Chapter

# Rabies Virus Infection in Livestock

*Abdelmalik I. Khalafalla and Yahia H. Ali*

## Abstract

Rabies is a lethal zoonotic encephalomyelitis and a major challenge to public and animal health. Livestock are affected by rabies mostly through bites of rapid dogs or wildlife carnivore's species. They are considered as 'dead-end' hosts that do not transmit the virus. Rabies in livestock has been endemic in many developing countries for many years and diagnosed through clinical signs and dog-biting history. An introduction on rabies situation in farm animals will be given then subchapters including `rabies in bovines, rabies in small ruminants, rabies in swine and rabies in camelids. In each subchapter we shall discuss, epidemiology, modes of transmission, diagnosis and prevention and control measures.

**Keywords:** rabies, old world camelids, new world camelids, epidemiology, diagnosis, spread

## 1. Introduction

Rabies is the oldest known zoonotic fatal viral disease that affects only warm-blooded mammals. The rabies virus (RABV) infects the central nervous system transmitted through direct contact (such as through broken skin or mucous membranes in the eyes, nose, or mouth) with saliva or brain/nervous system tissue by an infected animal.

RABV almost exclusively infects neurons and eventually causing disease in the brain and death. The virus particle binds cell-surface receptors and follows the endosomal pathway. The virus's life cycle then advances, and following several days or months, the virus enters the peripheral nerves (**Figure 1**). It is then transported to the central nervous system by retrograde flow in the axons [1].

People usually get rabies from the bite of a rabid animal. Around 99% of human cases of rabies are due to dog bites or rarely from non-bite exposures, which include scratches, abrasions, or open wounds. RABV can infect any mammal. However, animal species reported to be involved in the transmission of rabies to domestic farm animals are dogs, foxes, wolves, jackals, and vampire bats (**Figure 2**).

The species of livestock and the carnivores that transmit RABV to them vary from geographical area to another. For instance, according to Kasem et al. (2019), camels, sheep and goats are the most affected species among farm animals by rabies (21.5%, 16.5%, and 16.5%, respectively) and foxes and wolves (11.4% and 2.5%, respectively) are the most common wild animals infected with rabies in Saudi Arabia (**Figure 3**). **Table 1** show reported animal rabies cases according to the reviewed articles in some Asian, African, European, and Latin American countries.

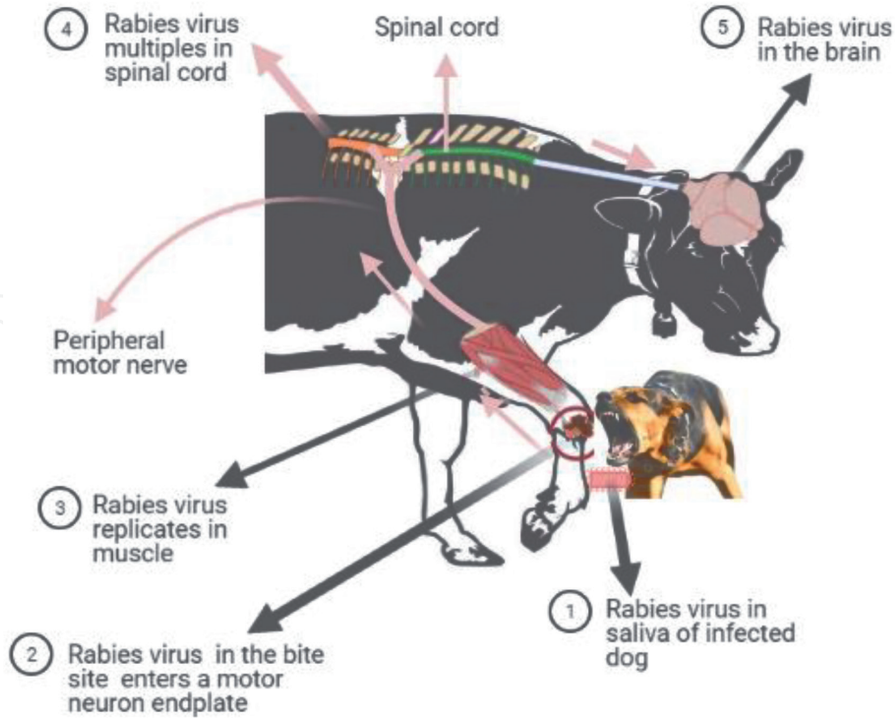


**Figure 1.**
*Pathogenesis and spread of rabies virus in animals from the bite site to the central nervous system.*

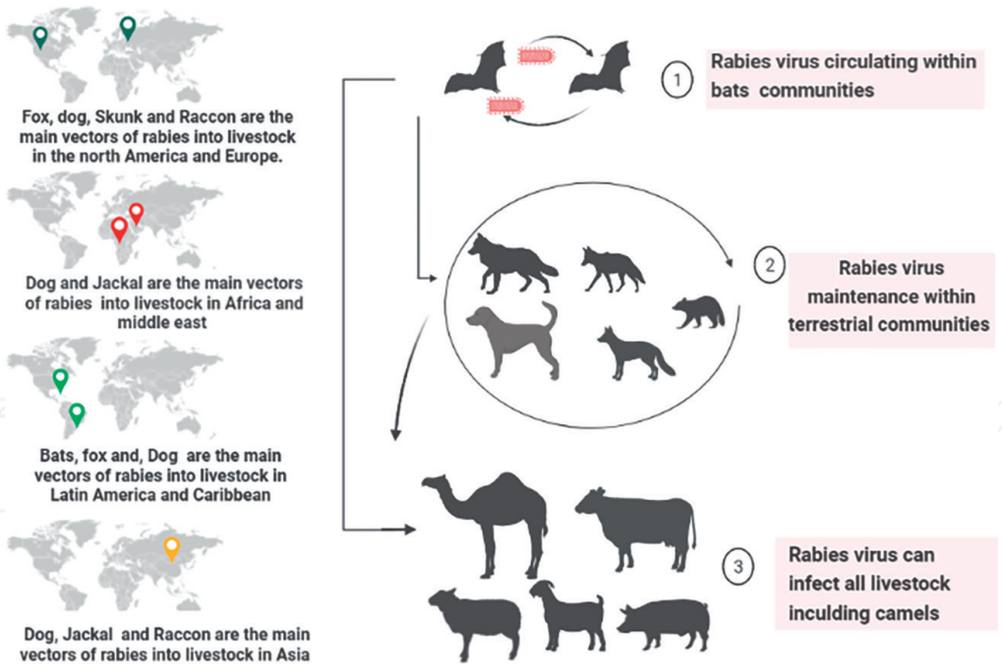


**Figure 2.**
*Rabies virus transmission cycle in bats, terrestrial animals, and livestock.*

The circulation of rabies virus among livestock has extraordinarily influenced endeavors to control the disease in humans as these animals are in regular contact with individuals. Additionally, affected livestock pose a potential risk to veterinarians and farmers, which underline the importance of applying rabies control measures to humans [15]. Rabies is a transmissible disease among animals causing economic

