

Zoonotic diseases of potential concern among alpacas

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Summary

The aim of the present article is to describe the specific nature of the zoonoses associated with alpacas. Of the potential zoonoses, it is known that tuberculosis (TB), cryptosporidiosis and dermal mite have been transmitted to humans. In addition, associations have been noted between the South American Camelids (SAC) and *Escherichia coli* human verocytotoxigenic infections (VTECs). The zoonotic potential of TB in camelids primarily poses a threat to veterinarians and owners, it can also be transmitted to the rest of society, as although only a limited number of camelids enter the food chain, alpacas are very popular in public shows, exhibitions and festivals. Such close contact offers many opportunities to infect humans or other farm animals. The authors presented the potential routes of infection and discussed the clinical symptoms of individual zoonoses in both alpacas and humans.

Keywords: alpaca, bovine tuberculosis, *Mycobacterium bovis*, *Sarcoptic mange*, verocytotoxigenic *Escherichia coli*, Cryptosporidiosis

The South American Camelids (SAC) are a small group that includes llamas (*Lama glama*), guanacos (*Lama guanicoe*) vicuñas (*Vicuña vicugna*) and alpacas (*Vicuña pacos*). However, this nomenclature is controversial, and some authors use the term *llama* for all four species (15). Alpacas and llamas are domesticated animals, while guanacos and vicuñas are wild species (26).

Most SACs are kept for breeding and their high-quality fine wool. They are also known to have a mild temperament and good predisposition to training; as a result, they are increasingly used in alpacotherapy and agritourism (29, 30). There is also a small but growing market for SAC meat products in England and Wales (Collings D., Collings S.: Alpaca meat; <http://www.alpacaworldmagazine.com/autumn-2015/>). In their native South America, they are used as sources of meat, hide, fibre and transport, and their faeces are used as fuel and fertilizer (14), and in some parts of South America, particularly remote rural areas, alpacas often are the main livelihood of farmers (27).

Over the past three decades, international interest in breeding alpacas and other SACs has grown, partly

due to demand for their fine fleece; the global SAC population in 2020 was estimated to be over 9.1 million individuals (FAOSTAT 2018, Available online at: <http://www.fao.org/faostat/en/#data/QA> (accessed October 13, 2020), 44) with the largest population of alpacas in Europe being in Great Britain, with around 35,000 individuals (<http://www.bas-uk.com/>). A significant increase in alpaca breeding has also been noted in Poland.

The aim of the present article is to describe the specific nature of the zoonoses associated with alpacas. Of the potential zoonoses, it is known that tuberculosis (TB), cryptosporidiosis and dermal mite have been transmitted to humans (1, 51, 73). In addition, associations have been noted between SAC and *Escherichia coli* human verocytotoxigenic infections (VTECs) (61). The occurrence of mange in alpacas is recorded in practically every country in Europe (17). According to available literature, tuberculosis has also been recorded in alpacas in European countries, such as Great Britain, France, Ireland, Poland, Spain and Switzerland (23, 38, 40, 45, 71). A potential threat to alpaca breeding is also presented by cryptosporidiosis, a disease which causes

the deaths of the youngest animals in the herd, resulting in economic losses in breeding, and one that has zoonotic potential. Cases of cryptosporidiosis in alpacas have only been reported in Great Britain to date (76).

Tuberculosis

In mammals, tuberculosis (TB) is caused by bacteria (mycobacteria) belonging to the *Mycobacterium tuberculosis* complex (MTBC). Currently, 11 species of mycobacteria can be distinguished within the MTBC; all apart from one, *M. bovis* BCG, are pathogenic both for animals and humans (58, 67). Tuberculosis is a chronic, debilitating disease which is also highly contagious, and is passed on through aerosol (41). In countries with official bovine tuberculosis control programs, cattle that show a positive response to the tuberculin skin test (TST) are eliminated from the herd (82). Accurate data on the incidence of bovine tuberculosis in each country only apply to cattle. According to the Commission Implementing Regulation (EU) 2018/1882, infection with MTBC (*M. bovis*, *M. caprae*, *M. tuberculosis*) in bovine animals (*Bison* spp., *Bos* spp., *Bubalus* spp.) is listed as category B disease, therefore it must be controlled in all Member States with the goal of eradicating it throughout the European Union (EU), as referred to in Article 9(1)(b) of Regulation (EU) 2016/429 dated 9 March 2016 (63). The status regarding freedom from bovine tuberculosis (Officially Tuberculosis-Free) and occurrence of the disease in Members States and non-MSs in 2020 is presented in Figure 1.

