abortion), anthrax (Anthrax), Leptospirosis and Campylobacteriosis are of significance. Among those of parasitic origin, Echinococcosis, among viral diseases Paralytic Rabies and Rift Valley Fever, and among those of protozoa, Toxoplasmosis are most important (Ojeda et al. 2022). Table 4 shows the etiological agents related to the main ovine zoonoses and the effects they cause in animals and humans.

4. MAIN RISK FACTORS ASSOCIATED WITH OVINE ZOONOSES

Undoubtedly, one of the main risk factors for ovine zoonoses is their great diversity. Table 4 includes those with the highest incidence in sheep and humans. Along with bacterial diseases, parasitic zoonotic diseases are the most diverse and common, generating greater impacts on the productivity and health of sheep, such as Haemoncosis, caused by *Haemonchus contortus*. Of the parasitic zoonoses, only one out of 15 is included in Table 4 (Ojeda et al. 2022).

This diversity is directly associated with etiological agents. Its inherent biological characteristics, the resistance to survive in the external environment, its infective capacities, its adaptability to different hosts, among others, potentiate the risks. A preponderant factor is the different routes of transmission (Table 5). Contact with sick animals, body fluids, wounds, abortion products, trans placental transmission, during childbirth or lactation, as well as the consumption of forage and food, contaminated water or soil, fomites and aerosols, are some of the dissemination routes for these diseases (Sempere et al. 2019).

The interrelation established between etiological agents, animals, humans and the environment is a determinant of risk factors. In animals, their own conditions influence such as the productive and physiological state, age, origin, the use of antimicrobial and anti-parasitic treatments, their

susceptibility. Likewise, aspects such as the type and size of the herd, the production and grazing system, the coexistence of different livestock and domestic species such as dogs and cats, the introduction of non-certified animals, overcrowding, sanitary conditions associated with the accumulation of feces and fomites, mainly. In the case of humans, interaction with domestic and wild animals, non-observance of biosafety measures in handling animals and their waste, as well as sanitary deficiencies in food consumption, increase the risks of spreading zoonoses (Jiménez-Martín et al. 2015; Rizzo et al. 2016; Palomares et al. 2019).

The risks increase under current climatic conditions, which tend to generate important climatic variations and new microclimates, which favor the adaptation and diversification of pathogens, as well as the multiplication of vectors (Wu et al.2016).

Table 4: Main ovine zoonoses

Zoonotic diseases	Aetiological agent(s)	Effects		References
		Animals	Humans	
Anthrax	*Bacillus anthracis*	Fever Rumination stops Excitement then depression Breathing difficulties Incoordination Seizures Sudden death Incomplete hardening of the carcass after death Bloody discharges from natural body orifices Swelling in different parts of the body	*Skin form:* *Appearance of sores that* become ulcers with a black center Gastrointestinal form: Fever Nausea bloody diarrhea loss of appetite *Respiratory form:* Sore throat Cough Weakness breathing difficulties	Perret et al. 2001 Palomares et al. 2019 Ojeda et al. 2022
Black leg	*Clostridium chauvoei*	Emphysematous muscle inflammation Necrosis (gangrene) Incoordination Edematous swellings on the hip, shoulder, loin, chest and neck Deaths	Localized infection in superficial wounds Foul-smelling serous exudates Myonecrosis Cellulitis Myositis	Cesar 2010 Bush et al. 2021
Botulism	*Clostridium botulinum*	Anorexy Weakening with ataxia Incoordination of previous members Decreased muscle tone Chewing and swallowing problems Anuria Intestinal and ruminal hypotonia Dehydration Progressive paralysis Death	Nausea Threw up Abdominal pain Progressive head-to-limb paralysis respiratory distress Death (without timely care)	Cesar 2010 Uzal 2013 Ojeda et al. 2022

Brucellosis	*Brucella ovis* *Brucella melitensis* *Brucella abortus*	Depression Weight loss Diarrhea In females: Late abortion Lesions in the fetal membranes Retained placenta Mastitis In males: Epididymitis Orchitis Injuries to the scrotum and tunica vaginalis Reduced motility and sperm concentration	Some asymptomatic Fever Weakness Arthritis Hepatic injury Weight loss Abortion	Leite-Browning et al. 2019 WHO 2020b Ojeda et al. 2022
Campylobacteriosis	*Campylobacter fetus* subesp. *intestinalis* *Campylobacter jejuni*	Inflammation of fetal membranes (placentitis) Abortion in the last month of pregnancy Stillbirths Birth of weak pups that die after birth Postpartum metritis	Intestinal inflammation Diarrhea Abdominal pain Fever Nausea Threw up Seizures Meningitis	Gutiérrez et al 2008 López de Armentia et al. 2017 Ojeda et al. 2022
Caseous Lymphadenitis	*Corynebacterium pseudotuberculosis (*antes *Corynebacterium ovis)*	Progressive Anorexy Decrease in meat and milk production Reproductive disorders Skin form: External purulent abscesses, behind the ears, under the jaws, neck, shoulder, hind flank, scrotal sac, and udder. gut shape: Visceral lymph node abscesses Abscesses in liver, lungs and kidneys	Painful skin wounds with purulent exudate and necrotic tissue	Martínez-Hernández et al 2019 Valle et al. 2021
Chlamydiosis (enzootic abortion)	*Chlamydophila abortus* (antes *Clamydia psittaci*)	Epididymitis Encephalomyelitis Enteritis Pneumonia Conjunctivitis Respiratory disease Infertility In pregnant females: Endometrial ulceration Retained placenta Weakening of placenta Abortion (last third of pregnancy) Stillbirths Birth of weak pups	Conjunctivitis Pneumonia Abortions Flu-like signs (fever, chills, joint pain)	Leite-Browning et al. 2019 Palomares et al. 2019 Ojeda et al. 2022

