Zoonotic Diseases: Trypanosomiasis –An Overview

Sobia Malik[1,*], Mirza Imran Shahzad[2], Zaid Ali Shah[3], Iram Qadeer[1], Shakeela Parveen[1], Uzma Maqbool[1], Amir Shahzad[4], Rida Amjad[1], Mehwish Sultana[4] and Kashif Ali[6]

[1]Department of Zoology, The Government Sadiq College Women University, Bahawalpur, Pakistan
[2]Department of Biochemistry, The Islamia University Bahawalpur, Pakistan
[3]Department of Parasitology, University of Veterinary and Animal Sciences, Lahore, Pakistan
[4]Faculty of Veterinary & Animal Sciences, The Islamia University of Bahwalpur, Pakistan
[5]Division of Science and Technology, Department of Zoology, University of Education, Lahore, Pakistan
*Corresponding author: sobia.malik@gscwu.edu.pk

Abstract

Trypanosomes include various groups of parasitic hemoflagellates that infect animals and humans, with extensive worldwide distribution. Trypanosoma are parasitic protozoa that reside in the blood and cause trypanosomiasis, a prevalent disease in animals such as sheep, goats, horses, camels, and cattle. This illness is mostly transmitted by the tsetse fly, although other blood-sucking insects may also carry it. Surra is an animal trypanosomiasis caused by *Trypanosoma evansi* infection, which results in significant economic loss owing to death and morbidity. Surra's epidemiology and management receive far less attention than tsetse-transmitted animal trypanosomiases. Understanding its epidemiology is the first step toward disease control on a local and global scale. Medicinal plants have always been recognized as an alternate source of medicine due to the presence of secondary metabolites that confer activities like antioxidant, anti-inflammatory, anti-hypertensive, antibacterial and antiviral and antiprotozoal activities. Medicinal plants have been linked to the discovery of natural bioactive substances capable of slowing disease development and inhibiting protozoal enzyme activity.

Keywords: *T. evansi,* Trypanosomiasis, Medicinal plants, Transmission, Control

Cite this Article as: Malik S, Shahzad MI, Shah ZA, Qadeer I, Parveen S, Maqbool U, Shahzad A, Amjad R, Sultana M and Ali K, 2025. Zoonotic diseases: Trypanosomiasis –An overview. In: Abbas RZ, Akhtar T and Jamil M (eds), Pathways of Infection: Zoonoses and Environmental Disease Transmission. Unique Scientific Publishers, Faisalabad, Pakistan, pp: 257-262. https://doi.org/10.47278/book.HH/2025.467

A Publication of Unique Scientific Publishers

Chapter No: 25-036

Received: 16-Jan-2025
Revised: 30-Apr-2025
Accepted: 16-May-2025

Introduction

Zoonotic illnesses, or zoonoses, are infectious diseases that may transmit from animals (vertebrates) to people. They may be caused by bacteria, parasites, viruses, fungus, or prions. Zoonotic ill water and transmitted by contact with diseased bodily fluids, animal bites, contaminated water, and eating sick meat. Bats, cattle, rats, birds, and other vertebrates can transport them. The symptoms of zoonotic infections differ based on the individual ailment. Some typical symptoms are fever, lethargy, headaches, body pains, rash, diarrhea, and vomiting (Qureshi et al., 2023).

Zoonoses have several mechanisms of transmission. Direct zoonosis occurs when a disease is transferred directly from non-humans to humans by media such as air (influenza) or bites and saliva (rabies). In contrast, transmission can occur through an intermediary species (known as a vector), which carries the disease pathogen without becoming ill (Warren & Sawyer, 2019).

Numerous pathogens can produce zoonoses. These include bacteria, parasites, viruses, fungus, and prions. Most zoonotic diseases are bacterial, parasitic, or viral. Other zoonoses include ringworm (a fungal illness) and variant Creutzfeldt-Jakob disease (vCJD, also known as "mad cow disease"), a kind of prion disease (Elsohaby and Villa, 2024). According to Rahman et al. (2024), zoonotic illnesses can spread by contact with diseased animals' bodily fluids, including blood, feces, saliva, tick, mosquito, and flea bites.