In other animal species, tuberculosis should not be treated, neither among companion animals nor otherwise. EU Regulation 2016/429 of the European Parliament and Council concerning transmissible animal diseases, also known as the *Animal Health Law*, amends and repeals certain acts in the field of animal health. One of its provisions requires camelids to be periodically tested for tuberculosis every five years. This act should be implemented by April 2022 (63).

In the last decade, alpaca-borne tuberculosis has mainly emerged in areas demonstrating a high incidence of bovine tuberculosis in cattle and wildlife; these serve as reservoirs for *Mycobacterium bovis* (10, 23, 71, 78). The spread of infection among alpacas is often caused by the movement of asymptomatic vectors.

In Europe, most outbreaks of *M. bovis* in alpacas have been recorded in Great Britain, where the numbers of infected herds and sick animals are increasing: 200 registered alpacas were euthanised due to tuberculosis

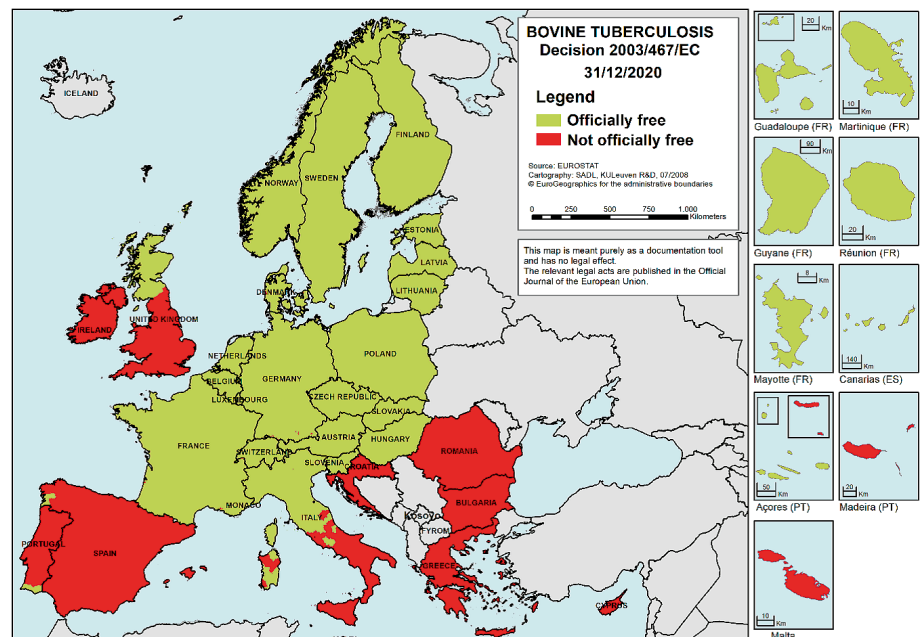


Fig. 1. Status of EU Member States, Norway and Switzerland and regions thereof in relation to bovine tuberculosis (https://ec.europa.eu/food/system/files/2021-12/la_annual-situation_2020.pdf)

in 2013, 51 for tuberculosis in 2016, and 288 a year later (40). Despite these culls, the problem of tuberculosis in alpacas stays, as showed by the fact that the UK Department of Environment, Food and Rural Affairs (DEFRA) is constantly working to improve TB control in non-cattle animals, particularly alpacas and other SACs. It is estimated that one hundred alpaca herds have been affected by bovine tuberculosis in the UK so far (DEFRA, Statistics on TB in Non-Bovine Species, TB in non-bovine species for 2011 to quarter 4 2020; <https://www.gov.uk/government/statistical-data-sets/other-tb-statistics>; August 27, 2020.). Tuberculosis has also been recorded in alpacas in other European countries, such as Switzerland, Ireland, Spain, France and Poland (23, 38, 45, 71).

Literature data shows that alpacas are highly susceptible to infection with *Mycobacterium bovis* and *Mycobacterium microti* (38, 39, 49, 54), and this has been confirmed by the experience of the authors. No reports of tuberculosis caused by other MTBC complex mycobacteria have been noted in alpacas. Infection with *M. bovis* or *M. microti* may go unnoticed until it leads to deaths in the herd. Deaths are rarely preceded by clinical symptoms (59). In alpacas, tuberculosis manifests as dyspnoea, mucopurulent nostril, apathy, lack of appetite and emaciation. A case of *M. bovis* mastitis in an alpaca is also described in the literature (66).