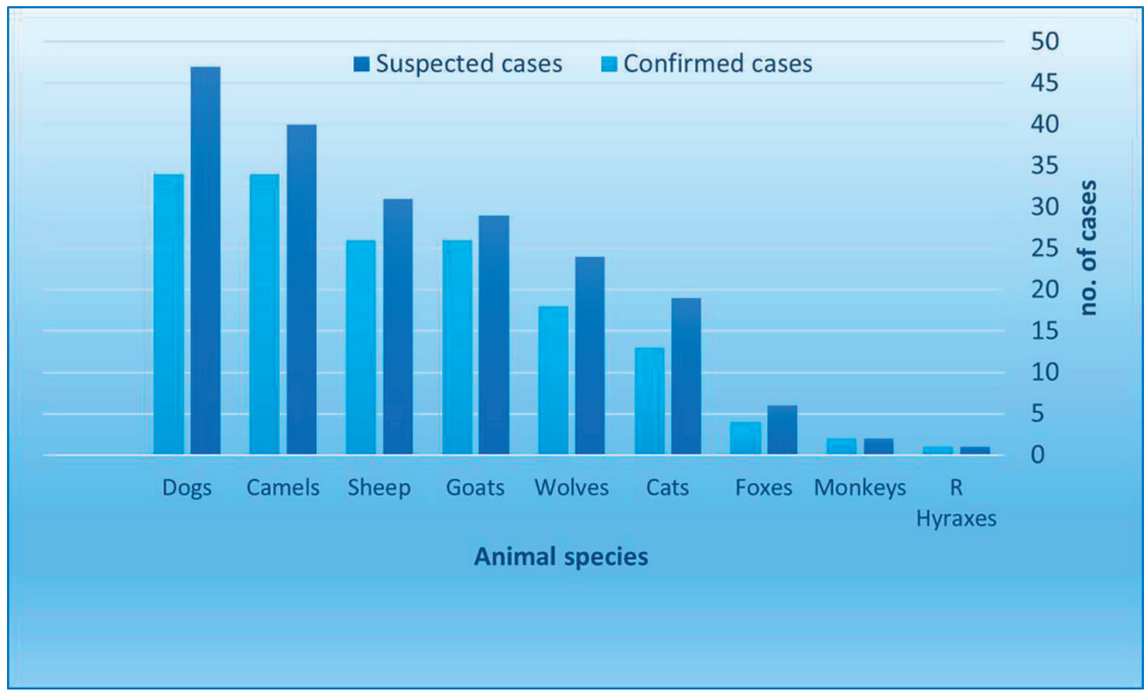


**Figure 3.**
*Suspected and confirmed cases of rabies in animals in Saudi Arabia recorded between 2010 and 2017 (modified from* ***Table 1*** *in Kasem et al. [15].*

losses directly or indirectly on the local and national economy. Due to their total reliance on livestock for their livelihoods, the losses due to rabies are relatively high for pastoral peoples in rural areas of the world due to their total dependence on livestock. Nevertheless, rabies in livestock remains underreported in developing countries because most of these countries lack adequate and efficient reporting systems and only clinical diagnosis is accessible.

## 2. Economic impact of rabies in livestock

Hampson et al. [38] estimated the economic costs of canine rabies to be 8.6 billion USD, mainly due to loss of productivity due to premature deaths, costs of post-exposure prophylaxis (PEP), and income loss for seeking PEP. Costs of Livestock deaths were 512 million USD per year, especially in livestock-dependent African economies (e.g., Sudan, Ethiopia, and Tanzania) and Asia (China, India, Bangladesh, and Pakistan). In Bhutan, rabies results in loss of cattle and their production, thus causing direct economic losses to the farmers besides a cost to the government due to managing outbreaks and provision of mass rabies PEP [39]. Most rabies human deaths were in Asia and Africa. Estimated rabies human deaths worldwide annually are 55,000, about 31,000 in Asia and 24,000 in Africa. In Bangladesh, dogs bit nearly 100,000 people, with at least 2,000 rabies deaths in 2009 [40].

Besides its public health significance, the occurrence of rabies in domestic animals (cattle, sheep, and goats), which are the source of food and income to the poor rural people, had raised its economic importance. The authors reviewed a report stating that the incidence of rabies in livestock is re-emerging disease reported in rabies endemic and free countries [29].

| Country | Animal species | | | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|---|
| | Dog | Cattle | Goat | Sheep | Equidae | Camel | Pig | Fox | |
| **Bangladesh** | | 10 | 1 | | 1 (Horse) | | | | Uddin et al. [2] |
| | 384 | 290 | 355 | | | | | | Islam et al. [3] |
| **India** | | | | | | 1 | | | Kumar and Jindal [4] |
| | | | | | | | 3 | | Preethi et al. [5] |
| **Sri-Lanka** | 6788 | 915 | 233 | 13 | | | | | Pushpakumara et al. [6] |
| **China** | | | | | | | 20 | | Jiang et al. [7] |
| | | 21 | | | | 15 | | | Liu et al. [8] |
| | | | | 36 | | | | | Zhu et al. [9] |
| **Nepal** | 374 | 442 | 122 | 60 | 14 (Horses) | | 21 | | Devleesschauwer et al. (2016) |
| **Iran** | | 6 | | | | | | | Simani et al. [10] |
| | | | | | | 12 | | | Mohammadpour et al. [11] |
| **Jordan** | | | | | | 8 | | | Al-Rawashdeh et al. [12] |
| **Oman** | 2 | | 312* | | | 40 | | 47 | Al-Abaidani et al. (2015) |
| | | | | | | 22 | | | Ahmed et al. [13] |
| **Indonesia (Bali)** | 7114 | 8 | 1 | | | | 1 | | Putra [14] |
| **Saudi Arabia** | 34 | | 26 | 26 | | 34 | | 18 | Kasem et al. [15] |
| **Uganda** | 15 | 6 | 4 | | | | | 1 | Omodo et al. [16] |

| Country | Animal species | | | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|---|
| | Dog | Cattle | Goat | Sheep | Equidae | Camel | Pig | Fox | |
| **Sudan** | | | | | | 83 | | | Ali et al. (2004) |
| | 1158 | 172 | 501 | 82 | 33(Horses), 467 (Donkeys) | 79 | | | Ali, et al. [17] |
| | 708 | 76 | 184 | 111 | 12 (Horses), 277 (Donkeys) | 60 | | | Ali, et al. (2009) |
| | 64 | 53 | 34 | 28 | 26 (Horses) | 11 | | | Baraa et al. [18], |
| | | | | | | 5 | | | Abbas and Omer [19], |
| | | 1 | 1 | | | 6 | | | Ahmed et al. [20], |
| | 4 | 1 | 1 | | 4 (Donkeys) | | | | Ali [21] |
| **Ethiopia** | 1951 | | | | | | | | Nibret [22] |
| | 1434 | | | | | | | | Reta, et al. [23] |
| | 1724 | 37 | | | 13 (Horses), 19 Donkey | | | | Oyda and Megersa [24] |
| | | 28 | 12 | 5 | 3 (Horses) | | | | Mulugeta et al. [25] |
| **Kenya** | 2796 | 1192 | 280 (sheep & goat) | | 113 | 1 | | 17 | Bitek et al. [26] |
| **Morocco** | 2458 | 2390 | 331(sheep & goat) | | 1455 (Horses) | 9 | | | Darkaoui et al. [27] |
| **Algeria** | 667 | 98 | | | | | | | Matter et al. (2015) |

| Country | Animal species | | | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|---|
| | Dog | Cattle | Goat | Sheep | Equidae | Camel | Pig | Fox | |
| **Nigeria** | | | 1 | | | | | | Kaltungo et al. (2018) |
| | | 1 | | | | | | | Ibrahim et al. [28] |
| | | 5 | 1 | 1 | | | | | Tekki et al. [29] |
| **Sierra Leone** | | 9 | | | | | | | Suluku et al. [30] |
| **Ghana** | | | | | | | 3 | | Tasiame et al. (2016) |
| **Namibia** | 644 | 592 | 131 | | | | | | Hikufe et al. (2019) |
| **USA** | 62 | 36 | 11* | | 13 (Horses) | | | 314 | Xiaoyue et al. (2018) |
| **Brazil** | | | | | | | 2 | | Pessoa et al. [31] |
| | | | 6 | | | | | | Moreira et al. [32] |
| **Mexico** | | 1037 | | | | | | | Bárcenas-Reyes et al. [33] |
| **Guatemala** | | 154 | | | | | | | Gilbert et al. [34] |
| **Russian Federation** | 3731 | 6740 | | | | | | 4347 | Botvinkin and Kosenko [35] |
| **Belarus** | 215 | 129 | | | | | | 734 | Botvinkin and Kosenko [35] |
| **Latvia** | 566 | | | | | | | 2281 | Westerling et al. [36] |
| **Lithuania** | 183 | 638 | | | | | | 802 | Westerling et al. [36] |
| **Estonia** | 131 | 81 | | | | | | 566 | Westerling et al. [36] |
| **Ukraine** | 78 | 7 | 1 | | 2 | | | 226 | Polupan et al. [37] |