Trypanosomiasis – "Surra"

Trypanosomes are protozoan parasites that are members of the genus Trypanosoma and the family Trypanosomatidae. Many species of Trypanosoma, including *T. brucei, T. congolense, T. equiperdum, T. evansi, T. simiae, T. suis*, and *T. vivax*, produce trypanosomiases, which are illnesses that affect a variety of animal hosts, including humans (Stevens & Brisse, 2004).

Trypanosomes are a broad group of parasitic hemoflagellates that cause trypanosomiasis, a disease that is prevalent in livestock species like sheep, goats, horses, camels, and cattle. In essence, the tsetse fly is the vector that spreads this disease, however other blood-sucking insects also occasionally do so. Depending on the species, these infections may be mechanically transmitted or go through complicated developmental stages in the dipteran vector, which is how these pathogens are often transmitted by hematophagous invertebrates (Peacock et al., 2011, Dyary et al., 2019).

T. evansi cause a chief parasitic sickness to recognize as "Surra". Griffith Evans made the initial discovery of Surra in 1880 in the Khyber Pakhtunkhwa, Pakistan, and area of Dera Ismail Khan (Luckins et al., 2004). According to several studies (Tehseen *et al.*, 2015; Hussain et al.,

2016; Tehseen *et al*., 2017), it is a common ailment in Pakistani camels and horses. There have also been recent cases involving animals (Muhammad et al., 2007; Shahid *et al*., 2013). Prior reports of canine trypanosomiasis in the nation have also been made, but (Gadahi et al., 2008; Rashid *et al*., 2008) the identification of the etiology at a species level has been disregarded. Dogs are particularly vulnerable to surra, which can manifest fatal clinical symptoms. Direct microscopy of a peripheral blood smear along with an enzyme-linked immunosorbent assay, a card agglutination test, and polymerase chain reaction are some of the diagnostic methods (OIE, 2019; Asif et al., 2020).

Worldwide Distribution

Trypanosomiasis is a widespread disease across all of Asia, Africa, and Central and South America (Table 1). It was first discovered in Southeast Asia almost a century ago (Luckins, 1988). Recent findings indicate that the illness is widespread in Peninsular Malaysia due to the high prevalence of the disease in cattle, buffalos, and other domesticated animals there (Chin, 2006; Adrian et al., 2010).

Table 1: Prevalence of Surra caused by *Trypanosoma evansi* in different countries of the world.

Country	Prevalence (%)	References
Jordan	33	(Al-Rawashdeh et al., 2000)
Sudan	33	(Jilo et al., 2017)
Niger	29	(Pacholek et al., 2001)
Kenya	28	(Njiru et al., 2002)
Nigeria	27	(Enwezor et al., 2005)
Mauritania	24	(Jilo et al., 2017)
India	22	(Jilo et al., 2017)
Ethiopia	21	(Zeleke and Bekele, 2001)
Iran	10	(Zarif-Fard, 2001)
Chad	30	(Delafosse et al., 2004)
Saudi Arabia	13.2	(Jilo et al., 2017)
Pakistan	10	(Shah et al., 2004)
Morocco	43.3	(Rami et al., 2003)
Egypt	65.9	(El-Naga et al., 2016)

A Causative agent - *Trypanosoma evansi*

T. evansi can only exist as the long, thin monomorphic trypomastigote type. From 15-36m in length. *T. evansi*, *T. b. rhodesiense, T. b. brucei, T. b. gambiense* and *T. equiperdum* cannot be separated from one another, according to 18S rDNA of *Trypanosoma* phylogenetic analysis. This result supports that *T. evansi* diverged from *T. b. brucei* (Stevens & Brisse 2004). The distinct kinetoplast DNA of *T. evansi,* which exhibits a lack of minicircle sequencing heterogeneity, can be used to identify it from *T. b. brucei. T. evansi* may be divided into a pair of strain groups, which are a camel type and a typical type, based on the traits of kDNA (Saw et al., 2010). A typical member of the genus, *T. evansi*, causes "Surra" illness in both domestic and wild animals (Dyary et al., 2014). *Trypanosoma evansi*, the pathogenic trypanosome species with the widest geographic range, may infect both domestic and wild animals. With various degrees of virulence, *Trypanosoma evansi* infects both domestic animals (such as equines, camels, bovines, dogs, goats) and also wild animals. Equines are crucial to the agricultural economy in locations with inadequate infrastructure. The trypanosome species *T. evansi, T. vivax, T. congolense, T. brucei,* and *T. equiperdum* can all infect these animals. Due to the disease's devastating impact on the health of working horses, it has drawn a lot of thought and concern. While the condition is chronic in camels and causes gradual weakening and emaciation of the animals, it is acute and lethal in equines (Desquesnes *et al*., 2013 a &b).