In Poland, the first case of tuberculosis in alpacas caused by *M. bovis* was recorded in the Silesian Zoological Garden in Chorzów (37). In this case, it was suspected that interspecific transmission had taken place from an antelope and/or a giraffe that shared the exhibition pavilion (35-37). The entire herd from this building was euthanized and the building was



Fig. 2. Gross lesions in the lungs of alpaca infected with *Mycobacterium bovis*

thoroughly disinfected. Post-mortem examination found the alpaca to have extensive tuberculous lesions in the left lung; these were so large that they disintegrated during dissection due to the size of the caseous mass (Fig. 2).

Following the import of alpacas from Great Britain, a tuberculosis outbreak took place in Poland in 2017-2019; microbiological testing confirmed 27 cases of tuberculosis in alpacas from six different herds. The samples were tested in the Reference Laboratory of Bovine Tuberculosis at the Department of Microbiology of the National Veterinary Institute – National Research Institute in Puławy (NVRI Poland). Among the 27 MTBC strains obtained, 26 belonged to a single transmission chain, which indicated a common source of infection (unpublished data).

The ante-mortem testing tools that have been successful in controlling *M. bovis* in cattle, the intradermal tuberculin test, have unfortunately been ineffective in alpacas, often giving false negative results. In alpacas naturally infected with *M. bovis*, the single intradermal comparative cervical tuberculin (SICCT) test proved low or even zero sensitivity when used repeatedly (38, 46, 79). Conversely, animals experimentally infected with *M. bovis* showed positive responses to the SITT or SICTT performed in the armpit region. Various *in vitro* diagnostic methods based on cellular immunity, e.g., IFN- γ or the humoral immune response, have also been tested, such as the Rapid Serological Test (RT), Dual Path Platform (DPP) and various ELISA tests (65, 78, 79). All serological tests proved greater specificity than the IFN- γ test (65); however, none of the serological tests were able to correctly find all sick animals in any of the above-mentioned studies.

Mange/Scabies

One of the most common diseases in alpacas is mange (scabies). Mange can be caused by a range of mite species, such as the burrowing *Sarcoptes*

scabiei and the non-burrowing *Chorioptes* spp. and *Psoroptes* spp. In alpacas, it can result from invasions by a single species of mite, or many dozen species, as a mixed invasion (4, 6, 43). In all animal species, including alpacas, the greatest impact is exerted by *Sarcoptes scabiei*, the agent of sarcoptic mange (17, 22). Sarcoptic mange is a potential zoonosis (51, 60), with reports of transmission from alpacas to humans (3, 4); it typically has the most severe clinical course in alpacas and is often difficult to treat (13). *Chorioptes* spp. and *Psoroptes* spp. are not known to be zoonotic (72). It is worth noting that there is little current research on the occurrence of mange and its aetiology in alpacas; however, Lusat et al. (43) note that in 52.2% of herds, alpaca owners reported the presence of mange; however, not all these cases were confirmed by laboratory tests.

S. scabiei is a highly contagious, interspecies pathogen (18, 56, 68, 70, 75) known to cause sarcoptic mange in free-living and domestic animals, and scabies in humans. Sarcoptic mange has been described in at least 148 mammal species (17). The systematics of *Sarcoptes* spp. remain poorly understood; however, *S. scabiei* appears to be a single species with various host-restricted genetic variants, with each given variant being able to reproduce and complete a full life cycle only within a given host group (60, 62, 70). If the mite is transmitted to a group of animals other than the target, it cannot complete its life cycle, and the infestation is self-limited. The individual genetic variants of *S. scabiei* can only be differentiated by molecular examination: no morphological differences exist between them (17, 20).