Coenurosis	*Taenia multiceps*	*Coenorus cerebralis* (Cystic vesicle of *T. multiceps*) Depression Ataxia Incoordination Paresis Episodes of excitement Sudden collapse Tremors Blindness Comatose states	Cysts (Cenuri) in: *Central Nervous System* Increased intracranial pressure Loss of consciousness Focal neurological deficits *Subcutaneous tissues* Painful fluctuating nodules *Eye muscles* Vision impairments	Valladares-Carranza et al. 2016 Leite-Browning et al. 2019 Ojeda et al. 2022
Contagious ecthyma	*Parapoxvirus/Poxvirus*	Skin lift Vesicles that form encrustations on the lips, oral cavity, ears, vulva, scrotum, udder, and feet	Painful sores on the hands	Leite-Browning et al. 2019 Ojeda et al. 2022
Dermatophilosis	*Dermatophilus congolensis*	Exudative-proliferative dermatitis Hyperkeratosis	Pustules on arms and hands Ulcerations on the skin	García et al. 2020
Foot and mouth disease	Aftovirus de la familia Picornaviridae	Fever Blisters on tongue, lips, mouth, udders and between hooves Decrease in milk production Abortions In lambs, death from heart failure	Vesicular lesions Fever Runny nose Cut body Articulations pain	WOAH 2021 Ojeda et al. 2022
Echinococcosis	*Echinococcus granulosus*	Fluid and masses in the abdomen Hepatomegaly and abdominal enlargement Breathing difficulties	Pain in the liver region inflammation of the abdomen Sputum with blood Cough Jaundice Hemoptysis	Gottstein and Beldi 2017 Tercero y Olalla 2008
Hemorrhagic sepsis	*Manheimia multocida* *M. haemolytica*	Pyrexia Congestion of the mucous membranes Dehydration Hollow eyes Nervous breakdown Weakness Cough Dyspnea Hyperpnoea muscle tremors Nasal and ocular discharge from serous discharges Anorexy reduced rumination Pleuritis Emission of frothy fluids from the mouth in the terminal phase	Cellulitis with or without abscesses Fever Dyspnea Pleuritic pain Spontaneous bacterial peritonitis Secondary peritonitis due to perforation of viscera Intra-abdominal abscesses Less frequent: Endocarditis Eye infections Genital and urinary tract infections Meningitis	CFSPH 2009b Pinto 2016 Cueto y Pascual 2018

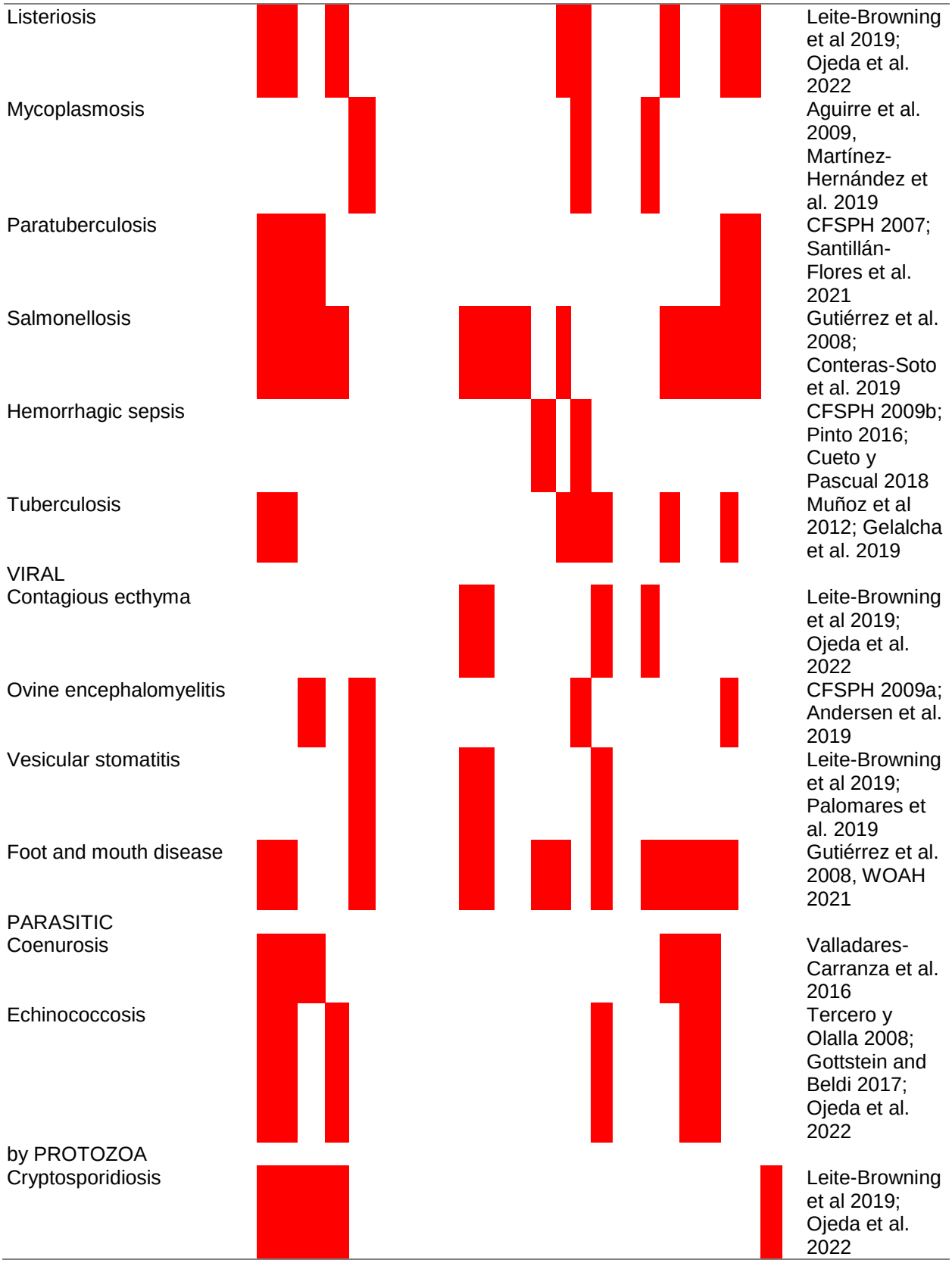
Leptospirosis	*Leptospira interrogans* *Leptospira* spp.	Stillbirths Premature births Abortions Anemia Jaundice Hepatic injury	Some asymptomatic High fever Headache Shaking chills Myalgia Threw up Jaundice Meningitis In severe cases, death	Luna et al. 2019 Leite-Browning et al. 2019
Listeriosis	*Listeria monocytogenes*	Abortion Depression Fever Anorexy Reduction in milk production they walk in circles Seizures Facial paralysis Death	Fever Headache and abdominal Pain Muscle contracture Nausea Vomiting Myalgia Miscarriage or premature birth Newborns with health problems	Leite-Browning et al. 2019 Ojeda et al. 2022
Mycoplasmosis	*Mycoplasma ovis*	Persistent intravascular infections Submandibular edema Hemolytic anemia Hemoglobinuria Jaundice Less meat production Infertility Death in severe cases	Pyrexia Moderate chronic neutropenia Acute hemolysis	Aguirre et al 2009 Martínez-Hernández et al. 2019
Ovine Encephalomyelitis	Virus louping ill de la familia *Flavivirus*	Initial febrile viremic stage Depression Anorexy Encephalitis Muscle tremors and/or stiffness Incoordination Ataxia Hypersensitivity Salivation Nervous Nibbling Movement "in jumps" Death in animals with neurological signs	Fever Headache Articulations pain Meningoencephalitis Neurological signs of paralysis Fever inducing bleeding	Andersen et al. 2019 CFSPH 2009a
Q-Fever	*Coxiella burnetiid*	Abortions Stillbirths Prenatal depression Antepartum anorexia Reproductive disorders	High fever Headache and myalgia Chills and sweating Dry cough Vomiting Diarrhea Pain in abdomen and chest Hepatitis	Rizo et al. 2016 Leite-Browning et al. 2019