Transmission

The parasite begins its life in the fly's midgut before migrating to the salivary glands, where it waits to be injected into the mammalian host upon biting. The parasite bloodstream form, which may re-infect the fly vector after biting, resides in the blood (Roditi & Lehane 2008). *T. evansi* spread by biting flies from one infected host to another, particularly stable and horse flies (*Tabanus*). However, there are some situations when vectors may serve a specific purpose. *Tsetse flies* (Glossina), like other bloodsucking insects, are common in areas of Africa where *T. evansi* also thrives. North America is the only region where *Trypanosoma evansi* is not present. In South and Central America, vampire bats which act as both vectors and reservoir hosts, can spread *T. evansi* (Stevens & Brisse, 2004).

Clinical Signs in Domestic Animals

The health, productivity, and working efficiency of camels are severely impacted by blood-borne protozoan infections like trypanosomiasis in several camel-rearing countries of the world, including Pakistan. Several clinical symptoms, including pyrexia, infrequent shivering, in appetence, urticarial swelling, lethargy, deterioration of health, and pad edoema, were noted a small number of patients. The majority of domestic and wild animals exhibit anemia and fever as the initial clinical signs of surra, which includes oedema, cachexia, emaciation, and the lymph spleen/nodes enlargement. The impact of *T. evansi* on the host is contingent upon the host's species, the infectiousness of the trypanosome strains, and other variables such as coexisting diseases, overall host stress, and regional epizootiological conditions. Other clinical signs that have been seen in water buffalo and cattle include salivation, jaundice, diarrhea, fever, lacrimation, oedema, urticaria, conjunctivitis, dyspnea, nasal discharge, superficial lymph nodes swelling, alopecia, less milk yield, infertility or abortion, weakness, incoordination and paralysis (Riaz et al., 2021).

Table 2: Medicinal plants involved in treatment of Trypanosomiasis.

