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REVIEW OF PARASITIC INFECTIONS OF BACTRIAN CAMELS IN MONGOLIA

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ABSTRACT

Mongolia is home to 454,000 domesticated two-humped camels (*Camelus bactrianus*) and several hundred wild Bactrian camels (*Camelus ferus*) but knowledge about the diversity of camel infectious pathogens in this country is still limited. In this article, all studies carried out on camel infectious diseases in Mongolia are reviewed. More than 100 documents published between 1936 and 2022 were systematically analysed to get information on this topic. In this communication we review articles that dealt with parasitic infections of Bactrian camels in Mongolia such as trypanosomosis, coccidiosis, toxoplasmosis, sarcocystosis, piroplasmosis, hydatidosis, trichostrongylidosis, parabronemosis, dipetalonemosis, tick infestation, sarcoptic mange, myiasis and vermipsillosis. The results showed that parasititoses are an issue in Mongolia in terms of economics and public health.

Key words: *Camelus bactrianus,* infectious diseases, prevalence, Mongolia

Mongolia is a landlocked country in East Asia covering a territory of 1.5 million km^2 and a population of just three million people. According to the Food and Agriculture Organisation of the United Nations, there were 57.5 million small ruminants, 5 million cattle, 4 million horses and more than 450 thousand Bactrian camels in Mongolia (Fig 1) (FAOSTAT, 2021). Camel husbandry in Mongolia is practiced primarily by pastoralists in the Gobi Desert. Camels produce milk, wool and meat and are also used for racing and less commonly now, as a beast of burden.On the other hand, camels are carriers of zoonotic pathogens and sources of infection for humans, livestock and wildlife in Mongolia.

Outbreaks of camel diseases between 1947 and 1966 occurred in the Gobi Desert and steppe regions of Mongolia with clinical findings such as ataxia and intractable diarrhoea but the aetiology was not determined. Hundred-thousands of camels were affected in these disease outbreaks and more than 90,000 camels died (Erdenebileg, 2001).

In this paper, the parasitic diseases of Bactrian camels in Mongolia are outlined by focusing on the aetiology of diseases and infections and determining their distribution pattern in order to show camel's public health importance in Mongolia.

Materials and Methods

Relevant studies were reviewed through Medline (PubMed), ISI Web of Scopus and Google Scholar. These were systematically searched to find all publications from Mongolia using the keywords of "Bactrian camel", "Infectious disease" and "Mongolia". The retrieved papers and books that reported camel diseases with major public health importance were included in the present study. More than 100 documents published between 1936 until late 2022 were analysed. The included papers were written in English, Russian and Mongolian languages.

Results

Protozoal infections

Surra

Camel trypanosomosis (surra) is caused by *Trypanosoma evansi*. This extracellular blood parasite is mechanically transmitted by haematophagous dipterea such as tabanids, stomoxes and hippobosces. Bactrian camels were suspected of having surra in the western part of Mongolia, but little information is available. Several serological studies on non-tsetse transmitted trypanosomoses were carried out in horses from all districts in Mongolia. Since serological methods do not allow to differentiate between infections with *Trypanosoma equiperdum* (dourine)

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and *T. evansi*, the presence of surra in Mongolia cannot be ignored. Thus, Clausen *et al* (2003) examined 1122 horse sera and detected CFT and ELISA seroprevalence of 7.6 and 6.7%, respectively with only one stallion showing typical clinical signs of dourine. The isolation of *T. equiperdum* from the urethral tract of a stallion in the Töv province by Suganuma *et al* (2016) was the first prove for the presence of dourine in Mongolia. Davaasuren *et al* (2017) reported an outbreak of a horse disease on a farm in Ulaanbaatar with one stallion showing typical signs of dourine and a total of 46% of the 50 horses gave positive serological (ELISA) results. Molecular examination revealed that beside typical *T. equiperdum* another closely related trypanozoon was present on the farm. In a nationwide survey on horse trypanosomosis with an rTeGM6-4r-based immunochromatographic test, Mizushima *et al* (2018) tested 1701 equine sera and detected 42 positives. Later, Mizushima *et al* (2020) used a rTeGM6-4r-based ELISA, which was applied for surra against cattle and water buffalo and dourine against horse. This test revealed that the overall sero-prevalence of non-tsetse transmitted trypanosomoses in Mongolia was 4.8%. It is interesting that the sero-prevalence in horses in two Gobi provinces (Ömnögovi, Govi-Altai) with high Bactrian camel populations was 11.0 and 10.4%. In order to clarify the role of Bactrian camels in the epidemiology of surra, specific investigations have to be carried out.