Paratuberculosis	*Mycobacterium avium* subsp. *paratuberculosis (*MAP*)*	Irreversible weakening Inflammation and disorders in the intestinal tract Inflammation of the mesenteric lymph nodes Progressive weight loss Profuse diarrhea Pasty stools Intermandibular edema Reduction in milk production Death	Serious local infections Tissue detachment Chronic synovitis Tendinitis	CFSPH 2007 Santillán-Flores et al. 2021
Salmonellosis	*Salmonella abortus ovis*	Placentitis at the cotyledon level Possible abortion in the second half of pregnancy With abortion, females can develop metritis and peritonitis. Infertility in females Birth of septicemic and weak pups Necrotic foci in the liver and lungs In pups lung infections and diarrhea Death in severe cases	Inflammation of the gastrointestinal tract Diarrhea Threw up Nausea Headache Muscle contractures Myalgia	Gutiérrez et al. 2008 Contreras-Soto et al. 2019
Staphylococcus disease	*Staphylococcus* spp.	Mastitis Milk coagulation Presence of blood, pus and lumps of casein in the milk Drop in milk production	Skin infections Endocarditis Pneumonia Osteomyelitis	Esnal y Extramina 2019 Martínez-Hernández et al. 2019 Ojeda et al. 2022
Tuberculosis	*Mycobacterium tuberculosis* Complex (MTC)	Immunosuppression Encapsulated gaseous lesions Lesion in mesenteric lymph nodes (large and prominent) Loss of appetite and weight Dyspnea and intermittent dry cough Signs of low-grade pneumonia Diarrhea	Severe coughing up blood or sputum Chest pain Weakness or fatigue Loss of appetite Weight loss Shaking chills Fever Night sweats	Muñoz et al. 2012 Muños-Mendoza et al. 2015 Gelalcha et al 2019
Toxoplasmosis	*Toxoplasma gondii*	Embryonic or fetal death or late Abortion Fetal mummification Stillbirths Loss of successive pregnancies	Abortions Infected newborns with eye and brain damage Swollen lymph nodes Muscle pains brain and organic damage Vision problems or blindness	Diakoua et al 2013 Leite-Browning et al. 2019

In 2020, worldwide sheep inventory reported 126,613,454 head. Of this total, 49.29% is concentrated in 14 countries (Fig. 2). The largest producer is China with 17,309,553 heads (13.67% of world production), followed by India with 6,809,976 heads (5.38%) and Australia with 6,352,937 heads (5.02%) (FAOSTAT, 2022).

Table 5: Routes of transmission of the main ovine zoonoses

ZOONOSES	ANIMALS													HUMANS						REFERENCES
	Acquisition				Vertical		Horizontal				C	A	M	F	Oral (Food)				V	
	CF	A	S	V	IU	P	BF	BP	H	I					C	MP	L	D	A	
BACTERIAL																				
Anthrax	■								■	■				■						Perret et al. 2001; Martínez-Hernández et al. 2019
Botulisms	■		■						■					■	■	■	■			Cesar 2010; Uzal 2013; Ojeda et al. 2022
Brucellosis	■	■			■	■	■	■		■	■	■	■	■			■			Leite-Browning et al 2019; WHO 2020b; Ojeda et al. 2022
Campylobacteriosis	■	■					■	■		■				■	■	■		■		Gutiérrez et al. 2008; López de Armentia et al. 2017; Ojeda et al. 2022
Black leg	■									■				■	■	■				Cesar 2010; Bush et al. 2021
Chlamydiosis	■	■			■		■	■		■				■						Palomares et al. 2019; Ojeda et al. 2022
Dermatophilosis			■						■	■										García et al. 2020
Staphylococcus disease			■						■	■				■						Esnal y Extramina 2019; Martínez-Hernández et al. 2019
Q-Fever	■			■			■	■		■										Rizo et al. 2016; Leite-Browning et al 2019
Leptospirosis	■	■	■				■	■	■	■										Leite-Browning et al 2019, EFSA/ECDC
Caseous lymphadenitis	■								■	■				■			■			Martínez-Hernández et al. 2019; Valle et al. 2021; Rodríguez et al. 2021