Plants	Family	Country	References
***Acmellacaulirhiza* Del.**	Asteraceae	Nigeria	(Nwodo et al., 2015)
Tridax procumbens		Nigeria	(Nwodo et al., 2015)
Artemisia scoparia		Pakistan	(Qasim at al., 2014)
Artemisia maritime		Nigeria	(Nwodo et al., 2015)
Bidens pilosa		Kenya	(Ogoti et al., 2009)
Inula grantioides		Pakistan	(Qasim et al., 2014)
Artemesia annua		Kenya	(Ogoti et al., 2009)
Tithonia diversifolia		Nigeria	(Olukunle et al.,2010)
Saussurea costus		Egypt	(Okba et al., 2018)
Echinops amplexicaulis		Ethiopia	(Kitata et al., 2017)
Commiphora wightii	Bursuraceace	Egypt	(Okba et al., 2018)
Maytenus parviflora	Celasteraceae	Egypt	(Okba et al., 2018)
Anogeissus leioccarpus	Combretaceae	Nigeria	(Nwodo et al., 2015)
Terminalia avicennioides		Nigeria	(Nwodo et al., 2015)
Terminalia superba		Nigeria	(Nwodo et al., 2015)
Citrullus colocynthis	Cucurbitaceae	Pakistan	(Mirani et al., 2014)
Euphorbia poisonii	Euphorbiaceae	Nigeria	(Nwodo et al., 2015)
Alchornea cordifolia		India	(Guadani et al., 2010)
Euphorbia hirta		Nigeria	(Mgbemena et al., 2016)
Euphorbia hirta		Pakistan	(Qasim at al., 2014)
Euphorbia hirta		Egypt	(El-Hawary et al., 2021)
Euphorbia hirta		Japan	(Saw et al., 2010)
Euphorbia prostrata		Pakistan	(Jamel & Ashfaq, 2016)
Euphorbia caducifolia		Pakistan	(Qasim et al., 2014)
Acalypha wilkesiana		Nigeria	(Olukunle et al.,2010)
Acacia nilotica	Fabaceae	Nigeria	(Anyam et al., 2021; Goronyo et al., 2022)
Acacia nilotica		Pakistan	(Qasim et al., 2014)
Acacia senegal		Pakistan	(Qasim et al., 2014)
Acacia jacquemontii		Pakistan	(Jamel & Ashfaq, 2016)
Acacia modesta		Pakistan	(Jamel & Ashfaq, 2016)
Prosopis africana		Nigeria	(Nwodo et al., 2015)
Prosopis cineraria		Pakistan	(Qasim et al., 2014)
Prosopis juliflora		Pakistan	(Qasim et al., 2014)
Cassia sieberiana		Africa	(Iwaka et al., 2022)
Parkia biglobosa		Africa	(Traoré et al., 2020)
Parkia clappertoniana		Nigeria	(Banwo et al., 2004
Detarium microcapum		Africa	(Dassou et al., 2015)
***Acacia polyacantha* Wild.**		Africa	(Noudèkè et al., 2017)
Pterocarpus erinanceus		Africa	(Nwodo et al., 2015)
Solanecio angulatus		Tanzania	(El-Hawary et al., 2021)
Piliostigma reticulatum		Africa	(Dassou et al., 2015)
Afrormosia laxiflora		Nigeria	(Atawodi et al., 2003)
Ocimum grattissimum	Lamiaceae	Nigeria	(Olukunle et al.,2010)
Khaya senegalensis	Meliaceae	Nigeria	(Adeiza et al., 2009)
Khaya senegalensis		Africa	(Iwaka et al., 2022)
Melia Azedarach		Nigeria	(Nwodo et al., 2015)
Melia Azedarach		UK, China	(El-Hawary et al., 2021)
Azadirachta indica		Nigeria	(Tauheed et al., 2022)
Azadirachta indica		Kenya	(Ogoti et al., 2009)
Azadirachta indica		Africa	(Iwaka et al., 2022)
Azadirachta indica		Pakistan	(Mirani et al., 2014)
Azadirachta indica		Japan	(Saw et al., 2010)
Pseudocedrela kotschyi		Africa	(Nwodo et al., 2015)
Khaya anthotheca		Uganda	(Oboh et al., 2013)
Toona ciliate		Iran	(Nekoei et al., 2022)
Zapoteca portoricensis		Cameroon	(Kitata et al., 2017)
Moringa oleifera	Moringaceae	Nigeria	(Nwodo et al., 2015)

***Ranunculus multifidus* Forssk**	Ranunculaceae	Ethopia	(Seifu et al., 2018)
Morinda morindiodes	Rubiaceae	Nigeria	(Olukunle et al.,2010)
***Withaniasomnifera* (L.) Dunal**	Solanaceae	Ethopia	(Seifu et al., 2018)
Nicotiana tabacum		Ethopia	(Kitata et al., 2017)
Solanum dasyphylum		Ethopia	(Odongo et al., 2018)
Withania sominifera		Pakistan	(Qasim et al., 2014)
Salvadora oleoides	Salvadoraceae	Pakistan	(Nisar et al., 2014)

Prevention and Control

Since there is no vaccination for trypanosomiasis due to the great antigenic variation displayed by this protozoan parasite, chemotherapy appears to be the sole means of treatment currently in use (Brun et al., 2010). The mainstay of trypanosomiasis management by the preventative or curative administration of trypanocidal drugs to animals.

i- Chemoprophylaxis

Currently, diminazene aceturate, suramin, isometamidium, homidium, and cymelarsan are the most often prescribed medications for treating *T. evansi* infections. The ability of quinapyramine to cause multiple drug resistance led to its discontinuation (Holmes et al., 2004). Currently, Diminazene (aromatic diamidine) is the preferred medication for treating trypanosomiasis in domestic animals which originates from Surfen C. Diminazene. Infections of *Babesia species, T. vivax* and *T. congolense* are very resistant to them, while infections of *T. evansi* and *T. b brucei* are less resilient. But for quinapyramine, trypanosomes resistant to other medications are frequently vulnerable to diminazen (Holmes et al., 2004; Saw et al., 2010). Suramin is water soluble, and its solutions quickly deteriorate in the air. Although it works slowly in *in-vitro*, but exhibits strong clinical effectiveness against *T. b. rhodesiense* and *T. b. gambiense* (Suzuki et al., 2004).