Coccidiosis

Coccidiosis of camels is an intestinal protozoan infection caused by apicomplexan parasites of the genus *Eimeria*. *Eimeria* spp. are gut-dwelling intracellular parasites, transmitted by faecal-oral route; oocysts are shed from infected animals and sporulated oocysts are then ingested via contaminated feed or water. Examination of faecal samples of camels from three Mongolian provinces, namely Bayanhongor, Övörkhangai and Ömnögovi revealed the presence of *E. rajasthani*, *E. dromedarii* and *E. cameli* in a prevalence of 40.8, 33.5 and 19.7 %, respectively (Khatanbaatar *et al*, 2017). Mixed-*Eimeria* spp. infections were more frequently (31.6 %) observed than mono infections.

Toxoplasmosis

Toxoplasmosis is a zoonotic disease caused by the protozoan parasite *Toxoplasma gondii*, which infects warm-blooded animals including human and livestock as an intermediate host. The cat and other felids are the only final host for this parasite.

Little is known about Toxoplasma in Bactrian camels and there is only one serological study from Qinghai Province, in northwestern China where seven out of 234 serum samples from Bactrian camels were positive for *Toxoplasma* antibodies in a commercial indirect haemagglutination test at a cut-off of 1:64. A study of *T. gondii* DNA in Bactrian camel milk revealed 5 out of 9 examined camels from the

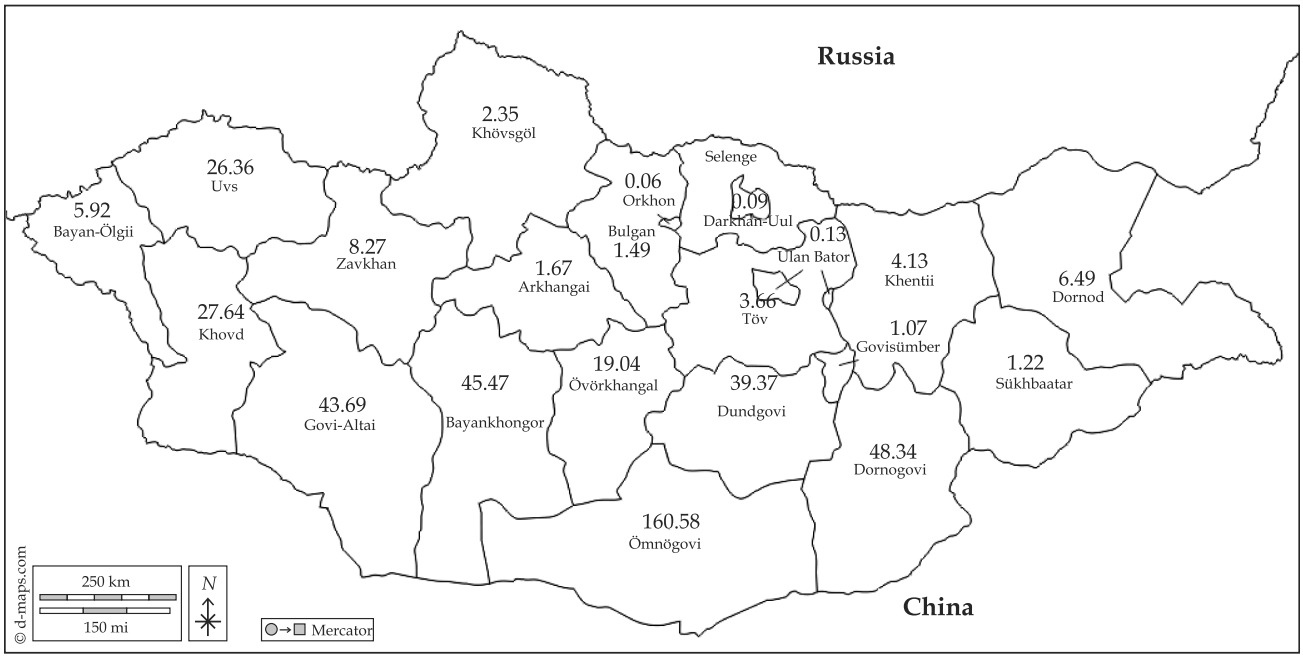

Fig 1. The number of Bactrian camels (in thousands) categorised by provinces according to the National Statistics Office of Mongolia. https://en.nso.mn/ 2022.