Listeriosis
Leite-Browning et al 2019; Ojeda et al. 2022
Mycoplasmosis
Aguirre et al. 2009, Martínez-Hernández et al. 2019
Paratuberculosis
CFSPH 2007; Santillán-Flores et al. 2021
Salmonellosis
Gutiérrez et al. 2008; Conteras-Soto et al. 2019
Hemorrhagic sepsis
CFSPH 2009b; Pinto 2016; Cueto y Pascual 2018
Tuberculosis
Muñoz et al 2012; Gelalcha et al. 2019
VIRAL
Contagious ecthyma
Leite-Browning et al 2019; Ojeda et al. 2022
Ovine encephalomyelitis
CFSPH 2009a; Andersen et al. 2019
Vesicular stomatitis
Leite-Browning et al 2019; Palomares et al. 2019
Foot and mouth disease
Gutiérrez et al. 2008, WOAH 2021
PARASITIC
Coenurosis
Valladares-Carranza et al. 2016
Echinococcosis
Tercero y Olalla 2008; Gottstein and Beldi 2017; Ojeda et al. 2022
by PROTOZOA
Cryptosporidiosis
Leite-Browning et al 2019; Ojeda et al. 2022

Toxoplasmosis	Diakoua et al. 2013, Jiménez-Martin et al 2015

ANIMALS. Acquisition: CF=Contaminated food, A=Contaminated water sources, S=Contaminated soil, V=Vectors. Vertical: UI=Intrauterine, P= during childbirth. Horizontal: BF=Body fluids, BP= Contact with birth products, H=Wounds, I=Inhalation/Aerogen: HUMANS. C= Direct contact with infected animals, placenta and/or aborted fetuses, A=Aerogenous route (Aerosols), M= Manipulation of meat or viscera, F=Fomites. Oral: C=Contaminated meat, MP=Meat products, L=Contaminated milk, D=Contaminated dairy products. A= Contaminated water, V=Vector transmission.

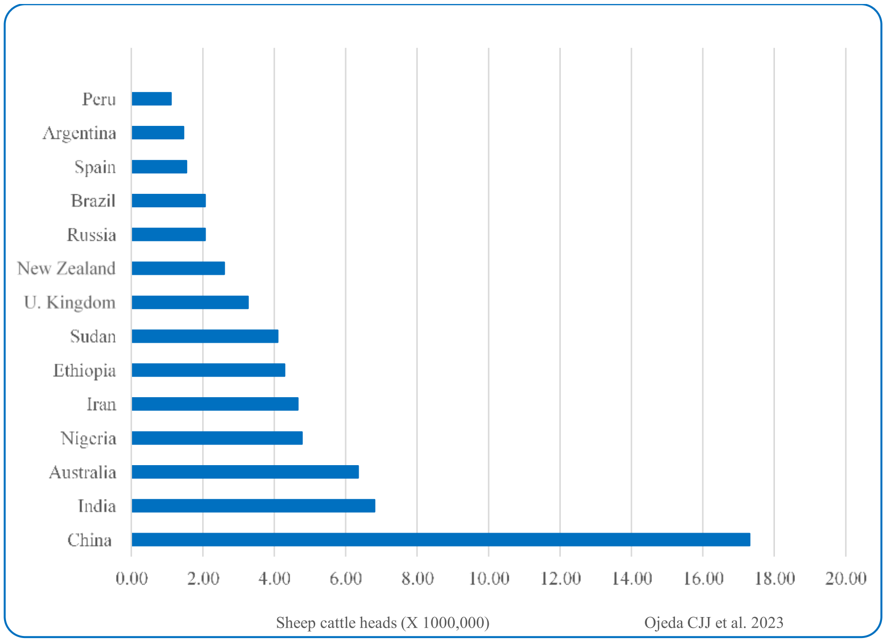


Fig. 2: Main sheep producing countries in 2020: **Source:** Own elaboration based on data obtained from FAOSTAT (2022)

5. WORLD INDICATORS OF THE MAIN OVINE ZOONOSES

The World Health Information System (WHAIS) of the World Organization for Animal Health (WOAH) records data for 14 different zoonoses associated with sheep (WOAH 2023). For 11 zoonoses, the cases for mixed herds (sheep and goats) have also been reported (Table 6). In the case of brucellosis, figures are presented separately for *Brucella abortus*, *B. melitensis* and *B. suis*.

There are differences between the numbers of susceptible animals, positive cases and deaths, of sheep compared to mixed herds. For the 16 zoonotic diseases that are registered, in mixed flocks a greater number of susceptible animals reported (10.6 million) compared to 7.3 million in sheep. In sheep, the highest frequencies correspond to zoonotic taeniasis (61.8%) and foot and mouth disease (14.7%), and for mixed flocks, brucellosis (due to B. melitensis) with 61.7% and foot and mouth disease (22.3%). For six of the zoonoses, susceptibility is greater in mixed flocks than in sheep flocks, including anthrax, brucellosis, foot and mouth disease, tuberculosis and rabies. However, in general the number of positive cases is much lower in mixed flocks (1.6%) than in sheep (14.2%). Proportionally to the number of susceptible animals, positive cases for brucellosis are 3.27% in sheep versus 1.43% in mixed flocks, in foot-and-mouth disease 9.01% vs. 2.42% and in tuberculosis 6.72% vs. 1.80%, respectively. With some exceptions, the relationship is inverse as in hemorrhagic sepsis (4.55% vs 15.97%). In general, sheep-only flocks are more susceptible to disease development (Rizzo et al. 2016; Palomares et al. 2019).