For animal trypanosomiasis treatment in 1950s, quinapyramine (bis-quaternary chemical) was developed and *T. congolense, T. vivax* and *T. b brucei* infections in cattle, sheep and goats have been effectively treated with it. *T. evansi, T. equinum* and *T. equiperdum* infections were also treated with Quinapyramine. In the 1970s, medicine was taken off the market in many regions of Africa due to the emergence of drug resistance. However, the medication has since been re-released on the market under two alternative names. Trypacide Pro-salt is advised for prophylaxis and Clinical instances should be treated subcutaneously with trypacide sulphate (Saw et al., 2010). The melaminyl thioarsenite group of chemicals, which was created in the 1940s, includes melarsenoxide cysteamine. The medication's primary ingredient is a white powder that is very soluble in water. Camels, cattle, horses, and buffaloes are the main species in which melarsenoxide cysteamine is most effective against *T. evansi* infections. Melarsenoxide cysteamine has been proven to be extra efficient against *T. equiperdum* and *T. evansi* than suramin, isometamidium, and diminazen (Saw et al., 2010).

Phenanthridinium derivatives include isoetamidium and homidium. Isoetamidium and homidium can be separated from each other by possessing an extra m-amidinophenyl-azo-amine moiety, which is really a component of the diminazene molecule. *T. congolense* and *T. vivax* are successfully eradicated by homodium and isometamidium. Infections caused by *T. b. brucei* and *T. evansi* in camels, horses, and donkeys can similarly be treated with isotamidium. Homidium was extensively used in the 1960s and 1970s, but its efficacy has been greatly reduced as a result of strong resistance (Saw et al., 2010). Research on novel compounds to cure surra, sleeping sickness, and nagana is crucial because of the negative side effects of currently available trypanocidal medicines or the spread of drug-resistant trypanosomes in vast regions. (Anene et al., 2001; Matovu et al., 2001; Kibona *et al*., 2006, Saw et al., 2010).

ii- Medicinal plants Involved in the Treatment of Trypanosomiasis

A range of important natural elements are thought to be abundant in existing plants and medicinal herbs. Since natural compounds are considered to be the ethically upstanding and plentiful source of bioactive molecules with anti-trypanosomal action, it is required to discover and evaluate a variety of natural products originating from numerous medicinal plants (Kayser et al., 2003; Abbas et al., 2025).

The three main basic sources of natural commodities are plants, sea life, and microorganisms. (Benarba & Pandiella, 2020; Bagherniya et al., 2021) (Table 2). Various anti-effects, including antioxidant, antibacterial, anti-inflammatory, antipyretic, anti-diabetic, anti-ulcer, anti-tumor, anti-hypertensive, and antiviral qualities, were demonstrated by secondary metabolites derived from medicinal plants (Karthick & Akram, 2020).

T. evansi is the most common parasite in Asia, and it is resistant to a number of the current commercial treatments and therapies, including quinapyramine, diminazene, and suramin Steverding, 2010; Dyary et al., 2014). As a result, more people are using various herbal medications and conventional treatments for trypanosomiasis. The utilization of natural products is the main potential source for such economic therapy. Almost 50% of all useful drugs have been derived from natural sources since ancient times. In many parts of the world plants were used in traditional medicine. To produce semi-synthetic and synthetic drugs with great safety and effectiveness against parasitic infections plant based substance have been used as lead compounds (Tagboto and Townson, 2001).

Conclusion

A significant zoonotic hazard is the parasite illness surra, which affects a wide variety of domestic animals. The possibility of human illnesses emphasizes the significance of all-encompassing approaches to disease prevention, vector management, and education. To lessen the disease's effects on animal and human populations, cooperation between veterinary and public health authorities is essential, as is research to comprehend the zoonotic components of surra. Recognizing and treating zoonotic illnesses like surra is crucial for the health of both people and the animals that coexist in our habitats as international contacts and travel grow. It is critical that the risk of human infection by animal trypanosomes, which could become a new zoonosis, be regarded seriously and given greater consideration. In order to reduce unintentional infection, livestock should also be handled carefully. Innovative drug development is required to treat trypanosomiasis.

References

Abbas, R. Z., Qureshi, M. A., & Saeed, Z. (2025). Botanical compounds: A promising control strategy against Trypanosoma cruzi. Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas, *24*(3), 308-327.