Ömnögovi province positive (Iacobucci, 2019). The presence of Toxoplasma types I, II and III linages was suggested.

Sarcocystiosis

Sarcocystosis is a diheterooxenic protozoan infection that is usually asymptomatic for the herbivorous intermediate host. A survey of *Sarcocystis* infection in farm animals (cattle, yak, hainag, sheep, horse and camel) was conducted in Mongolia between June 1998 and July 1999. Compressed muscle samples from the diaphragm, heart, tongue, esophagus and intercostal region were examined under the microsope. In 5 camels from Zawkhan Province, muscle micro cysts of *Sarcocystis* sp. were detected (Fukuyo *et al,* 2002). The species was not determined. Three species of *Sarcocystis* that form microcysts in the muscles of dromedaries are mentioned in the literature (Wernery *et al,* 2014). One species of muscle macrocysts was found in camels in Kazakhstan (Kuraev, 1981).

Piroplasmosis

Babesiosis and Theileriosis are caused by intraerythrocytic protozoan parasites that are transmitted by ticks. Although, Bactrian camels are not described as hosts of *Babesia* and/or *Theileria* species, no confirmed information is available about camel babesiosis due to the lack of experimental infections. Svoboda *et al* (2011) examined horses, camels and dogs in Khentii province for the presence of *Babesia* and *Theileria* and found 67% of horse blood smears are positive for *Theileria equi*. *T. equi* DNA was detected in 93% of these horses but camels and dogs were negative, both in blood smears and DNA detection.

Molecular examination of 305 blood samples of Bactrian camels from 6 Mongolian provinces showed the presence of DNA of 3 different *Babesia* species, *Babesia bovis*, *B. bigemina*, and *Babesia* sp. Mymensingh, with prevalences of 32.1%, 21.6%, and 24.3%, respectively and 52.5% of the surveyed animals harboured DNA of at least one of these species (Otgonsuren *et al,* 2022). Despite this high prevalence, so far, *Babesia* development stages have not been demonstrated in blood smears of Bactrian camels and no disease was reported. The DNA of these *Babesia* species had previously been reported from bovines in Mongolia (Otgonsuren *et al,* 2020). In Mongolia, cattle and Bactrian camels usually share common pasture lands for grazing and tick species infesting cattle use also Bactrian camels as hosts and inoculate *Babesia* sporozoites DNA which were then detected in the camel blood. In a molecular study on the role of ticks as vectors for tick borne diseases, Narankhajid *et al* (2018) examined ticks from camels in the Gobi Altai province and detected *Babesia* DNA in 17 out of 64 specimens. *Babesia* positive ticks belonged to *Dermacentor nuttalli, De. marginatus* and *Rhipicephalus asiaticum*. The role of Bactrian camels in the epidemiology of babesiosis remain unclear. Finding of DNA alone is not an indicator that the host is involved in the life cycle.

Helminth infection

Scientists of the Soviet Union started to investigate the helminth fauna of Mongolia in the first half of the last century and the results obtained by the Mongol Agricultural Expedition of the Academy of Science of the USSR from 1947 to 1952 were published by Ivashkin (1955). Later Sharhuu (1986) continued research in this field and proposed control programmes. In Mongolia a total of 21 helminth species were listed for Bactrian camels. *Dipetalonema evansi*, *Dictyocaulus cameli* and *Nematodirella cameli* were camel specific and were reported for Bactrian camels in Mongolia for the first time (Sharhuu and Sharkhuu, 2004).