The female *S. scabiei* digs holes in the skin, where it lays its eggs. The eggs hatch in three to eight days, migrate to the surface of the skin, pass the nymph stage and become adults within four to six days. The entire life cycle can be completed in seven to fourteen days (20). Transmission occurs by either direct contact with an infected animal or by indirect contact through the environment; adult *S. scabiei* are estimated to be able to survive outside of the host for up to 30 days (20). Furthermore, mechanical transfer of mange is also possible, e.g., on wool care tools. Infested animals show pruritus of varying severity and skin lesions such as erythema, papules, pustules, crusts, alopecia, and hyperkeratosis, i.e., the skin becoming thickened. Secondary bacterial and fungal infections may occur. In cases of high intensity infection, metabolic changes occur in the host, resulting in the impairment of its thermoregulatory abilities, which may lead to death (4, 22, 47, 57). There are also reports of asymptomatic cases of *S. scabiei* in animals. It is possible that both *Sarcoptes* and the host population may show adaptation, as described by Davidson et al. (12) in foxes.

In alpacas, lesions caused by mite infestation are often found on the legs, typically between the toes

and on the medial side of the thigh, as well as on the abdomen, armpits, perineum and foreskin, and on the head, typically around the mouth and ears (4, 13, 20). The changes caused by *Chorioptes* spp. may resemble those caused by *S. scabiei*, but are often milder, and a subclinical course is possible in some animals. *Psoroptes* spp. most often causes changes around the auricle and external auditory canals; however, in such cases, other changes resembling those following infestation by *Chorioptes* spp. or *S. scabiei* can be seen in other parts of the body. Movement of the ears and brief head shaking may show otitis, a sign of *Psoroptes* spp. infestation (4, 20).

Treatment of mange in alpacas can pose a considerable challenge, and one that can last a long time (13). Anti-mange pour-on drugs are poorly distributed and absorbed, possibly due to the lack of lanolin in alpacas or the hyperkeratosis associated with sarcoptic mange, while systemic treatments (e.g., ivermectin, doramectin, eprinomectin, moxidectin) often require multiple administrations. It is also often necessary to treat secondary infections. Cure is not always achieved (3, 6, 76).

Cryptosporidiosis

Cryptosporidiosis, a widespread disease seen in humans and animals, is caused by Apicomplexa type parasitic intracellular protozoa of the genus *Cryptosporidium*, classified as parasitic coccidia. At least 22 species of *Cryptosporidium* have been identified, with the greatest zoonotic potential being demonstrated by *C. parvum* type II, which is dominant in humans and animals. However, other species of this genus can also cause disease in humans, especially in non-immunocompetent patients; the most common infection in humans is by *C. hominis* (74).

Being opportunistic parasites, *Cryptosporidium* protozoa are known to cause disease in patients with weakened immune systems, such as those with AIDS, and those who have received transplants, or chemotherapy and antibiotic therapy. In addition, children up to five years of age and young animals with incompletely developed immune systems are also at risk. Among farm animals, post-weaning ruminants most often suffer from cryptosporidiosis, which makes it a disease of economic importance. While the problem mainly affects calves, lambs and kids, it is also observed in alpacas, which are becoming a more common sight as farm animals in Europe.

In this group of animals, the disease is most often caused by *C. parvum* and presents with symptoms of diarrhoea, weight loss and cachexia (7, 76). The life cycle of the parasite is simple (monohymen) and the invasive form is an islanded oocyst. Infection occurs via the oral route, i.e. faecal-oral transmission, through the consumption of water and food contaminated with

invasive oocysts. Human-human, human-animal and animal-human transmission routes have been recorded (86). Briefly, after infection, the parasite undergoes asexual reproduction, and then sexual reproduction, in the intestinal cells of the small intestine, resulting in the production of thin-walled oocysts playing a role in auto invasion, and thick-walled oocysts found in the faeces. After consumption, the oocysts sporulate in the host organism.

The oocysts keep the ability to survive in the environment for many months or even years. In addition, they are resistant to many disinfectants, including those used for water disinfection; as such, there is a considerable risk of waterborne contamination associated with drinking and recreational water. *Cryptosporidium* oocysts can enter groundwater from manure, slurry, animal, and human excreta. The risk of human infection is increased by the fact that only a few oocysts are needed for an invasive dose (8, 55). Research from the USA (5) found that possibly 7% of alpaca calves (crias) and 8% of their mothers (dams) are asymptomatic but shed *Cryptosporidium* oocysts; such individuals are a source of infection to other animals in the herd and to humans (21). In alpacas, the disease manifests as persistent diarrhoea, abdominal pain, weight loss and decreased appetite, and sometimes fever, lethargy and the deaths of the youngest animals in the herd (21, 83). Cryptosporidiosis may also include auscultatory symptoms, such as loss of intestinal peristaltic tone (73).