Table 6: Accumulated data, total per year and percentage per world region of the main ovine zoonoses (2018-2022) registered in WOAH

ZOONOSES		SUSC	Cases	Deaths	2018	2019	2020	2021	2022	AF	AM	AS	EU	OC
SHEEP														
Anthrax		300,656	28,341	28,189	1,128	26,105	469	390	249	91.86		6.13	0.18	1.83
Brucellosis	*B. abortus*	5,672	545	3	189	69	277	4	6	54.31	39.08	6.61		
	B. melitensis	792,113	25,935	521	4,656	4,790	3,917	6,315	6,257	2.79		86.62	10.59	
	B. suis	0	1	0		1							100	
Encephalitis		16	6	0	1	1	2		2			50.00	50.00	
Zoonotic taeniasis		4,489,645	865,487	5	171,126	188,448	190,336	225,618	89,959	76.82	20.49		2.69	
Foot and mouth disease		1,068,214	96,224	6,096	13,886	6,667	4,795	65,924	4,952	10.23		89.77		
Hemorrhagic septicemia		67,894	3,086	2,251	2,699	387				79.29		20.71		
Tuberculosis		119	8	0		8					87.50		12.50	
C. pleuropneumonia		250	47	32	47					100				
Paratuberculosis		190,454	3,080	305	97	901	38	1,448	596	57.31	1.98	37.18	3.54	
Q-Fever		166,163	4,589	175	18	1,245	605	1,116	1,605	13.07	0.04	77.56	9.33	
Salmonellosis		61,211	1,750	137	492	992	113	142	11	0.86		37.94	61.20	
Rabies		90,742	1,261	680	349	331	313	216	52	60.82	6.82	32.36		
Rift Valley Fever		34,802	7074	3840	389	774	69	172		100				
West Nile Fever										100				
MIXED HERDS (SHEEP AND GOATS)														
Anthrax		1,236,704	6,113	4,729	2,094	3,608	253	158		37.35		62.65		
Bruc.	*B. abortus*	26,122	1,492	0		1,484	8			1.74	98.26			
	B. melitensis	6,514,810	93,064	608	35,265	26,762	11,003	14,964	5,070	0.52		70.16	29.32	
Zoonotic taeniasis		165,423	1,147	79	534	419	172	22		4.71		95.03	0.26	
Foot and mouth disease		2,352,224	56,850	6,389	13,362	6,008	14,041	12,834	10,605	26.49		73.51		
Hemorrhagic septicemia		6,767	1,081	351	1,069	12				32.38		67.62		
Tuberculosis		39,982	720	0		256	12	45	406	35.69	58.19		6.11	
Paratuberculosis		13,973	1,009	269	17	24	424	141	403			68.09	31.91	

Q-Fever	30,531	1,732	131	26	214	72	600	820		38.91	61.09
Salmonellosis	20,532	1,367	127	849	0	246	250	22		63.06	36.94
Rabies	113,506	463	361	115	216	100	29	3	12.31	87.69	
Rift Valley Fever	37,947	326	104	139	181	6			100		

SUSC= Susceptible. AF= Africa, AM=Americas, AS=Asia, EU=Europe, OC=Oceania
Source: Own elaboration based on the processing of data registered in WOAH (2023).

An important factor is the geographic distribution of zoonoses. The environmental conditions that prevail, the socioeconomic conditions and the productive practices of breeding in each region, are usually determining factors. As observed, from 2018-2022 in sheep the highest number of zoonoses (considering in all cases Brucellosis as one, regardless of the *Brucella* species) occurs in Africa (11), followed by Asia (9), Europe (8), Americas (7) and Oceania (1). For mixed herds, in Asia and Africa (8), Europe (6) and Americas (2). Among other aspects, it stands out that, both in Asia and in Africa, they raise sheep and mixed flocks mainly by transhumance, which contributes to the spread of zoonoses. In contrast, there are four zoonoses reported for a region. Brucellosis caused by *Brucella suis*, with the only case for Spain. The 47 cases of contagious pleuropneumonia for Chad in Africa. Rift Valley fever is present in sheep and mixed herds in 12 African countries where the highest cumulative prevalences reported for South Africa (335), Senegal (246) and Madagascar (154). Four positive cases of West Nile fever has been reported in 2019 for South Africa (WOAH 2023).

In Asia and Africa, in addition to the mentioned factors, the volume of production also determines the diversity of zoonoses. As noted above, the main producers worldwide are located in Asia and Africa. Of the 2020 world sheep inventory, Asia contributes 43.24%, Africa 33.04%, Europe 9.88%, Oceania 7.08% and the Americas 6.77%. However, this relationship between production volume and zoonoses does not necessarily have a directly proportional relationship, that is, as the volume increases, the number of zoonoses increases. The condition that occurs in Asia and Africa does not happen the same when comparing the Americas with Oceania. For 2020, the sheep inventory in the Americas was 8,573,865 heads vs. 8,959,933 in Oceania, with 7 and 1 zoonoses in sheep, respectively.

This indicates that the causality of zoonoses at the regional level is multifactorial. Climatic conditions, infrastructure, nutrition and welfare of animals, epidemiological surveillance, among many other factors, intervene. The figures show that the behavior of each zoonosis in each region is variable, due to the association with these factors. In some, despite international measures to promote its prevention and control, adverse conditions can interfere with these purposes, such as Anthrax, which had a significant increase in cases between 2018 and 2019, going from 1,128 to 26,105 cases. In others, such as zoonotic taeniasis caused by *Echinococcus granulosus*, which experienced sustained growth from 2018-2021, in 2022 the number of cases dropped to about a third of the previous year. Others present fluctuations that make their future behavior unpredictable. In the same way, between one year and another the number of zoonoses registered is variable.

Even when this information provides elements to infer the dimension of the problem associated with ovine zoonoses, it only does so partially. In principle, because WHAIS does not integrate data for other zoonoses of great importance. The records do not include bacterial diseases such as Campylobacteriosis, Chlamydiosis (enzootic abortion), Leptospirosis and Listeriosis, among others, or viral such as ovine encephalomyelitis. As well as those caused by protozoa such as Coccidiosis, Cryptosporidiosis and Toxoplasmosis. Additionally, the figures represent a sample of the regional sheep inventory. For example, for Africa in 2020 the inventory is

41,830,381 heads of sheep, the number of susceptible animals is 55,956, which is equivalent to 0.13% of the inventory. Although it is possible to consider that not all animals are in a condition of susceptibility, this percentage represents only a small part of the real problem for this disease.