Orientobilharziosis

The schistosome *Orientobilharzia tukestanica* was described by Skrjabin (1913) from a cow in Kazakhstan. *O. turcestanica* inhabits blood vessels of intestines and livers of ruminants as main final hosts, and pulmonate snails (*Radix auricularia*) act as intermediate host. In Mongolia, this trematode species was first mentioned by Shumakovic (1936). Apart from Bactrian camels Sharhuu and Sharkhuu (2004) named cattle, sheep and goat as hosts. Final hosts become infected when wading in shallow waters or at drinking when water is infested with cercariae. In humans, *O. turcestanica* cercariae can cause cercarial dermatitis (Wang *et al,* 2009).

Echinococcosis/ Hydatidosis

Echinococcosis is a zoonotic disease where canids act as final hosts and herbivores and omnivores including humans are the intermediate hosts. Already Shumakovic (1936) and Ivashkin (1955) mentioned the presence of *Echinococcus granulosus* Bactrian camels in Mongolia without giving data on the distribution of the parasite. A more recent study carried out in the Ömnögovi district found 22 (= 30.5%) out of 72 slaughtered camels infected with hydatid cysts. A low number of cysts (1–3) was recovered mainly from the lungs (n=12) and less frequent from livers (n=6). Mixed infections of livers

and lungs were seen in four animals (Chinchuluun *et al,* 2018). Bold *et al* (2019) concluded that human cystic echinococcosis is significantly related to camel density. Nineteen (19.8%) out of 96 slaughtered camels in the Ömnögovi district had hydatid cysts. On the other hand, the Ömnögovi district had the highest incidence of cystic echinococcosis in humans in Mongolia (8 cases per 100,000).

Based on molecular peculiarities, the former species *E. granulosus* was split into different strains that had become five independent species of which *E. granulosus* sensu stricto (G1-3) and *E. canadensis* (G6-10) were found in human cases from Mongolia (Jabbar *et al,* 2011; Ito *et al,* 2014). Based on recent findings, Ito and Budke (2015) drew a map on the distribution of 85 human cystic *Echinococcus* cases in the country. Of these, 27 cases, mainly *E. canadensis* (G6/7) but also *E. granulosus* sensu stricto (G1) were diagnosed in Gobi districts where most of the Bactrian camels are kept.

Little is known about echinococcosis in final hosts in Mongolia. In nomadic husbandry systems, dogs play a major role as a direct source for human infections. Thus, Zoljargal *et al* (2001) found 17 (25.4%) out of 67 dogs in the Govi Altai positive in a copro-antigen test and in a second study, 5 out of 14 necropsied dogs had a patent *Echinococcus* infection in the Bulgan province (Wang *et al,* 2009). With regards to possible final hosts amongst wild canids, 118 wolfs were examined in northern Mongolia. Of these, two harboured the G6/7 strain and three were infected with the G10 strain of *E. canadensis* (Ito *et al,* 2014).

Trichostrongylidosis

According to Sharhuu and Sharkhuu (2004), the following trichostrongylid species were found in Bactrian camels in Mongolia: *Marshallagia mongolica, M. skrjabini, Ostertagia dahurica, O. orloffi, Teladorsagia kasachstanica, Trichostrongylus colubriformis, T. proboluris, Cooperia surnabada, C. oncophora, Nematodirus oiratianus and N. cameli.* Most of these species were found at necropsies carried out by Sharhuu (1986).

Dipetalonemosis

Dipetalonemosis in camels caused by *Dipetalonema evansi*, a filarial nematode of the family of Onchocercidae, is considered an economically significant mosquito-borne disease. The life cycle of *D. evansi* was studied by Katajceva (1969) in Turkmenistan and *Aedes caspius* was found as intermediate host and vector. It is quite possible that also other mosquitos are involved in the life cycle. The adult filarial worms have predilection sites in the blood vessels of lungs, hearts and tecticles of dromedaries and Bactrian camels. For the first time in camels of Mongolia, Ivashkina (1953) observed and described *D. evansi*.

During an examination of blood in connection with a surra survey, microfilaria as an additional finding were diagnosed and DNA of *D. evansi* and another *Dipetalonema* species was detected in 4.5% of 400 blood samples (Bilegjargal *et al,* 2021).