*Both sheep and goats.*

**Table 1.**
*Reported animal rabies cases according to the reviewed articles in some Asian, African, European, and Latin American countries.*

## 3. Laboratory diagnosis of rabies in livestock

During the eclipse phase after infection, the rabies virus replicates in non-nervous tissue such as muscle. After several days or months, the virus enters the peripheral nerves and is transported to the central nervous system and then disseminated within the CNS and the highly innervated tissues, resulting in clinical signs. Most of the virus is found in nervous tissue, salivary glands, saliva, and cerebrospinal fluid (CSF), which should all be handled with extreme caution. As there are neither gross pathognomonic lesions nor specific and constant clinical signs for rabies, confirmatory laboratory diagnosis must be performed [41]. Laboratory diagnosis of rabies is based on the direct detection of rabies viral antigen using different histopathological and serological techniques with the dominance of fluorescent antibody test (FAT) (**Figure 4**). RABV infection induces the formation of cytosolic protein aggregates called Negri Bodies (NBs) detected by histopathology. However, this test is no longer recommended for diagnosis [41]. Brain samples are tested using the rapid immuno-chromatographic and direct Fluorescent Antibody assay in Nigeria [28, 29]. In China, FAT and RT/PCR are used for diagnosing rabies [8]. Real-time PCR is used as well in different laboratories [30]. Diagnosis of rabies is performed in Ethiopia by animal inoculation, cell cultures, serological tests, histological examination, molecular methods, and immunohistochemistry [42].

In Iran, laboratory diagnosis of rabies is practiced using different techniques, antigen in saliva using mouse inoculation test (MIT), fluorescence antibody test (FAT) and rapid tissue cell inoculation test (RTCIT). Antibodies against rabies in serum and cerebrospinal fluid (CSF) using mouse neutralization test (MNT) [10].

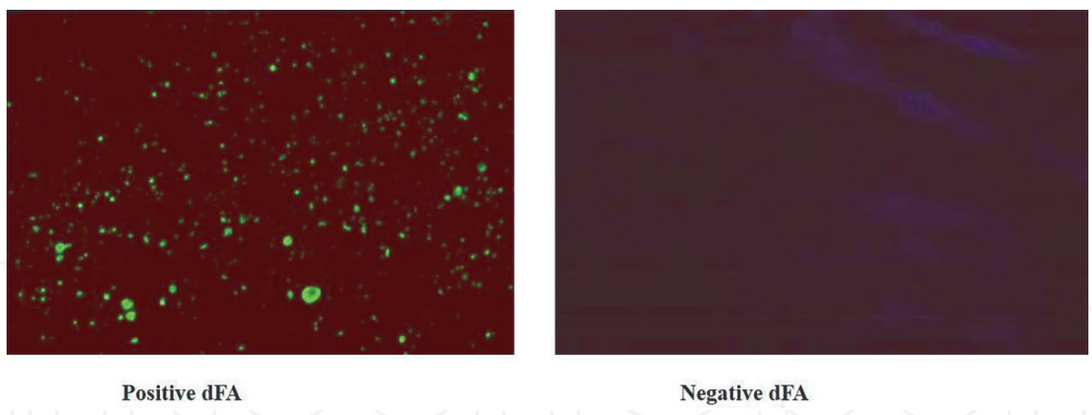


**Figure 4.**
*Direct fluorescent antibody test (dFA), brain impression smears (source: Centers for Disease Control and Prevention (CDC)).*

## 4. Prevention and control measures

It is important to remember that in developed countries, where canine rabies is eliminated, the virus may circulate in wildlife. In contrast, in most developing countries, the principal reservoir is dogs. The major rabies control strategies are vaccination of susceptible animals, mainly dogs and cats, elimination or control of stray dogs, and pre- and post-exposure vaccination of humans at risk. For rabies vaccination in animals, inactivated virus (for companion animals and livestock), live attenuated virus (for wildlife and free-roaming dogs), or recombinant vaccines (for

wildlife, cats, and dogs) are used [41]. In China, local rabies vaccines have been used for emergency immunization of beef and dairy cattle and Bactrian (two-humped) camels [8]. In Ukraine, vaccination of domestic dogs and cats, besides oral vaccination of wild animals, mainly foxes, is adopted to control rabies [37]. In Latin America, due to attacks of bats, rabies is a significant problem, especially in cattle; many countries tend to vaccinate cattle but with an inadequate response from owners. In Guatemala, cattle vaccination coverage was estimated to be 11% [34]. In Latin America (e.g., Guatemala), vampire bat control activities (poisoning or culling) are used to control rabies in cattle, besides vaccination of cattle, although it is not widely used due to high cost [34]. In Morocco, free annual rabies vaccination campaigns for dogs are practiced; nevertheless, only around 6% vaccination coverage rate is achieved. Elimination of stray dogs is done by shooting or using strychnine poison [43]. In Algeria, a mean of 131 positive dog rabies cases were reported annually; this is considered extremely high compared to neighboring Tunisia and Morocco. Elimination of stray dogs and vaccination of canines are the main control measures adopted [44].

Vaccination of livestock in affected areas was implemented in 2012 in Bela Vista city, Arkansas state, USA, where a rabies outbreak was reported. More than 200 cattle were vaccinated with two doses of the vaccine to prevent the disease in bovine, equine, goat, and sheep (reviewed by [29]).

## 5. Rabies in cattle

Cattle, like other warm-blooded animals, are susceptible to rabies infection. The incidence of rabies in cattle is variable according to the management system.

### 5.1 Epidemiology

The incidence of rabies in cattle is continuously reported worldwide. In India and Bangladesh, cattle were found to be the most affected domestic animals with rabies [2]. Cattle were the first most likely livestock tested positive for rabies in Mongolia [45]. Rabies was considered one of the most common infectious diseases affecting cattle and is most reported in cattle in Bhutan [39]. In Sri Lanka, cattle were the second most clinically diagnosed species with rabies during 2005–2014 [6]. In China, during 2004–2018, results of a rabies survey showed that cattle were the second most (12.5%) affected species according to rabies laboratory-confirmed cases [46]. In India, rabies' prevalence was 61.4% in cattle and buffalo [47]. In Nepal, cattle and buffalo appeared to be the most affected species even than dogs [48]. According to Bárcenas-Reyes et al. (2019), there is an increase in rabies cases in humans and cattle in Latin America and the Caribbean. Taghreed and Asmaa [49] reviewed some published rabies reports in Oman, Saudi Arabia, Egypt, Algeria, Iraq, and Yemen. Dogs were the main rabies reservoir, and the disease was found in camels, foxes, cattle, sheep, and goats. Dogs, cattle, and humans are the most common hosts for rabies in Ethiopia. Cattle come second to dogs [24]. Out of 48 animal deaths of rabies, cattle (28) were more affected than other animal species [25]. The same picture was reported in Nigeria [29]. In Kenya, cattle were found to be the second most rabies-affected species.

Within samples submitted for rabies diagnosis, those of cattle, goats, sheep, and horses showed a higher percentage of positivity than dog and cat ones [26]. In Namibia, cattle rabies cases are second to dogs during 2011–2017 [50], also in Uganda during 2011–2013 [16]. In South Africa, rabies has been mainly diagnosed in dogs (52%), followed by (34%)

cattle [51]. In a review about rabies in Morocco, most of the reviewed reports showed that cattle were found to be the second most affected animal after dogs [27, 52].

In Euro-Asia and Europe, until 2001, cattle were the first rabies affected species in the Russian Federation, second in Belarus [35], the first one in Lithuania, the second one in Latvia, and the third after dogs and cats in Estonia [36]. In Guatemala, 154 cattle rabies due to vampire bat bites were reported (reviewed by [34]). In the United States, Canada, and Mexico, few cases were reported in cattle [53]. The same situation showing a very few reported rabies cases in cattle in Ukraine during 2012–2016 was reported [37].