Adrian, M. S., Sani, R. A., Hassan, L. and Wong, M. T. (2010). Outbreaks of trypanosomiasis and the seroprevalence of *T. evansi* in a deer breeding center in Perak, Malaysia. *Tropical Animal Health and Production*. *42*, 145-150.

Asif, M., Ashraf, K., Jamil, T., Ahmad, N., Ullah, S., Hussain, S., Iqbal, M., Nasrullah, M., Khan, A.H. and Ghani, M.U. (2020). Canine *Trypanosoma evansi* Infection (Surra) in Lahore, Pakistan-Short Communication. *Veterinarija ir Zootechnika*, *78*(100):1-4.

Anene, B. M., Onah, D. N. and Nawa, Y. (2001). Drug resistance in pathogenicAfrican trypanosomes: what hopes for the future? *Veterinary Parasitol*ogy. 96:83-100.

Al-Rawashdeh, O. F., Sharif, L. A., Al-Qudah, K., & Al-Ani, F. K. (1999). Trypanosoma evansi infection in camels in Jordan. *Revue D Elevage Et De Medicine Veterinaire Des Pays Tropicaux, 52*(3/4), 233-238.

Bagherniya, M., Khedmatgozar, H., Fakheran, O., Xu, Jhonston, T.P. and Sahebkar, A. (2021). Medicinal plants and bioactive natural products as inhibitors of NLRP3 inflammasome. *Phytotherapy Research*. *35*(9):4804-4833.

Brun, R., Blum, J., Chappuis, F. and Burri, C. (2010). Human African trypanosomiasis. *Lancet 375*: 148-159.

Benarba, B. and Pandiella, A. (2020). Medicinal plants as source of active molecules against COVID-19. *Frontiers in Pharmacology. 11*:1189.

Chin, P. L. (2006). Prevalence of blood parasites in UPM cattle, DVM Thesis, University Putra Malaysia.

Desquesnes, M., Dargantes, A., Lai, D.H., Lun, Z.R., Holzmuller, P. and Jittapalapong, S. (2013a). *Trypanosoma evansi* and surra: A review and perspectives on transmission, epidemiology and control, impact, and zoonotic aspects. *BioMed Research International*. DOI: 10.1155/2013/321237.

Desquesnes, M., Holzmuller, P., Lai, D.H., Dargantes, A., Lun, Z.R. and Jittaplapong, S. (2013b). *Trypanosoma evansi* and surra: a review and perspectives on origin, history, distribution, taxonomy, morphology, hosts, and pathogenic effects. *BioMed Research International*. DOI: 10.1155/2013/194176.

Qureshi, M. A., Fatima, Z., Muqadas, S. M. L., Najaf, D. E., Husnain, M., Moeed, H. A., & Ijaz, U. (2023). Zoonotic diseases caused by mastitic milk. Zoonosis, Unique Scientific Publishers, Faisalabad, Pakistan, 4, 557-572.

Delafosse, A. and Abdesalam A. D. (2004). "Prevalence of *Trypanosoma evansi* infection and associated risk factors in camels in eastern Chad." *Veterinary Parasitology*, *119*(2): 155-164.

Dyary, H.O., Arifah, A.K., Sharma, R.S., Rasedee, A., Mohd-Aspollah, M.S., Zakaria, Z.A., Zuraini, A. and Somchit, M.N. (2014). Antitrypanosomal screening and cytotoxic effects of selected medicinal plants. *Tropical Biomedicine. 31*(1): 89–96.

Dyary, H.O., Arifah, A.K., Sukari, M.A. and Sharma, R.S.K. (2019). Antitrypanosomal and cytotoxic activities of botanical extracts from *Murraya koenigii* (L.) and *Alpinia mutica* Roxb. *Tropical Biomedicine. 36*(1): 94–102.

Elsohaby, I., & Villa, L. (2023). Zoonotic diseases: Understanding the risks and mitigating the threats. BMC Veterinary Research, 19(1), 186.

El-Naga, T.R., Abouand S., Barghash, M. (2016). "Blood Parasites in Camels (Camelus dromedarius) in Northern West Coast of Egypt." *Journal of Bacteriology & Parasitology*. *7*(1):258.

Enwezor, Felicia N. C. and Anthony K. B. S. (2005). "Camel *trypanosomosis*-A review." *Veterinarskiarhiv*, *75*(5): 439-452.