Added to the real impact that these zoonoses have on animals are the effects on human health. Sheep zoonoses that affect public health mostly include those transmitted by food, associated with the consumption of meat or meat products, milk and its derivatives, with deficient cooking or pasteurization processes. Among these are Campylobacteriosis, Salmonellosis, Yersiniosis, Escherichia coli infections (STEC infections), Listeriosis, Trichinosis, among others. Other zoonoses, due to direct contact with infected animals, such as tularemia, a disease present in different animal species, but to which sheep are particularly susceptible (CFSPH 2019). Alternatively, by other routes of transmission such as aerosols, fomites contaminated with feces or urine, contact with the birth products of a sick animal, or through vectors, which increases the risk of contracting them.

Due to their routes of transmission, some occur more frequently in people related to the care and attention of animals. However, those that represent a greater risk are Foodborne Diseases. In most cases, the effects on public health are precisely unknown, due to the lack of systematized records. The referents appear in isolation through estimates, reports on specific outbreaks or general information provided by the World Health Organization. This organization refers, for example, that Campylobacteriosis in humans is associated with the consumption of contaminated food, such as meat, milk and its derivatives (WHO 2020). In the case of Listeriosis, it has been found that cold cuts (meat pies and other sausages) and soft cheeses made with contaminated products served as high-risk foods (WHO 2018). For this zoonosis, the CDC (2017) estimates that annually 1,600 people contract the disease and that about 260 (16.25%) die from it. In Spain, in 2019, 254 people were affected, four deaths and six abortions caused by the disease. In 2020, the number of cases increased to 1,900, of which 817 (43%) required hospitalization, with a mortality rate of 13%, which implies that 1:8 people died from the disease (Lurueña 2022). In 2022, 16 cases were reported in 6 states of the American Union (7 in New York), 81.25% required hospitalization and 1 died (CDC 2023).

Of the different health instances, only the European Food Safety Authority and the European Center for Disease Prevention and Control annually record information on cases of zoonoses that occur in the European Union. For 2021 (Table 7), they report 14 zoonoses in which sheep are involved (EFSA/ECDC 2022).

Of the 14 zoonoses, 11 are systematically reported and three (Yersiniosis, West Nile Fever and Toxoplasmosis) are only monitored based on the epidemiological situation that occurs. Based on the incidence and notification rate (N/1000 000 population), the most important are Campylobacteriosis and Salmonellosis. By the number of deaths, Listeriosis and Salmonellosis. Most of the reported cases correspond to infections acquired within the European Union. The report of cases acquired outside the EU indicates that one of the risk factors is associated with global movements that have increased significantly in recent years. Comparison with reported data shows that the number of cases has increased by 10 zoonoses, with the largest increase for *Escherichia coli* STEC infections. A reduction is only shown in cases of Echinococcosis (Zoonotic Taeniasis), Q-Fever, Trichinosis and West Nile Fever.

Table 8 shows the contrast between the number of cases and deaths reported in humans and animals. Until now, information systems do not have records that allow us to know the real scope of zoonotic diseases, in principle due to the lack of systematization of reports from humans in the world. Additionally, because not all zoonoses are integrated into the WHAIS registry. In this case, the ECDC (2022) reports 14 zoonoses in humans for the European Union and WHAIS (WOAH 2023) only includes five of these. Campylobacteriosis,

Table 7: Cases of zoonoses in humans in the European Union for 2021 based on data registered in EFSA/ECDC

Zoonoses	CASES	HOSP	DEATHS	NR	FC	ACQUIRED IN:			Changes compared to 2020 in %
						In EU	Outside EU	Country unknown	
Campylobacteriosis	127,840	45,121	26	41.1	249	81,311	704	45,825	2.10
Salmonellosis	60,050	11,785	71	15.7	773	43,720	925	15,405	14.30
Yersiniosis (*)	6,789	1,564	0	1.9	248	3,478	18	3,293	11.80
E. coli STEC Infections	6,084	2,133	18	2.1	31	4,355	117	1,612	36.90
Listeriosis	2,183	956	196	0.49	23	1,484	2	697	14.10
Tularemia	876	221	2	0.2		715	160	1	33
Equinococcosis	529	121	0	0.15	0	128	81	320	-7.50
Q-Fever	460	0	4	0.11		359	3	98	-12.00
Brucellosis	162	60	0	0.03	1	76	21	65	0.03
Tuberculosis	111	0	0	0.03	0	55	47	9	12.40
Trichinosis	77	26	0	0.02	1	29	2	46	-32.50
Rabies	0	0	0	0	0	0	0	0	0
West Nile Fever(*)	158	70	21	0.04		153	5	0	-57
Toxoplasmosis (*)	133	98	0	0.02	95	124	7	2	1.80

HOSP= Hospitalized, NR= Notification rate N/1000, 000 population, FC Foodborne cases
(*) Zoonoses monitored based on the epidemiological situation
Source: Own elaboration based on the processing of data registered in EFSA/ECDC (2022).

Table 8: Comparison of reported cases and deaths, for animals and humans in the European Union (2021)

ZOONOSES	Animals		Humans		Countries (Highest reported cases)			
	Cases	Deaths	Cases	Deaths	Animals	No.	Humans	No.
Campylobacteriosis	*	*	127,840	26			Germany	47,912
							Czech Republic	16,305
							Slovakia	6,099
Salmonellosis	126	0	60,050	71	Italy	67	Czech Republic	10,032
					Spain	43	France	9,315
					Romania	16	Germany	8,144
Yersiniosis	*	*	6,789	0			Germany	1,912
							France	1,451
							Czech Republic	456
E. coli STEC Infections	*	*	6,084	18			Germany	1,635
							Denmark	927
							Ireland	878
Listeriosis	*	*	2,183	196			Germany	560
							France	435
							Italy	241
Tularemia	N/R	N/R	876	2			Sweden	292
							France	143
							Germany	113
Echinococcosis	1,350	0	529	0	Spain	1,349	Germany	152
					Hungry	1	Bulgaria	89
							Austria	42
Q-Fever	192	0	460	4	Spain	145	Spain	149
					Germany	39	Germany	99
					Hungry	7	France	92
Brucellosis (*B. melitensis*)	65	0	162	0	Spain	54	Italy	32
					Italy	11	Spain	25
							Greece	24
Tuberculosis	N/R	N/R	111	0			Germany	42
							Spain	32

							Italy	12
Trichinosis	N/R	N/R	77	26			Bulgaria	29
							Croatia	17
							Austria	10
Rabies	0	0	0	0				
West Nile Fever	N/R	N/R	158	21			Italy	65
							Greece	59
							Romania	7
Toxoplasmosis	*	*	133	98			France	110
							Germany	14
							Poland	9
Paratuberculosis	37	0	N/R	N/R	Spain	29		
					Germany	8		
Totals	1,770	0	205,452	462				

*= Not included in the WHAIS database. S/R= No data record in WHAIS or EFSA for that year: **Source:** Own elaboration based on the processing of data registered in EFSA/ECDC (2022) and WOAH (2023).