### 5.2 Clinical signs

The paralytic form of rabies is the main sign in cattle, but some animals also show depression and excitation [54]. Foaming, bellowing, hitting and biting any object, hazing at humans and other cows were reported in Sierra Leone [30]. In Peru, abortive rabies cases were reported, rabies virus neutralizing antibodies were detected in 11% of cattle in areas of vampire bats, no deaths were observed in those animals within two years [55]. The observed clinical signs of rabies in cattle in two localities in India and Bangladesh were aggression, mania, profuse salivation, frenzy, and restlessness [2].

### 5.3 Transmission

Rabies virus is transmitted mainly through bites from rabid dogs, which accounts for over 90% of confirmed rabies cases [29]. However, according to Acha [56], rabies affecting bovines is primarily a problem of the southern area of the Hemisphere where vampire bats transmit it. In Africa, domestic dogs are the essential reservoir and transmitter of rabies to humans and other domestic animals [22, 57]. However, according to Warrell [58], jackals are the reservoir species in Botswana, Namibia, Zimbabwe, and bat-eared foxes in northern South Africa.

Rabies is transmitted to cattle mainly by the bite of rabid dogs in Bhutan [39]. In China, dogs are the primary transmitters, while in border areas, wild foxes are [46]; camels and wild foxes were reported to transmit rabies to cattle [8]. In Saudi Arabia, the main reservoirs of rabies are reported to be foxes and wild dogs [15].

In Europe, the increase in rabies cases in domestic animals like cattle, sheep, horses, cats, and dogs is associated with increased disease incidence in red foxes. Wild animals are reported as a cause for more than 90% of the animal rabies cases in the U.S. and Canada in 2010 [59]. Foxes are the main affected animals and the source of rabies infection in Ukraine [37]. In Latin America and the Caribbean, the main transmitter of rabies is the blood-sucking bat [33, 54]. In Colombia, the major transmitters, reservoirs, and vectors of the rabies are insectivorous, frugivorous and hematophagous bats; Vampire bat, which appeared as the main rabies reservoir from Mexico to South America [60].

Cattle can transmit rabies to humans as well as other animals. In Iran, a case of human rabies due to contact with the saliva of rabid cattle was reported [10].

## 6. Rabies in goats

### 6.1 Epidemiology

In Ethiopia, of 48 animal deaths of rabies, 12 were goats which were the second more affected animal species [25]. In Sudan, a review on rabies showed that goats

were the most rabies-affected species after dogs, as clear from previous reports [17, 18, 61, 62]. In Kenya, the third most rabies-affected species were sheep and goats [26]. The same situation was reported in Morocco [27] and Namibia [50]. In South Africa, rabies-diagnosed cases in goats were the third-highest figures after dogs and cattle [51]. The same situation was reported in Uganda during 2011–2013 [16].

Reported dog bite in goats was higher than in cattle in Bangladesh [3]. The reported prevalence of rabies in goats in India was 48.7% [47]. Sheep and goats showed the third-highest positivity reported for rabies diagnosis in Oman [63]. In Saudi Arabia during 2010–2017, confirmed rabies cases in goats were the third-highest number following dogs and camels [15]. In Sri Lanka, goats were the third most species that clinically rabies diagnosed during 2005–2014 [6]. In Nepal, goats were the fourth most affected species [48]. However, Uddin et al. (2015) reported that goats showed a low level of rabies prevalence (0.5%) in Bangladesh.

Compared to other species, a low number of cases were reported in goats in United States, Canada, and Mexico [53]. A very few rabies cases in goats in Ukraine were reported during 2012–2016 [37]. Rabies virus neutralizing antibodies were detected in 5% of goats in areas of vampire bats in Peru, seropositive animals remained healthy for further two years suggesting abortive rabies infection [55].

## 6.2 Clinical signs

Uddin et al. (2015) reported that in Bangladesh, profuse salivation and restlessness were the only observed clinical signs of rabies in goats. The authors reviewed other reports describing salivation (16%) and restlessness (3%), others reporting 100% for salivation, behavioral change, or mania, 70% for aggression or hyperesthesia. In Nigeria, Restlessness, agitation, and aggression were observed in rabies-affected goats [29]. A paralytic form of rabies was reported in goats in Brazil [54]. The same picture was reported in Brazil, where six goats bitten by bats showed apathy, isolation from the herd, sternal and lateral recumbency. Previously reported clinical signs showed that the furious form of rabies is more commonly appears in goats, aggressiveness occurs in 83%, excessive bleating in 72%, salivation in 29%, and paralysis in 17% of cases (**Figure 5**) [32]. In Nigeria, a case of rabies in goat was presented with nibbling on the metal fence, foamy salivation, excessive bloating, and inability to eat or drink [64].

**Figure 5.**
*Rabid Saanen buck presenting depression, somnolence and abnormal standing position (source: [32]).*

### 6.3 Transmission

Dogs are the primary rabies transmitter to goats; rabies reservoirs are variable in different countries. Canine rabies is dominant in Africa, Asia, the Middle East, and Latin America, where bats play an increasing role in the latter. In North America and Europe, canine rabies has been greatly eliminated; rabies is maintained in wildlife, as reviewed by Tilahun et al. [65]. In Bali, dogs are the primary source of rabies infection to human and domestic animals [14]. Most reported rabies cases in goats were due to dog attacks, especially in African and Asian countries [3, 16, 18, 21, 47]. Sheep and goats accounted for a meager percentage as a source of rabies infection for humans in Ethiopia [23].

## 7. Rabies in sheep

### 7.1 Epidemiology

In Kenya, sheep and goats were the third most rabies-affected species [26]. The same situation was reported in Morocco [27] and Namibia [50]. In South Africa, rabies diagnosed in sheep were the fourth-highest figures after dogs, cattle, and goats [51]. In Oman, sheep and goats showed the third-highest positivity reported for rabies diagnosis [63]. During 2004–2018 in China, it was noticed that sheep were the third most (9.7%) affected species [46]. Confirmed rabies in sheep was the third-highest number following dogs and camels in Saudi Arabia during 2010–2017 [15]. Within the affected species, a low number of cases was reported in sheep in United States, Canada, and Mexico [53].

### 7.2 Clinical signs

In sheep, attacking people and other animals besides other abnormal behavior was seen in Nigeria [29]. In Nigeria, observed clinical signs in a rabid ewe were aggressiveness, restlessness, corneal opacity, muscular tremor, hydrophobia, and salivation [57]. In an outbreak of rabies in sheep in China, clinical signs observed were arched back, tremors, and a swimming movement of all four limbs, followed by paralysis and death [9]. A paralytic form of rabies was reported in sheep in Brazil [54]. In another study in Brazil, clinical signs observed were abnormal gait, trembling, lateral recumbency, convulsion, opisthotonos, and fever [66]. Abortive rabies cases were reported in sheep in Peru, rabies virus neutralizing antibodies were detected in 3.6% of sheep that were healthy for two years later [55].

### 7.3 Transmission

The main transmitter of rabies to sheep is dogs. In Africa, the source of most rabies reported cases in sheep was the dog [29, 57, 62]. In China, dogs are the main rabies transmitters, while in border areas, wild foxes are [46]; wild foxes were reported to transmit rabies to sheep [8]. An increase in rabies cases in sheep is associated with a rise in the disease incidence in red foxes in Europe [59]. Rabies transmission from sheep to human was reported; three patients got rabies from direct contact with their sheep which a wolf had attacked in Iran [10].