Gadahi, J., Arijo, A., Abubakar, M., Javaid, S. and Arshed, M. (2008). Prevalence of blood parasites in stray and pet dogs in Hyderabad area: Comparative sensitivity of different diagnostic techniques for the detection of microfilaria. *Veterinary World, 1*:229-232.

Holmes, P. H., Eisler, M. C. and Geerts S. (2004). Current chemotherapy of animal trypanosomiasis. *In*: Maudlin, I., Holmes, P. H., Miles, M.A. (Eds.) The trypanosomiases, CABI Publishing, Wallingford, UK. pp. 431-444.

Hussain, R., Khan A., Abbas, R.Z., Ghaffar A., Abbas, G., Rahman, T. and Ali, F. (2016). Clinico-Hematological and Biochemical Studies on Naturally Infected Camels with Trypanosomiasis. *Pakistan Journal of Zoology, 48*(2): 311-316.

Jilo, K., Abdela, N., Dabasa, G. and Elias, M. (2017). Camel Trypanosomiasis: A Review on Past and Recent Research in Africa and Middle East. *American-Eurasian Journal of Scientific Research, 12*(1): 13-20.

Karthick, R. and Akram, M. (2020). Anti-viral medicinal plants and their chemical constituents, experimental and clinical pharmacology of antiviral plants. *Journal of science technology and research*, *1*(1).

Kayser, O., Olbrich, C., Yardley, V., Kiderlen, A. F. and Croft, S. L. (2003). Formulation of amphotericin B as nanosuspension for oral administration. *International Journal of Pharmaceutics*, *254*(1): 73–75.

Kibona, S.N., Matemba, L., Kaboya, J.S. and Lubega, G.W. (2006). Drug-resistance of *Trypanosoma b. rhodesiense* isolates from Tanzania. *Tropical Medicine and International Health,* 11: 144-155.

Luckins, A.G. and Dwinger, R.H. (2004). Non-tsetse-transmitted animal trypanosomiasis. *In*: Maudlin, I., Holmes, P.H., Miles, M. A. (Eds.) The trypanosomiases, CABI Publishing, Wallingford, UK. Pp.269-281.

Matovu, E., Seebeck, T., Enyaru, J. and Kamisnky, R. (2001). Drug resistance in *T. brucei* spp., the causative agents of sleeping sickness in man and naganain cattle. *Microbes and Infection*, 3: 763-770.

Muhammad, G., Saqib, M., Sajid, M. and Naureen, A. (2007). *Trypanosoma evansi* infections in Himalayan black bears (*Selenarctos thibetanus*). *Journal of Zoo and Wildlife Medicine, 38*: 97-100.

Njiru ZK., Brett B., Ole-Mapeny I.M., Githiori J.B. and Ndung'u J.M. (2002). Trypanosomosis and helminthosis in camels: comparison of ranch and traditional camel management systems in Kenya. *Journal of Camel Practice and Research*, 9(1): 67-71.

OIE. (2019). *Trypanosoma evansi* infection (Surra). In: Manual of diagnostic tests and vaccines for terrestrial animals. Paris, France. Pp. 660-674.

Peacock, L., Ferris, V., Sharma, R., Sunter, J., Bailey, M., Carrington, M. and Gibson, W. (2011). Identification of the meiotic life cycle stage of *Trypanosoma brucei* in the tsetse fly. Proceedings of the National Academy of Sciences of the United States of America, 108: 3671-3676.

Pacholek X, Gamatic D., Franek S.G. and Tibayrene R. (2001). Prevalence of *Trypanosoma evansi* trypanosomosis in young camels in west Niger. *Elev. Med. Vet. Pays. Trop*., *44*: 177-182.

Rami, M., T. Atarhouch, M.N. Bendahman, R. Azlaf, R. Kechna and A. Dakkak, 2003. Camels trypanosomosis in Morocco. A pilot disease control trial. *Veterinary Parasitology*, *115*: 223-231.

Rahman, M. T., Sobur, M. A., Islam, M. S., Ievy, S., Hossain, M. J., El Zowalaty, M. E., & Ashour, H. M. (2020). Zoonotic diseases: etiology, impact, and control. Microorganisms, 8(9), 1405.Rashid, A., Rasheed, K. and Hussain, A. (2008). Trypanosomiasis in dog; a case report. *Journal of Arthropod-Borne Diseases, 2*: 48-51.