Yersiniosis, *E. coli*/STEC infections, Listeriosis and Toxoplasmosis are not on the list of diseases in the WHAIS information system. It stands out that the first three are the most prevalent in humans and that there is no information to associate the corresponding animal species. For another four, although the disease is on the list, there are no recorded data for 2021 or the species. In sheep, Tularemia registers 32 positive cases and zero deaths (2005-2007), all for Bulgaria. Rabies 139 cases, 45 deaths (2005-2016) with distribution in 5 countries (Bulgaria, Croatia, Latvia, Poland and Romania). Tuberculosis associated with the *Mycobacterium tuberculosis* complex and Trichinosis report 3 and 56 cases, respectively for pigs and wild boars (2007-2019), none for sheep. As for West Nile Fever, the cases reported in sheep are for Africa and Canada (WOAH 2023).

The absence of data in both categories for some zoonoses makes a 1:1 comparison impossible. For cases that meet this condition, the prevalence reported in humans are higher than in animals, except for brucellosis. The controls established in the EU have made it possible to significantly reduce the cases of this zoonosis and even eradicate it in some countries (EFSA/ECDC 2022). In the list of countries with the highest incidence, there is not necessarily a direct correspondence between the number of cases between animals and humans. For example, for Salmonellosis, positive cases in sheep include Italy with 67 (3,768 in humans), Spain with 43 (3,912) and Romania with 16 (518). However, in humans, the highest incidences correspond to the Czech Republic (10,032 cases), France (9,315) and Germany (8,144). In Echinococcosis, cases in sheep are only reported for Spain (1,349 cases in animals vs. 33 in humans) and Hungary. The proportions are for Spain and Hungary (1 vs 7). The highest incidences are for Germany (152), Bulgaria (89) and Austria (42). In these cases, the disease may be associated with infections outside the EU, or that the pathogens came from other domestic or wild animal species.

According to the EFSA/ECDC reports (2022), of the 27 countries that make up the European Union, 15 (55.6%) show effects on public health due to the report of zoonoses. Based on the incidence and diversity of zoonotic diseases in humans, Germany stands out with 10, France (6), Italy (4) and Spain and the Czech Republic, both with 3 zoonoses. These data allow us to infer the impact generated by zoonoses on human health in different regions of the world. The complexity of the risk factors is that they are not unidirectional and that in many cases they tend to be convergent, which tends to exacerbate the problems faced.

6. CONCLUSIONS

Sheep farming is a livestock activity that is gaining strength throughout the world. Its contributions to food security, economy and development contrast with the effects on animal and human health.

This is mainly due to the diversity of factors that increase the risks of these diseases occurring. The changing environmental conditions associated with climate change are propitious for originally endemic diseases to expand their distribution. The population increase, the greater contact with wild species, the increase in international transit, commercial exchange and changes in lifestyles, which include the consumption of processed foods, among other factors, are increasing these risks alarmingly.

The fact that for the same zoonosis there are different definitive and incidental hosts, which include both domestic and wild species, is increasing the risk of transmission of these diseases. In addition to this, deficiencies in epidemiological surveillance, in animal health controls and prevention measures, tend to exacerbate this problem. Although the food needs of human populations require an increase in food production, deficiencies in biosecurity and animal welfare measures in animal husbandry, as well as inadequate handling during slaughter and food processing, they are violating this objective. In addition to the economic impact due to the losses generated by the low productive performance or death of animals, as well as the costs of veterinary care, zoonoses violate food safety. The impact on the availability and safety of food seriously jeopardizes human health and the future development of populations.

REFERENCES

Aguirre DH et al., 2009. Brote de Micoplasmosis clínica por *Mycoplasma ovis* en ovinos de Salta, Argentina. Diagnóstico clínico, microbiológico y molecular. Revista Argentina de Microbiología 41: 212-214.

Andersen NS et al., 2019. Continued expansion of tick-borne pathogens: Tick-borne encephalitis virus complex and *Anaplasma phagocytophilum* in Denmark. Ticks andTick-Borne Diseases 10(1):115-123.

Bush LM et al., 2021. Infecciones de los tejidos blandos por clostridios (Gangrena gaseosa; mionecrosis). Manual MSD. Open Access.

CDC, 2017. Listeria (Listeriosis). Centers for Disease Control and Prevention.

CDC, 2023. Nuevo brote de Listeria en EEUU asociado al consumo de quesos y embutidos. Centers for Disease Control and Prevention

Cesar D, 2010. Enfermedades clostridiales. Revista Plan Agropecuario 135: 48-52

CFSPH, 2007. Paratuberculosis. The Center for Food Security & Public Health.

CFSPH, 2009a. Encephalomyelitis of Sheep: Louping-ill infectious. The Center for Food Security & Public Health.

CFSPH, 2009b. Hemorrhagic septicemia. The Center for Food Security & Public Health.

CFSPH, 2019. Tularemia. The Center for Food Security & Public Health.

Contreras-Soto MB et al., 2019. The last 50 years of *Salmonella* in Mexico: Sources of isolation and factors that influence its prevalence and diversity. Revista Bio Ciencias 6(2): e640.

Cueto LM and Pascual HA, 2018. *Pasteurella multocida*. SEIMC. Sociedad Española de Enfermedades Infecciosas y Microbiología Clínica 2: 7-13.

Diakoua A et al., 2013. *Toxoplasma gondii* and *Neospora caninum* seroprevalence in dairy sheep and goats mixed stock farming. Veterinary Parasitology 198(3-4): 387-390.