## 8. Rabies in camelids

### 8.1 Epidemiology

Camelids are susceptible to rabies. However, most of the publications described clinical rabies in dromedary camels (*Camelus dromedarius*), with few reports in Bactrian camels (*Camelus bactrianus*) [8, 46] and the New World camelids [67]. From 2006 to 2013 in Oman, foxes reported the highest positivity rate (70.1%), camels accounted for the second higher positivity (59.7%) for rabies diagnosis [63]. Camels were the second most likely livestock after cattle to test positive for rabies in Mongolia from 1970 to 2005 [45]. Camels were the fourth (4.2%) mainly rabies tested positive animals during 2004–2018 in China [46]. In China, rabies infection in camels was reported [8]. According to the confirmed rabies cases in Saudi Arabia during 2010–2017 [15], Dogs and dromedary camels were the most affected species. In Iran, a review on zoonotic diseases published articles [11] revealed that camels are one of the essential sources as well as carriers of infection for humans, livestock, and wildlife in Iran and worldwide. Rabies is highly endemic in Iran; it is circulated easily in wildlife and livestock. The authors reviewed reported camel rabies cases in Iran, 3 cases during 1996–2006; an outbreak of camel rabies was reported for the first time in 2008 in central Iran. A rabid wolf attacked 8 camels; another camel rabies in the east was reported in 2012 [11]. In Jordan, Rabies in 8 camels was described [12]. In India, a report of clinical signs of rabies in she-camel was described [4].

Reports of rabies in dromedary camels from Morocco, Mauritania, Sudan, Yemen, Saudi Arabia, UAE, Niger, Jordan, India, Israel, and Iran were reviewed by Abbas and Omer [19]. Ali et al. (2004) reviewed dromedary camel rabies in Sudan; the first confirmed rabies cases were in 1926, then laboratory-confirmed cases continued to be reported, 17 cases from 1927 to 1939, 21 from 1940 to 1970. Other cases were reported in different parts of the country, 21 in the north and 16 in the Western States. Camel population in Sudan is about 4.8 million; the reported rabies cases are very few compared to the population, which is mainly due to under-reporting. Other cases in camels were reported as well in Sudan [20].

In a review about camel diseases, many rabies cases have been reported in Mauritania, Saudi Arabia, Iran, and Pakistan; infection is usually due to rabid dog bites [68]. In Niger, an outbreak of rabies in the camel herd due to feral dog bites was reported [69].

Rabies outbreak in camels in Iran was described [70]. An outbreak of dog rabies in the camel herd was reported in Sudan in 1998, and it resulted in the death of 19 camels [71]. Antibodies against rabies were detected in non-vaccinated camels imported for slaughtering in Nigeria, which may indicate subclinical rabies infection [72]. Very few suspected rabies cases in camels were reported in Morocco during 1991–2015 [27].

### 8.2 Clinical signs

Camels with furious rabies form show restlessness, anxiety, salivation, and attacking and biting form followed by terminal paralysis, lateral recumbency (**Figure 6**) and a characteristic flexion of four limbs, reviewed by Abbas and Omer [19]. Mohammadpour et al. (2020) reviewed a report stating that a furious form of rabies is seen in most of cases in camels.

Rabies clinical signs observed in Bactrian camels were reduced appetite, excessive activity and agitation, cessation of rumination, lip twitching, hypersalivation, tachypnea and howling, paralysis [8]. Some reports described the occurrence of

**Figure 6.**
*A case of rabies in a dromedary camel showing lateral recumbency and excessive salivation.*

rabies dumb form more frequently. Most rabies cases (67%) in camels in Oman were of the dumb form; observed clinical signs were restlessness, salivation, head and neck rotation in all directions, paralysis, recumbency, and death [73]. Clinical signs seen in rabid camels were hyperesthesia, profuse salivation, anorexia, and paralysis [12]. In India, clinical signs of rabies in the camel described the appearance of hyperexcitability, bellowing, aimless running, salivation, convulsions, swaying of the hindquarters and recumbency, biting tendency to the owner and wooden objects [4]. Noticed rabies clinical signs in camels were unusual behavior including aggression, pica, ptyalism, and terminal paralysis [69]. During an outbreak of rabies in camels, reported clinical signs were high sensitivity, ferocity, biting faces of other camels, bloat, restlessness, limb paralysis, and yawning [70]. In a rabies outbreak, clinical signs noticed in most of the affected camels were restlessness, irritability with very harsh and loud sounds. Later excitement became noticeable. There were then rubbing incoordination (staggering gait), tenesmus, abnormal sexual behavior: (she-camels mounting each other), raising of tails, and slight salivation, terminated by paralysis of the hindquarter, recumbency, and death of 19 camels [71]. In Khartoum, two camel rabies cases in 1996, 1997 showed off food, salivation, nervous signs followed by biting fence and their forelimbs and abdomen, then recumbency, hind limbs paralysis, and death [74]. An almost similar picture was previously reported by Afzal et al. [75], which were hyper-excitability, salivation, attacking inanimate objects, biting of its forelimbs, sternal recumbency, paralysis of hind legs, and death.

## 8.3 Transmission

Transmission of rabies to camels is mainly through dog bites, except in some countries where wild animals like foxes and wolves are involved. In China, the main rabies transmitters are dogs; meanwhile, in border areas, the wild fox is [46]; camels were reported to be rabies-infected by dogs and wild foxes [8]. In Iran, a rabid wolf was reported to transmit the infection to camels [11]. In Oman, the main animals involved in rabies transmission are foxes [63]. In another study in Oman, it was noticed that most rabid camels were bitten by foxes, which confirmed the major role of foxes in rabies transmission [13]. In Saudi Arabia, the majority (70%) of camel rabies cases were due to wild dog bite, while wild foxes accounted for about 17% of cases [73]. Almost in all reported camel rabies cases in Sudan, dogs were the source of infection [18, 62, 71, 74]. The same finding was reported in other African as well as Asian countries, Niger [69], Mauritania, Saudi Arabia, Iran, and Pakistan [68], China [8] Saudi Arabia [15].

## 9. Rabies in pigs

### 9.1 Epidemiology

Pig rabies is not commonly reported; information about rabies in pigs is scarce. Tasiame et al. (2016) described an outbreak of dog-originated pig rabies in a herd of 23 pigs in Ghana with 13% mortality. In China, the first report for rabies cases in pigs was documented [7]. In China during 2011, an outbreak of pig rabies resulted in 14 deaths was reported [76]. In the USA, DuVernoy et al. [77], was the first to describe the clinical picture of a wild animal's originated pig rabies. During 2004–2018 in China, it was noticed that pigs were the least rabies-affected species (1.4%) compared to sheep, cattle, camels, and foxes [46]. In Brazil, Pessoa et al. (2011) reported the occurrence of pig rabies presented with neurological signs; it was attacked by a bat; there are several reports of detection of rabies virus in swine in Brazil. Preethi et al. (2020) reported the occurrence of pig rabies for the first time in South India; three pigs in a herd of 25 pigs were attacked by a stray dog. Osiyemi et al. [78] reported rabies cases in pigs in Nigeria.

### 9.2 Clinical signs

Observed clinical signs in pigs are anorexia, hyperexcitation, constipation, twitching of the head, and foaming [79]. Jiang et al. (2008) described clinical signs of rabies in pigs, the furious form was seen in almost all infected pigs, and it included hyperexcitation, roaring, and attacks on other pigs. In India, clinical signs in rabid pigs were aggressiveness, inability to stand with violent grunting, paralysis, lateral recumbency, convulsions, rapid chewing, head twitching, hyperexcitation, and profuse salivation, change in vocalization. Out of 25 pigs, mortality was 12% [5]. In the USA, rabies clinical signs that appeared in pigs were fever, restlessness, salivation, aggression, anorexia, head rubbing, depression, vocalization, and progressive paralysis (DuVernoy et al., 2008). In Brazil, two pig rabies cases were reported: one with flaccid paralysis of the pelvic limbs; the other showed nervous signs, anorexia, and paresis, then pelvic limbs and tail paralysis. Generally, observed clinical signs were exclusive of the paralytic form [31].

### 9.3 Rabies transmission in pigs

Like other species, the transmission of rabies in pigs is mainly through dog bites and wild animals, especially in Latin America. In Brazil, Pessoa et al. (2011) reported the occurrence of bat-originated pig rabies. In the USA, DuVernoy et al. (2008) reported pig rabies caused by wild animals. In China, the first report for rabies cases in pigs was associated with dog bite [7]. In China during 2011, an outbreak of pig rabies was reported to be dog originated [76]. Tasiame et al. (2016) described an outbreak of dog-originated pig rabies in Ghana.