Roditi, I. and Lehane, M. (2008). Interactions between trypanosomes and tsetse flies.*Current Opinion in Microbiology*, *11*: 345 – 351.

Riaz, H., Khalid, Mehmood, Rao, Z.A., Iahtasham, K., Abu, B.S., Sabiqaa, M., Muhammad, S.Q., Hafiz, M.I., Rabia, A., Muhammad, T.G., Ahrar, K. and M. Tayyib. (2021). Epidemiology and patho-physiological studies in *trypanosoma evansi* infected camels and buffaloes in Pakistan. *Pakistan Journal of Agriculture Sciences, 58*(2): 711-718.

Saw, A., Saruda, T., Kyaw, S.L., Junichi, H., Takao, I., Lat, L. H., Ni, N.M., Tin, T. M., Nyunt, P., Satoshi, M., Tatsuya, S., Yuzaburo, O., Hideyuki, M. and Ken, K. (2010). Evaluation of Myanmar Medicinal Plant Extracts for Antitrypanosomal and Cytotoxic Activities. *Journal of Veterinary Medical Sciences, 72*(4): 525–528.

Shahzad, W., Munir, R., Khan, M. S., Ahmad, M. D., Ijaz, M., Ahmad, A. and Iqbal, M. (2010). Prevalence and molecular diagnosis of *Trypanosoma evansi* in Nili-Ravi buffalo (*Bubalus bubalis*) in different districts of Punjab (Pakistan). *Tropical Animal Health and Production, 42*:1597-1599.

Shahid, M., Janjua, S. and Burbach, J. S. (2013). PCR-Based Detection of *Trypanosoma evansi* infection in semi-captive asiatic black bears (*Ursus thibetanus*). *Pakistan Veterinary Journal, 33*:442-445.

Shah, S.R., Phulan, M.S. Memon, M.A. Rind R. and Bhatti, W.M. (2004). Trypanosomes infection in camels. *Pakistan Veterinary Journal*, 24: 209-210.

Steverding, D. (2010). The development of drugs for treatment of sleeping sickness: a historical review. *Parasites and Vectors* .3: 15.

Stevens, J.R. and Brisse, S. (2004). Systematics of trypanosomes of medicalandveterinaryimportance.*In*: Maudlin, I., Holmes, P. H., Miles, M.A.(Eds.) The trypanosomiases, CABI Publishing, Wallingford, UK. Pp.1-23.

Suzuki, E., Kessler, M., Montgomery, K. and Arai,A. C. (2004). Divergenteffectsofthepurinoceptorantagonistssuraminandpyridoxal-5'-phosphate-6-(2'-naphthylazo-6'-nitro-4',8'-disulfonate) (PPNDS)onα-amino-3-hydroxy-5-methyl-4-isoxazolepropionicacid (AMPA)receptors. *Molecular Pharmacol*ogy, *66*:1738-1747.

Tagboto, S. and Townson, S. (2001). Antiparasiticpropertiesofmedicinalplantsandothernaturallyoccurringproducts. *Advances in Parasitology*, *50*: 199-295

Tehseen, S., Jahan, N., Qamar, M.F., Desquesnes, M., Shahzad, M.I., Deborggraeve, S. and Büscher, P. (2015). Parasitological, serological and molecular survey of *Trypanosoma evansi* infection in dromedary camels from Cholistan Desert, Pakistan. *Parasites & Vectors*, *8*(1): 413-415.

Tehseen, S., Jahan, N., Desquesnes, M., Shahzad, M. I. and Qamar, M.F. (2017). Field investigation of T*rypanosoma evansi* and comparative analysis of diagnostic tests in horses from Bahawalpur, Pakistan. *Turkish Journal of Veterinary and Animal Sciences*, 41:288-293.

Warren CJ, Sawyer SL (April 2019). "How host genetics dictates successful viral zoonosis". *PLOS Biology*. 17 (4).

Zeleke, M. and Bekele T. (2001). Camel herd health and productivity in eastern Ethiopia selected seminomadic households. Revue. Elev. Med. Vet. Pays. Trop., 55: 213-217.

Zarif-Fard, M.R. and Hashemi-Fesharki R. (2001). Study on tissue and blood protozoa of camels in southern Iran. *Journal of Camel Practice and Research.* 35: 193-194.