Parabronemosis

Parabronemosis is caused by the spirurid *Parabronema skrjabini* that inhabits the abomasum of domestic and wild ruminants and Old World Camelids. The horn fly, *Haematobia irritans*, acts as intermediate host (Liu *et al,* 2020, 2021). Apart from Bactrian and wild Bactrian camels in Mongolia, Sharhuu and Sharkhuu (2004) listed the following hosts for *P. skrjabini*: cattle, yak, sheep, goat, maral, roe deer, argali ibex Mongolian and goitered gazelles and Mongolian saiga.

Arthropod infections

In unpublished documents of an ectoparasite control programme (1970 – 1989) based on bilateral governmental treaty between Mongolia and the German Democratic Republic, three parasitoses of Bactrians caused by arthropods were mentioned, namely sarcoptic mange, tick infestation and cephalopinosis.

Tick infestation

Hard ticks are frequent ectoparasites of Bactrian camels in Mongolia. *Hyalomma asiaticum*, *Dermacentor nuttalli, D. dagestanicus, Rhipicephalus pumilio* ticks are reported in Mongolian Bactrian camels. *Hyalomma asiaticum* is more widespread in the Gobi Desert and is often found in the armpits and groins of camels. *Dermacentor nuttalli* and *D. dagestanicus* ticks are distributed among camels in Gobi Gurwansaikhan mountain steppe regions: Altai, Mongolian Altai and Gobi. Rh. pumilio spread in camels around Bor Tsonji Gobi in the East Gobi region (Dash, 1986; Erdenebileg, 2001). In a more recent study, Narankhajid *et al* (2018) collected to *De. nuttalli, De. marginatus* and *Hy. asiaticum* from camels in the Gobi Altai district. A survey of ticks in Bactrian camels in the Gobi of Inner Mongolia of China revealed the presence of *Rhipicephalus sanguineus, Hyalomma dromedarii, Hy. asiaticum* and *Dermacentor niveus* (Li *et al,* 1997).

Camel mange

Camel mange, an extremely contagious parasitic disease caused by the *Sarcoptes scabiei* and

is transmitted by direct or indirect contact. Although it is one of the most important parasitic diseases affecting camel (Erdenebileg, 2001) little is known about the disease in Bactrian camels in Mongolia.

Wohlfahrtiosis

Wohlfahrtiosis is a parasitic disease caused by the larval stages of flesh flies of the genus *Wohlfahrtia*. While *Wohlfahrtia magnifica* causes obligate myiasis in in animals and men, *W. nuba* mainly colonise carcasses and only few cases of (facultative) myiasis are known. Schuman *et al* (1976) found *W. magnifica* as the cause of genital myiasis in female camels in Mongolia. Genital myiasis occurs 4-6 weeks after calving. A spontaneous recovery was seen at the beginning of October when adult flies disappear due to unfavourable cold temperatures.

Examination of 1676 Bactrian camels from 45 selected herds in six different areas of the Chatanbulag Sumon in the Eastern Gobi district, Mongolia, led to an estimate of *W. magnifica* infestation rates between 8-10%. Most myiasis cases were found in older females (> 4 years); younger animals were infested at a lower rate. Highest prevalence rates (15%) were seen during June and July in the Aman Us Chudak region (Valentin *et al,* 1997).

Cephalopinosis

Cephalopinosis or nasopharyngeal myiasis in dromedaries and Bactrian camels is caused by the larval stages of the camel nasal bot fly *Cephalopina titillator*. Compared to dromedaries, little research has been done on cephalopinosis in Bactrian camels. The inconspicuous female fly deposits its eggs around the nostrils and first stage larvae migrate through the labyrinth of the ethmoid bone of the nasal cavity. Second and third stage larvae are found in the nasopharynx. Under conditions of continental climate in east Asia, only one generation is produced per year and the whole larval development lasts 9-11 months. Fully grown third stage larvae are sneezed out and pupate in surface layers of the ground. The presence of *C. titillator* in Mongolia was mentioned by Erdenebileg (2001). Li *et al* (1997) and Yao *et al* (2022) studied the distribution of camel nasal bots in Bactrian camels in the neighbouring province of Inner Mongolia in China and found a prevalence of 96.2 and 54.2%, respectively. Under similar climatic conditions as in Mongolia, fly imagines are present around camel herds between June and September.