## Acknowledgements

We are deeply indebted to Dr. Shamsaldeen Ibrahim Saeed for nicely drawing the illustrations (**Figures 1** and **2**).

*DOI: http://dx.doi.org/10.5772/intechopen.98228*



## Author details

Abdelmalik I. Khalafalla[1,2*] and Yahia H. Ali[3,4]

1 Department of Microbiology, Faculty of Veterinary Medicine, University of Khartoum, Sudan

2 Veterinary Laboratories Division, Abu Dhabi Agriculture and Food Safety Authority, Abu Dhabi, UAE

3 Department of Virology, Central Veterinary Research Laboratories, Khartoum, Sudan

4 Biology Department, Faculty of Science and Arts, Northern Border University, Kingdom of Saudi Arabia

*Address all correspondence to: abdelmalik.khalafalla@adafsa.gov.ae

## References

[1] CFSPH (2012). Rabies and Rabies-Related Lyssaviruses, CFSPH. Available at https://www.cfsph.iastate.edu/Factsheets/pdfs/rabies.pdf (accessed 22/04/2021)

[2] Uddin H., Nur-E-Azam M., Tasneem M., Bary M. A., Chowdhury P., Hoque M. A. (2015). Occurrence and management of suspected rabies in livestock species due to dog bites at Satkania Upazilla veterinary hospital, Bangladesh and Madras veterinary college hospital, India. Bangl. J. Vet. Med., 13 (2): 67-71 ISSN: 1729-7893 (Print), 2308-0922 (Online).

[3] Islam K.M.F., Hossain M.I., Jalal S., Kader M.N., Kumar S., Islam K., Shawn A.I., Hoque A. (2016). Investigation into dog bite in cattle, goats and dog at selected veterinary hospitals in Bangladesh and India. Journal of Advanced Veterinary and Animal Research, 3(3): 252-258.

[4] Kumar A., Jindal N. (1997). Rabies in a camel - A case report. Tropical animal health and production. 29. 34. 10.1007/BF02632346.

[5] Preethi D., Julie, B., Bhadra, P.V. (2020). Rabies in domestic pig- first report from South India. J. Indian Vet. Assoc. 18 (1): 123-127.

[6] Pushpakumara D.P.N., Ashoka D., Ranjani H., Preeni A., Craig S. (2019). Surveillance Opportunities and the Need for Intersectoral Collaboration on Rabies in Sri Lanka. Journal of Veterinary Medicine, Volume 2019, Article ID 7808517, 8 pages https://doi.org/10.1155/2019/7808517.

[7] Jiang, Y., Yu, X., Wang, L., Lu, Z., Liu, H., Xuan, H., Hu, Z., Tu, C (2008). An outbreak of pig rabies in Hunan province, China. Epidemiology and infection, 136 (04): 504-508.

[8] Liu Y, Zhang H-P, Zhang S-F, Wang J-X, Zhou H-N, Zhang F, et al. (2016) Rabies Outbreaks and Vaccination in Domestic Camels and Cattle in Northwest China. PLoS Negl Trop Dis 10(9): e0004890. doi: 10.1371/journal.pntd.0004890.

[9] Zhu Y., Zhang G., Shao M., Lei Y., Jiang Y., Tu C. (2011). An outbreak of sheep rabies in Shanxi province, China. Epidemiol. Infect, 139, 1453-1456.

[10] Simani S., Fayaz A., Rahimi P., Eslami N., Howeizi N., Biglari P. (2012). Six fatal cases of classical rabies virus without biting incidents, Iran 1990-2010. Journal of Clinical Virology 54: 251– 254.

[11] Mohammadpour R., Champour M., Tuteja F., Mostafavi E. (2020). Zoonotic implications of camel diseases in Iran Vet Med Sci., 6(3): 59-381.

[12] Al-Rawashdeh, O.F., Al-Ani, F.K., Sharif, L.A., Al-Qudah, K.M., Al-Hami, Y., Frank, N. (2000). A survey of camel (*Camelus dromedarius*) diseases in Jordan. Journal of Zoo and Wildlife Medicine 31(3): 335-338.

[13] Ahmed M. S., Body M.H., El-Neweshy M.S., ALrawahi A.H., Al-Abdawani M., Eltahir H.A., Mahir G. ALmaewaly M.G. (2020). Molecular characterization and diagnostic investigations of rabies encephalitis in camels (*Camelus dromedaries*) in Oman: a retrospective study. Trop Anim Health Prod, 52:2163-2168.

[14] Putra, K. S. A. (2018). Epidemiology of rabies. International Journal of

Chemical & Material Sciences, 1(1), 14-24. https://doi.org/10.31295/ijcms.v1n1.4.

[15] Kasem S., Hussein R., Al-Doweriej A., Qasim I., Abu-Obeida A., Almulhim I., Alfarhan H., Hodhod A.A., Abel-latif M.A., Hashim O., Al-Mujalli D., AL-Sahaf A. (2019). Rabies among animals in Saudi Arabia. Journal of Infection and Public Health 12: 445-447.

[16] Omodo M., Gouilh M.A., Mwiine F.N., Okurut A.R.A., Nantima N., Namatovu A., Nakanjako M.F., Isingoma E., Arinaitwe E., Esau M., Kyazze S., Bahati M., Mayanja F., Bagonza P., Urri R.A., Lovincer M.N., Nabatta E., Kidega E., Ayebazibwe C., Nakanjako G., Sserugga J., Ndumu D.B, Mwebe R., Mugabi K., Gonzalez J. Sekamatte M. (2020). Rabies in Uganda: rabies knowledge, attitude and practice and molecular characterization of circulating virus strains. BMC Infectious Diseases (2020) 20:200 https://doi.org/10.1186/s12879-020-4934-y.

[17] Ali, Y.H; Intisar, K.S.; Wegdan, H.A.; Ali, E.B. (2006). Epidemiology of rabies in Sudan. JAVA. 5(3) 266-270.

[18] Baraa, A.M., Ali,Y.H, AbdelGadder Balal, Salma ElMagboul. (2012). Assessment of rabies situation in Sudan during 2007-2010. Sud J Vet Sci Anim Husb 51(1) 19-31.

[19] Abbas B., Omer O. (2005). Review of infectious diseases of the camel. Veterinary Bulletin, *75*(8), 1-16.

[20] Ahmed B.A, Ali Y.H, Ahmed O., Elmagboul S, Ballal A. (2016). Detection of rabies in camel, goat and cattle in Sudan using Fluorescent antibody test (FAT) and Polymerase Chain Reaction (RT-PCR). Journal of Advanced Veterinary and Animal Research, 3(3): 274-277.

[21] Ali, Y.H. (2002). Outbreak of Rabies in south Darfur (Sudan). Vet Rec. 150 (19) 610-612.

[22] Nibret Moges N. (2015). Epidemiology, Prevention and Control Methods of Rabies in Domestic Animals: Review Article. European Journal of Biological Sciences 7 (2): 85-90, ISSN 2079-2085, DOI: 10.5829/idosi.ejbs.2015.7.02.93255.

[23] Reta, T., Teshale, S., Deressa, A., Mengistu, F., Sifer, D., Freuling, C.M. (2014). Rabies in animals and humans in and around Addis Ababa, the capital city of Ethiopia: A retrospective and questionnaire based study. Journal of Veterinary Medicine 6(6): 178 – 186.

[24] Oyda S., and Megersa B. (2017). A review of rabies in livestock and humans in Ethiopia. International Journal of Research - Granthaalayah, 5(6), 561-577. https://doi.org/10.5281/zenodo.823626.