Cases of cryptosporidiosis in alpacas were noted in Australia (31), China (87), Peru (24, 25, 50) and USA (5, 73, 83).

Infections of verocytotoxigenic *Escherichia coli* (VTEC, STEC)

Other etiological agents of zoonotic importance are the toxin-producing strains of *Escherichia coli* (STEC; VTEC), especially the strain VTEC O157 (16). While O157 is most found in the digestive tract, it rarely causes clinical signs of disease. Animals excrete it via the saliva and faeces (26). VTEC is one of the main pathogens in humans; it can cause gastrointestinal dysfunction and haemolytic uremic syndrome (HUS) (9, 42, 84).

Most studies of VTEC carriage or infection in alpacas has been performed in England and Wales (26, 61). This is because Great Britain is home to the largest population of alpacas in Europe, and there is a small, but growing, market for South American Camelid (SAC) meat products in England and Wales (Collings D., Collings S.: Alpaca meat; <http://www.alpacaworldmagazine.com/autumn-2015/>). In a study of post-mortem examination and bacteriological monitoring of faecal samples in ninety-six alpaca herds, three out of 188 tested samples were found to be positive for VTEC O157 (1.6%) (61).

Zoonotic potential of these diseases

Tuberculosis is considered a major cause of death worldwide. The World Health Organization (WHO) places tuberculosis within the top 10 most common causes of death from a single infectious agent and is regarded as more lethal than HIV/AIDS. The WHO estimated that, in 2019, approximately 10 million new cases of tuberculosis occurred worldwide, equivalent to 130 cases per 100,000 people (85). In Poland, the reported incidence was 14.3 cases per 100,000 inhabitants in 2018 (32); however, while this level lower, it is still too high to classify Poland as a low-incidence country according to the WHO definition (< 10 cases per 100 000) (85).

The zoonotic potential of tuberculosis in camelids is also becoming increasingly clear. While it primarily poses a threat to veterinarians (69, 79, 81) and owners (69), it can also be transmitted to the rest of society, as although only a very limited number of camelids enter the food chain, alpacas are a very popular in public shows, exhibitions and festivals: such close contact offers many opportunities to infect humans or other farm animals.

In the UK, half of the registered camelid herds are in areas where tuberculosis is highly endemic (<http://www.bas-uk.com/>), with the potential to spread to cattle and wildlife. Animals continue to move between herds with little or no monitoring, standing for a potential biosecurity nightmare (78).

Bovine tuberculosis is a serious chronic disease of animals and humans, and several patients with bovine tuberculosis have been diagnosed in Poland (33, 34). According to data from the European Food Safety Authority and the European Centre for Disease Prevention and Control (EFSA and ECDC), bovine tuberculosis caused 22 deaths in Europe in 2019 (19).

In 2017, the WHO included scabies as a Neglected Tropical Disease (NTD). *Sarcoptes scabiei* is a potential zoonotic agent, and the human disease is referred to as zoonotic scabies. As in animals, human patients present with skin lesions accompanied by pruritus. Human infection can occur following contact with domestic or wild animals (51, 60). However, while cases of transmission have been noted from alpacas to humans, such transfer is comparatively rare (3, 4, 76). Even so, the problem may be underestimated.

In alpacas, cryptosporidiosis is caused by the species *Cryptosporidium parvum*, which is also the most common cause of zoonotic cases of human cryptosporidiosis (25, 50). Cases of *C. parvum* infection have been noted in people who have been in contact with sick alpacas in the USA; the animals ranged in age from three days to one month and were housed in one herd (73). In one case, a veterinary student began to manifest symptoms of acute gastroenteritis with persistent diarrhoea three to four days after contact

with a sick animal; this led to dehydration and the need for hospitalization. The patient was confirmed to be infected with *C. parvum*. After some time, the disease developed in a second student caring for sick alpacas and in three farm workers, as well as a household member (73). Cases of alpaca cryptosporidiosis following *C. parvum* infection have been reported in farmed animals in the USA, Great Britain, Peru, Australia, and China (24, 31, 73, 76, 87). Elsewhere, *C. ubiquitum* was found to be the etiological factor of cryptosporidiosis in alpacas in Peru, Australia and China (24, 31, 87), while *C. cuniculus* was identified in herds in Australia (35) and *C. occultus* diagnosed in alpacas in China (87). All these *Cryptosporidium* protozoa show zoonotic potential (24, 31, 73, 76, 87).