Vermipsillosis

Fleas of the family Vermispsyllidae occur on farm and wild animals in countries of central and east Asia. Three species, *Vemipsylla alacurt*, *Docardia ioffi* and *D. docardia* prevail in Mongolia (Ioff *et al,* 1965; Hiepe and Ribbeck, 1982). The life cycles of Vermispsyllidae spp. and their host spectrum under conditions of Mongolia was studied by Zedev (1976). Camels and other farm animals become infected in late autumn and the fleas hibernate on the host and suck blood. Thereby, the body of the females become worm like stretched and resembled a striped worm. Deposition of eggs takes place during the whole cold time of the year and the parasites die in spring. Preimaginal development takes place on the ground during the summer months. According to Erdenebileg (2001), heavily infested camels lose weight and condition over the winter.

Discussion

Camel husbandry is the main source of living for pastoralists in the semi-arid and arid zones of Mongolia, including the Gobi regions. Undoubtedly, camels represent a vital contribution to food security and human welfare in vulnerable households of dry areas. However, infectious diseases of livestock are major cause of production losses and may lead to even death.

Remote distances, poor infrastructure and lack of adequate diagnostic centres were the main reason for poor investigation of infectious diseases in Bactrian camels in Mongolia. As a matter of fact, linear distance from Ulaanbataar to places of the Gobi Desert where the majority of camels in Mongolia live is more than 500 km, mostly on unpaved roads. Also, sampling of materials under conditions of nomadic pastoralist systems was a challenge. Although, the situation has changed in the past 20 years, not all aspects of parasitic diseases are fully understood.

According to Wernery *et al* (2014) one of the most important camel parasitic diseases is surra but so far, there are only speculations on the presence of surra in Mongolia since serological results cannot differentiate between surra and dourine. There is no information about the presence of biting flies as the main vectors for surra. Findings of *O. trurkestanica* in camels in previous reports (Shumakovic, 1936, Sharhuu and Sharkhuu, 2004) suggested that muddy biotopes, such as watering places for animals are present in areas were camels are reared. Such places are the habitats of mud snails and offer good conditions for the larval development of horseflies,

the main vectors of surra. In other papers, the presence of the stomach worm *P. skrjabini*, in camels of Mongolia was mentioned (Sharhuu and Sharkhuu, 2004). The intermediate host for this parasite are hornflies, that can also act as a vector for surra.

Camels are prone to the faecal-oral way of transmission. Examples for this are the *Eimeria* coccideans, *T. gondii*, *Sarcocystis*, *Neospora* and *Echinococcus* spp. Toxoplasmosis in herbivores is always linked to the presence of cats but cats do not play a role in nomadic husbandry systems. More interesting would be a survey of neosporosis since it is linked to canids. Confirmed cases of hydatidosis in camels (Chinchuluun *et al,* 2018, Bold *et al,* 2019) do not present a direct danger for humans but feeding slaughtering offal to herding dogs is a jeopardy for both humans and livestock.

Some research work was done in Mongolia with regards to piroplasms and DNA of bovine and equine piroplasms were detected in camel blood. The researchers did not detect the parasites in examined blood smears. DNA of bovine and equine piroplasms was also detected in apparently healthy dromedaries from Jordan, Saudi Arabia and Egypt but blood smears were not examined (Quablan *et al,* 2012; Omer *et al,* 2021; Salman *et al,* 2022).

Hard ticks are important vectors for a number of viral, bacterial and parasitic diseases in animals and humans and camels may serve as a reservoir for these pathogens and also as a nutritional source for these vectors under the harsh climatic conditions of Mongolia. Thus, *Anaplasma* antibodies and their DNA were detected in Bactrian camels in Mongolia (von Fricken *et al,* 2018, Altantogtokh *et al,* 2022, Chaorattanakawee *et al,* 2022). A very interesting observation was made by Tyron (1983) who found that adult *Dermacentor nuttalli* sitting on shrubs in the Mongolian steppe and waiting for suitable hosts in early spring when temperatures were still below freezing point. This is important for control strategies.

Conflict of interests

The authors declare that they have no conflict of interest.

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