[25] Mulugeta Y., Lombamo F., Alemu A., Bekele M., Assefa Z., Shibru E., Beyene M., kitila G., Getahun G., Sifer D., Aklilu M., Regassa F., Deressa A. (2020). Assessment of the current rabies situation and its management in epidemic areas of southern Ethiopia. Highlights in BioScience 3. Article ID 20212. dio:10.36462/H.BioSci.202 12

[26] Bitek A.O., Osoro E., Munyua P.M. Nanyingi M., Muthiani Y., Kiambi S., Muturi M., Mwatondo A., Muriithi R., Cleaveland S., Hampson K., Njenga M. K., Kitala P.M., Thumbi S.M. (2019). A hundred years of rabies in Kenya and the strategy for eliminating dog-mediated rabies by 2030 [version 2; peer review: 4 approved] AAS Open Research 2019, 1:23 https://doi.org/10.12688/aasopenres.12872.2.

[27] Darkaoui S., Cliquet F., Wasniewski M., Robardet E., Aboulfidaa N., Bouslikhane M. Fassi-Fihri O. (2017). A Century Spent Combating Rabies in Morocco (1911-2015): How Much Longer? Front. Vet. Sci. 4:78. doi: 10.3389/fvets.2017.00078.

[28] Ibrahim S, Audu SW, Usman A and Kaltugo BY (2017) Rabies in a Six-Week Old Bunaji-Bull Calf in Zaria: A Case Report. J Microbes Microbio Techni 1(1): 101.

[29] Tekki I.S., Meseko C.A., Omotainse S.O., Atuman Y.J., Chukwukere, Olaleye S., Okewole P.A. (2014) Incidences of Rabies in Domestic Animals and Consequent Risk Factors in Humans. J Med Microb Diagn 3: 143. doi:10.4172/2161 0703.1000143.

[30] Suluku R., Nyandeboh J.P.J, Kallon M.N., Barrie A. Kabba B., Koroma B.M., Emikpe B.O. (2017). First Reported Case of Dog Associated Cattle Rabies in Koinadugu District, Northern Sierra Leone. Afr. J. Biomed. Res. 20 (3): 325- 327.

[31] Pessoa C.R.D., Maria Luana Cristiny Rodrigues Silva M.L.C.R., Gomes A.A.D., Garcia A.I.E., Ito F.H., Brandão P.E., Riet-Correa F.R. (2011). Paralytic rabies in swine. Brazilian Journal of Microbiology, 42: 298-302.

[32] Moreira IL., de Sousa., Ferreira-Junior JA., de CastroMB., Fino TCM., Borges JRJ., Soto-Blanco B., Câmara ACL (2018) Paralytic rabies in a goat. BMC Vet Res 14(1):338 doi: 10.1186/s12917-018-1681-z.

[33] Bárcenas-Reyes I., Nieves-Martínez D.P., Cuador-Gil J.Q., Loza-Rubio E., González Ruiz S., Cantó-Alarcón G.J., Milián-Suazo F. (2019). Spatiotemporal analysis of rabies in cattle in central Mexico. Geospatial Health, 14:805, 247-253.

[34] Gilbert A., Greenberg L., Moran D., Danilo Alvarez D., Alvarado M., Daniel L. Garcia D.L., Leonard Peruski L. (2015). Antibody response of cattle to vaccination with commercial modified live rabies vaccines in Guatemala. Preventive Veterinary Medicine, 118: 36-44.

[35] Botvinkin A., Kosenko M. (2015). Rabies in the European parts of Russia, Belarus and Ukrainea In Historical Perspective of Rabies in Europe and the Mediterranean Basin. Paris: OIE (World Organization for Animal Health) (2015). p. 47-63. Available from: http://www.oie.int/doc/ged/d11246.pdf.

[36] Westerling B., Z. Andersons, J. Rimeicans, K. Lukauskas A. Dranseika. (2015). Rabies in the Baltics In Historical Perspective of Rabies in Europe and the Mediterranean Basin. Paris: OIE (World Organization for Animal Health) (2015). p. 33-46. Available from: http://www.oie.int/doc/ged/d11246.pdf.

[37] Polupan I., Bezymennyi M., Gibaliuk Y., Drozhzhe Z., Rudoi O., Ukhovskyi V., Nedosekov V. De Nardi M. (2019). An Analysis of Rabies Incidence and Its Geographic Spread in the Buffer Area Among Orally Vaccinated Wildlife in Ukraine from 2012 to 2016. Front. Vet. Sci. 6:290. doi: 10.3389/fvets.2019.00290.

[38] Hampson K., Coudeville L., Lembo T., Sambo M., Kieffer A., Attlan M., Barrat J., Blanton J.D., Briggs D.J., Cleaveland S., Costa P.,Freuling C.M.,Hiby E. (2015). Estimating the global burden of endemic canine rabies. PLoS Negl Trop Dis (2015) 9(4):e0003786. doi:10.1371/journal.pntd.0003786.

[39] Rinchen S., Tenzin T., Hall D., van der Meer F., Sharma B., Dukpa K., Cork S. (2019). A community based knowledge, attitude, and practice survey

on rabies among cattle owners in selected areas of Bhutan. PLoS Negl Trop Dis 13(4): e0007305. https://doi.org/10.1371/journal.pntd.0007305.

[40] Samad MA (2013). Public health threat caused by zoonotic diseases in Bangladesh. Bangladesh Journal of Veterinary Medicine 9: 95-120.

[41] OIE, the World Organization for Animal Health (2018). Chapter 1.3.17. Rabies (Infection with Rabies virus and other Lyssaviruses) (https://www.oie.int//fileadmin/Home/eng/Health_standards/tahm/3.01.17_ RABIES.pdf, accessed 11 March 2021)

[42] Reta, T., Teshale, S., Deressa, A., Getahun, G., Baumann, M.P.O., Muller, T., Freuling, C. M. (2013). Evaluation of rapid immunodiagnostic test for rabies diagnosis using clinical brain samples in Ethiopia. Journal of Veterinary Science and Medical Diagnosis 2(3):1-3.

[43] Bouaddi K., Bitar A., Bouslikhane M., Ferssiwi A., Fitani A., Mshelbwala P.P. (2020). Knowledge, Attitudes, and Practices Regarding Rabies in El Jadida Region, Morocco Khadija. Vet. Sci. 2020, 7, 29; doi:10.3390/vetsci7010029.

[44] Yahiaoui, Fatima & Kardjadj, Moustafa & Laidoudi, Younes & Hacene, Medkour, Ben-Mahdi, Meriem. (2018). The epidemiology of dog rabies in Algeria: Retrospective national study of dog rabies cases, determination of vaccination coverage and immune response evaluation of three commercial used vaccines. Preventive Veterinary Medicine. 158 10.1016/j.prevetmed.2018.07.011.

[45] Sack A., Daramragchaa U., Chuluunbaatar M., Battsetseg Gonchigoo B., Gray G.C. (2018) Potential risk factors for zoonotic disease transmission among Mongolian herder households caring for horses and camels. Pastoralism: Research, Policy and Practice 8:2. DOI 10.1186/s13570-017-0109-x.

[46] Feng Y., Wang Y., Xu W., Tu Z., Liu T., Huo M., Liu Y., Gong W., Zeng Z., Wang W., Wei Y., Tu C. (2020). Animal Rabies Surveillance, China, 2004-2018. Emerg Infect Dis. (12): 2825-2834. doi: 10.3201/eid2612.200303.

[47] Singh R., Singh K.P., Cherian S., Saminathan M., Kapoor S., Reddy M.G.B., Panda S., Dhama K. (2017) Rabies – epidemiology, pathogenesis, public health concerns and advances in diagnosis and control: a comprehensive review, Veterinary Quarterly, 37:1, 212-251, DOI: 10.1080/01652176.2017.1343516.

[48] Devleesschauwer B., Aryal A, Sharma B.K, Ale A., Declercq A, Depraz S., Gaire T.N., Gongal G., Surendra Karki S., Pandey B.D., Pun S.B., Duchateau L., Dorny P., Speybroeck N. (2016). Epidemiology, Impact and Control of Rabies in Nepal: A Systematic Review. PLoS Negl Trop Dis 10(2): e0004461.