EFSA/ECDC, 2022. The European Union One Health 2021 Zoonoses Report. European Food Safety Authority/ European Centre for Disease Prevention and Control.

Esnal A and Extramina AB, 2019. Control de *Staphylococcus aureus* mediante identificación de portadores en el ganado ovino y caprino lechero, Analítica Veterinaria 2019: 1-3.

FAOSTAT, 2022. Food and agriculture data: Environment Livestock Trends. Food and Agriculture Organization of the United Nations.

García SA et al., 2020. La importancia de la dermatofilosis, REDVET 18(7): 24-33.

Gelalcha BD et al., 2019. Tuberculosis caused by *Mycobacterium bovis* in a sheep flock colocated with a tuberculous dairy cattle herd in Central Ethiopia. Journal of Veterinary Medicine 2019: Article # 8315137.

Gottstein B and Beldi G, 2017. Echinococcosis. In: Cohen J, Powderly WG, Opal SM, editors. Infectious Diseases (4th Ed.): Philadelphia, PA, Elsevier; pp: 120.

Gutiérrez CAC et al., 2008. Salmonellosis and Campylobacteriosis, the most prevalent zoonosis in the world. Veterinaria México 39(1):81-90.

Jiménez-Martín D et al., 2015. Seroepidemiology of tuberculosis in sheep in southern Spain. Preventive Veterinary Medicine 1: e105920

Leite-Browning ML et al., 2019. Principales enfermedades extranjeras y zoonóticas de los ovinos y caprinos de carne. FAZD CENTER. National Center for Foreign Animal and Zoonotic Disease Defense. EREEE 304: 3-11.

López de Armentia FJ et al., 2017. Hallazgo de *Campylobacter fetus* en semen ovino congelado. Universidad Nacional del Centro de Buenos Aires, Argentina.

Luna AMA et al., 2019. Frecuencia de anticuerpos de Leptospirosis en ovinos y control de la enfermedad por medio de vacunación. BM Editores-Ganadería 3: 28-39.

Lurueña MA, 2022. Listeria: el patógeno que trae de cabeza a la industria alimentaria. El País. Salud y Bienestar. 28 de noviembre de 2022.

Martínez-Hernández JM et al., 2019. Molecular detection of *Mycoplasma ovis* in an outbreak of hemolytic anemia in sheep from Veracruz, Mexico. Tropical Animal Health and Production 51(1): 243-248.

Moreno DC and Grajales HA, 2017. Characterization of ovine systems in Colombian high tropics: Management, productive and reproductive performance indicators. Revista de la Facultad de Medicina Veterinaria y de Zootecnia (Universidad de Colombia) 64(3): 36-51.

Muñoz MM et al., 2012. Tuberculosis due to Mycobacterium bovis and Mycobacterium caprae in sheep. Veterinary Journal 191(2): 267-269.

Muñoz-Mendoza M et al., 2015. Tuberculosis en ovino: Epidemiología, patología y evaluación de técnicas diagnósticas. XL Congreso Nacional y XVI Congreso Internacional SEOC-2015.

Ojeda CJJ et al., 2022. Principales enfermedades que afectan la productividad ovina e inocuidad alimentaria. En: García-Rubio VG (Comp). Potencialidades de la ovinocultura y los hongos comestibles (*Pleurotus* spp.) en la seguridad alimentaria y el desarrollo rural. México: Laberinto Ediciones; pp: 339-419.

PAHO/WHO, 2018. Zoonoses. Pan American Health Organization/World Health Organization

Palomares REG et al., 2019. Frequency and risk factors with the presence of *Chlamydia abortus* in flocks of sheep in Mexico. Revista Mexicana de Ciencias Pecuarias 11(3): 783-794.

Perret PC et al., 2001. Ántrax (Carbunco). Revista Chilena de Infectología 18(4): 291-299.

Pinto JCE, 2016. Epidemiología molecular de las poblaciones bacterianas de "*Mannheimia haemolytica* y *Pasteurella multocida*" asociadas a la presencia de lesiones neumónicas en corderos en matadero. Disertación Doctoral, Universidad Complutense de Madrid

Rizzo F et al., 2016. Q fever seroprevalence and risk factors in sheep and goats in northwest Italy. Preventive Veterinary Medicine 130:10-39.

Rodríguez DMC et al., 2021. Caseous lymphadenitis: virulence factors, pathogenesis and vaccines. Review. Revista Mexicana de Ciencias Pecuarias 12(4): 1221-1249

Santillán-Flores MA et al., 2021. Paratuberculosis epidemiological study (risk factors and prevalence) in ovine livestock production units in the State of Guanajuato, Mexico. Journal of Veterinary Medicine and Animal Health 13(3): 114-120.

Sempere RN et al., 2019. Mecanismos de transmisión de las enfermedades. Universitat de Valencia.

Tercero GMJ and Olalla HR, 2008. Hidatidosis. Una zoonosis de distribución mundial. Offarm 27(9): 88-94

Uzal FA, 2013. Enfermedades clostridiales de los rumiantes, con especial énfasis en ovinos. XLI Jornadas Uruguayas de Buiatría 2013: 68-70.

Valladares-Carranza B et al., 2016. Estudio clínico de cenurosis en ovinos del Estado de México, México. Quehacer Científico en Chiapas 11(2): 60-67.

Valle SE et al., 2021.Linfadenitis caseosa en rebaños caprinos y ovinos. Medicina Veterinaria al Día 2(3): 41-54.

Vega-Pla JL et al., 2022. Zoonoses: basis and foundation of the One Health. Sanidad Militar 78(3): 134-136

WHO, 2018. Listeriosis. World Health Organization.

WHO, 2020a. Campylobacter. World Health Organization.

WHO, 2020b. Brucellosis. World Health Organization.

WOAH, 2021. Foot and mouth disease. World Organization Animal Hearth.

WOAH, 2023. WAHIS: World Animal Health Information System, World Organization for Animal Health. Quantitative Data Dashboard.

Wu X et al., 2016. Impact of climate change on human infectious diseases: Empirical evidences and human adaptation. Environment International 86: 14-23