The main reservoir of Verotoxin-producing *Escherichia coli* (VTEC) is the digestive tract of ruminants, and one of the major sources of infection in humans is the consumption of contaminated beef and dairy products (47). Beef carcasses can become contaminated when slaughtered, either directly from faeces, or from skin contaminated with faeces; such contamination has clear food safety implications, as the carcasses are further processed into beef products (2, 52, 53, 64). In 2020, testing by the ISO/TS 13136 standard found the VTEC toxin to be present in 115/330 (34.8%) and 37/120 (30.8%) of samples from cattle and pigs (84). Zoonotic transmission occurs via the faecal-oral route, with humans becoming infected by eating contaminated food, or through contact with infected people, infected animals or the environment (26). The symptoms of VTEC 0157 infection in humans vary widely. Infections may be asymptomatic or range from mild gastroenteritis to acute symptoms of bloody diarrhoea. VTEC has also been isolated during haemolytic uremic syndrome and macular thrombocytopenic thrombosis (26). VTEC is one of the most common foodborne pathogens affecting humans worldwide. Due to their high pathogenic potential, they are often the cause of international epidemics resulting in numerous deaths (28).

Summary of the chapter on zoonotic potential of these diseases is presented in Table 1.

Herd health monitoring is important for all animal species. Alpaca breeders and keepers and veterinarians should be familiarized with the zoonotic diseases that may occur in these animals. We recommend against purchasing alpacas from unspecified sources and wholesale suppliers and recommend that all alpacas should be traceable. All purchases should be accompanied by documentation from the country of origin, if the alpaca is imported, an alpaca registration certificate, with a chip or earring number, and a history of treatments and vaccinations. The purchaser should also sign a sales agreement, supplying detailed information about the seller and the purchased alpaca. In addition, even the smallest herd of alpacas should be under the

Tab. 1. Potential route of transmission of tuberculosis, mange, cryptosporidiosis and VTEC infections from alpaca to humans

Zoonotic diseases	Potential route of infection/contamination	Clinical symptoms	
		Alpacas	Humans
Tuberculosis	direct contact with the animal also with the carcasses of sick animals (mycobacteria are transmitted mainly through the respiratory tract); contact with contaminated fleece	weight loss, respiratory rattle on auscultation, and mucopurulent nasal discharge, shortness of breath, cough; may be asymptomatic	cough lasting at least 3 weeks without improvement, fever, night sweats, weakness and easy fatigue, loss of appetite, weight loss, haemoptysis; people with tuberculosis may have some or all of these symptoms; sometimes the only symptom of TB is coughing
Mange	direct contact with the infested animal; indirect transmission (through the environment; adult <i>S. scabiei</i> are estimated to be able to survive outside of the host for up to 30 days; mechanical transfer of mange is also possible, e.g., on wool care tools)	pruritus of varying severity and skin lesions such as erythema, papules, pustules, crusts, alopecia, hyperkeratosis, thickened skin; may be asymptomatic	the most common are: itching and skin rash
Cryptosporidiosis	Faecal-oral transmission, either through direct contact with infected hosts (the oocysts are already mature when shed in the faeces) or through recreational and drinking water, food or fomites; indirect transmission of <i>Cryptosporidium</i> from sewage, animal droppings or manure and slurry reaching water sources (oocysts may persist in the environment for months to years); autoinfection possible	Diarrhoea, weight loss, anorexia, dehydration and even death especially in neonates and immunosuppressed older animals; herd-level incidences or outbreaks rather than individual diagnoses; may be asymptomatic	Diarrhoea, dehydration that are usually self-limiting; prolonged and life threatening for immunocompromised patients; may be asymptomatic
VTEC	consumption of contaminated food, or through contact with infected animals or the environment	usually asymptomatic ; diarrhoea of varying severity and clinical course (the most common diseases are young animals and are associated with the physiological colonization of the gastrointestinal tract by a germ)	infections may range from mild gastroenteritis (symptoms of foodborne illness) to acute symptoms of bloody diarrhoea; haemolytic uremic syndrome (HUS); macular thrombocytopenic thrombosis; may be asymptomatic

constant supervision of a veterinarian. If possible, this supervision should be performed by a single doctor or clinic. It is recommended that the herd be inspected once a year.

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