[49] Taghreed A., Asmaa A. (2019). A Systematic Review of epidemiology of Rabies in Arab countries. Journal of Health Informatics in Developing Countries, 13 (2), http://www.jhidc.org/

[50] Hikufe E.H., Freuling C.M., Athingo R., Shilongo A., Ndevaetela E-E., Helao M., Shiindi M., Rainer Hassel R., Bishi A., Khaiseb S., Kabajani J, Westhuizen J. V., Torres G., Britton A., Letshwenyo M., Schwabenbauer K., Mettenleiter T.C., Denzin N., Amler S., Conraths F.J., Mu¨ ller T., Maseke A. (2019). Ecology and epidemiology of rabies in humans, domestic animals and wildlife in Namibia, 2011 2017. PLoS Negl

Trop Dis 13(4): e0007355. https://doi.org/10.1371/journal.pntd.0007355

[51] Van Sittert S. J., Raath J., Akol G.W., Miyen J.M., Mlahlwa B., Sabeta C. T. (2010) Rabies in the Eastern Cape Province of South Africa – where are we going wrong? Journal of the South African Veterinary Association 81(4): 207-215.

[52] Matter H, Blancou J, Benelmouffok A, Hammami S, Fassi-Fehri N ( 2015). Rabies in North Africa and Malta in Historical Perspective of Rabies in Europe and the Mediterranean Basin. Historical Perspective of Rabies in Europe and the Mediterranean Basin. Paris: OIE (World Organization for Animal Health) (2015). p. 185-199. Available from: http://www.oie.int/doc/ged/d11246.pdf.

[53] Xiaoyue Ma., Benjamin P. M., Cleaton J. M., Orciari L.A., Yager P., Yu Li, Kirby J.D., Blanton J.D., Petersen B.W., Wallace R.M. (2018). Rabies surveillance in the United States during 2016. Journal of the American Veterinary Medical Association, 252 (8): 945-957.https://doi.org/10.2460/javma.252.8.945.

[54] Lima, E. F., Riet-Correa, F., Castro, R. S., de, Gomes, A. A. B., Lima, F. D. (2005). Sinais clínicos, distribuição das lesões no sistema nervoso e epidemiologia da raiva em herbívoros na região Nordeste do Brasil. *Pesquisa Veterinária Brasileira*, *25*(4), 250-264. https://doi.org/10.1590/S0100-736X2005000400011.

[55] Benavides J.A., Velasco-Villa A., Godino L.C., Satheshkumar P.S., Nino R., Rojas Paniagua E. R., Shiva C., Falcon N., Daniel G. Streicker D.G. (2020). Abortive vampire bat rabies infections in Peruvian peri domestic livestock. PLoS Negl Trop Dis 14(6): e0008194. https://doi.org/10.1371/journal.pntd.0008194.

[56] Acha PN (1981). A review of Rabies prevention and control in the Americas, 1970-1980. Overall status of Rabies. Bull. Off. int. Epiz., 1981, 93 (1-2), 9-52.

[57] Ahmad I., Kudi C.A., Anka M.S., Tekki I.S. (2017). First confirmation of rabies in Zamfara State, Nigeria—in a sheep. Trop Anim Health Prod, 49:659-662.

[58] Warrell M., (2010). Rabies and African bat lyssavirus encephalitis and its prevention, International Journal of Antimicrobial Agents, doi:10.1016/j.ijantimicag.2010.06.021.

[59] Chernet, A. and Nejash, A. (2016): Review of rabies control and prevention. Journal of Medicine, Physiology and Biophysics 23: 45 –53.

[60] Cifuentes J. J.F, Pérez L.R.D., Verjan G.N. (2017). Bat Reservoirs for Rabies Virus and Epidemiology of Rabies in Colombia: a review. Rev. CES Med. Vet. Zoot, 12 (2): 134-150.

[61] Ali, Y.H; Zeidan, M.I (1999) Rabies in Sudan 1992-1998: Sud. J. Vet. Sc Anim. Husb., 38(1,2 )162-167.

[62] Ali, Y.H.; Intisar, K.S. (2009). Epidemiology of Rabies in Sudan (2003-2007). Sud J Vet Sci Anim Husb, 48(1,2) 104- 111.

[63] Al-Abaidani I.A., Al-Abri S.A., K.P. Prakash, M. H. Hussain, M. H. Hussain A.H. Al Rawahi. (2015). Epidemiology of rabies in Oman: a retrospective study (1991-2013). Eastern Mediterranean Health Journal, 21 (8): 591-597.

[64] Kaltungo B.Y., Audu S.W., Salisu, I., Okaiyeto S.O., Balarabe Magaji Jahun B.M. (2018). A case of rabies in a Kano brown doe. Clin Case Rep.; 6: 2140-2143.

[65] Tilahun A., Yohanis N., Biruhtesfa A. (2018). Review on Rabies and its Zoonotic Importance. Academic Journal of Animal Diseases 7(2): 29-38.

[66] Rissi, D.R., Pierezan, F., Kommers, G. D., Barros, C. S.L. (2008). Ocorrência de raiva em ovinos no Rio Grande do Sul. Pesquisa Veterinária Brasileira, 28(10), 495 500. https://doi.org/10.1590/S0100-736X2008001000009.

[67] Fowler, M.E (2010). Medicine and Surgery of Camelids. 3rd edition. Ames IA, Wiley-Blackwell.

[68] Fassi-Fehri M. (1987). Diseases of camels. Revue Scientifique Et Technique (International Office of Epizootics), 6(2), 337-354.

[69] Bloch N, Diallo I. (1995). A probable outbreak of rabies in a group of camels in Niger. Vet Microbiol 46(1-3):281-283. doi: 10.1016/0378-1135(95)00092-o. PMID: 8545966.

[70] Esmaeili H., Ghasemi E., Ebrahimzadeh H. (2012). An outbreak of camel rabies in Iran. Journal of Camel Practice and Research, 19 (1):19-20.

[71] Elmardi O.I; and Ali Y.H. (2001) An outbreak of Rabies in camel (camelus Dromedaries) in North Kordofan state. Sud.J.Vet.Res. 17:125-127.

[72] Baba S.S., Bwala J.P., El-Yaguda A.D., Baba M.M. (2005). Serological Evidence of Rabies Virus Infection of Slaughter Camels (*Camelus dromedarius*) Imported To Nigeria. Tropical Veterinarian, 23 (3,4): 78-82.

[73] Al-Dubaib, MA (2007). Rabies in camels at Qassim region of central Saudi Arabia. Journal of Camel Practice and Research, 14: 101-103.

[74] Ali Y.H., Intisar K. Saeed, Zakia A (2004). Camel rabies in Sudan. Sud. J. Vet. Sci. Anim. Hus, 43(1,2) 231-234.

[75] Afzal M., Khan I. A., Salman R. (1993). Symptoms and clinical pathology of rabies in the camel. Vet. Rec., 133, 220.

[76] Yongwen L., Ying Z., Xiangyin L., Youtian Y., Xianfeng Y., Daiting Z., Xianbo D., Xiaowei W., Xiaofeng G. (2012). Complete Genome Sequence of a Highly Virulent Rabies Virus Isolated from a Rabid Pig in South China. Journal of Virology, 86 (22): 12454 12455.

[77] DuVernoy T.S. Mitchell K.C. Myers R.A. Walinski L. W. Tinsley M.O. (2008). The first laboratory-confirmed rabid pig in Maryland, 2003. Zoon. Pub. Health. 55, 431 435.

[78] Osiyemi, T.I., Onunkwo, O., Momoh, M.A. (1978). A case report of rabies in the pig in Nigeria. Bull Anim. Health. Prod. Afr. 26(4): 335-357.

[79] Tasiame W., Folitse R. D, Emikpe B.O, Adongo J. A. (2016). First reported case of dog associated pig rabies in Ghana. Afr. J. Infect. Dis. 10 (1): 55 – 57.