b UNIVERSITÄT BERN

Departement für klinische Veterinärmedizin, Wiederkäuerklinik
der Vetsuisse-Fakultät Universität Bern

Leiter des Instituts: Prof. Dr. med. vet. Adrian Steiner

Arbeit unter wissenschaftlicher Betreuung von
Prof. Dr. med vet. Gaby Hirsbrunner und Prof. Dr. med. vet. Patrik Zanolari

Infecious and non-infectious causes for pregnancy loss in South American camelids – A review

Inaugural-Dissertation

zur Erlangung des Doktortitels der
Vetsuisse-Fakultät, Universität Bern

vorgelegt von

Hannah Eggimann

Tierärztin
von Sumiswald, Bern

2024

Inhaltsverzeichnis

Universität Bern | Universität Zürich
vetsuisse-fakultät

Abstract in Englisch

Vetsuisse-Fakultät Universität Bern 2024

Hannah Eggimann

Wiederkäuerklinik / wiederkaeuerklinik.kontakt.vetsuisse@unibe.ch

Infectious and non-infectious causes for pregnancy loss in South American camelids – A review

South American camelids (SAC) are gaining popularity for various purposes, including fiber production, trekking, and companionship. High abortion rates pose a significant health issue in SAC herds, leading to substantial economic losses for breeders. Often, the causes of these abortions remain unidentified. This review provides a comprehensive summary of the known infectious and non-infectious causes of abortions in SAC.

South American Camelid, Llama, Alpaca, Abortion, Pregnancy loss

Universität Bern | Universität Zürich
vetsuisse-fakultät

Bern, 25. September 2024
Ort, Datum | Unterschrift, Gaby Hirsbrunner

Bern, 25. September 2024
Ort, Datum | Unterschrift, Patrik Zanolari

Zusammenfassung in Deutsch

Vetsuisse-Fakultät Universität Bern 2024

Hannah Eggimann

Wiederkäuerklinik / wiederkaeuerklinik.kontakt.vetsuisse@unibe.ch

Infektiöse und nicht-infektiöse Abortursachen bei Neuweltkameliden – Ein Review

Neuweltkameliden (NWK) erfreuen sich zunehmender Beliebtheit. Sie werden für unterschiedliche Zwecke genutzt, zum Beispiel zur Faserproduktion, als Trekkingtiere und als Haustiere. Hohe Abortraten stellen ein erhebliches Gesundheitsproblem in NWK-Herden dar und führen zu beachtlichen wirtschaftlichen Verlusten für die Züchter. Die Ursachen für die Aborte bleiben oft unerkannt. Dieses Review gibt einen umfassenden Überblick über die bekannten infektiösen und nicht-infektiösen Abortursachen bei NWK.

Neuweltkamelid, Alpaka, Lama, Abort, Totgeburt

Bern, 25. September 2024
Ort, Datum — Unterschrift, Gaby Hirsbrunner

Bern, 25. September 2024
Ort, Datum — Unterschrift, Patrik Zanolari

Animal Reproduction Science 268 (2024) 107571

Contents lists available at ScienceDirect

Animal Reproduction Science

journal homepage: www.elsevier.com/locate/anireprosci

Review article

Infectious and non-infectious causes for pregnancy loss in South American camelids – A review

Hannah Eggimann [a,b,*], Isabelle Rediger [a], Gaby Hirsbrunner [a,1], Patrik Zanolari [a,1]

[a] Clinic for Ruminants, Department of Clinical Veterinary Science, Vetsuisse-Faculty, University of Bern, Bern 3012, Switzerland
[b] Praxis Dr. Hutter, Thalacker 9, Zuzwil, BE 3303, Switzerland

ARTICLE INFO

Keywords:
South American camelid Llama
Alpaca Abortion
Stillbirth
Pregnancy loss

ABSTRACT

South American camelids (SAC) are gaining popularity for various purposes, including fiber production, trekking, and companionship. High abortion rates pose a significant health issue in SAC herds, leading to substantial economic losses for breeders. Often, the causes of these abortions remain unidentified. This review provides a comprehensive summary of the known infectious and non-infectious causes of abortions in SAC.

1. Introduction

South American camelids are experiencing increasing popularity in the Western world, primarily prized for their exceptionally soft wool, utility as trekking companions, and suitability as pets. Breeders face significant challenges due to low reproductive rates, re- ported to range between 45.5 % and 65.9 % (Aller et al., 2003; Bravo et al., 2010), and the prevalence of abortions or stillbirths, which are among the primary health concerns (Tibary et al., 2006). Abortion rates range between 24 % and 34.1 % (Ridland et al., 1993; Bravo et al., 2010), emphasizing the potential substantial economic losses within the breeding industry. High abortion rates among SAC can result in significant economic losses for the breeders. Often, the underlying cause of abortions remains undetermined, as careful examination of the fetus and placenta frequently fail to reveal a clear cause (Schaefer et al., 2012; Rüfli et al., 2021; Clarke and Breuer, 2022). Like other mammals, many infectious pathogens responsible for abortions in SAC are transmissible to other species, including humans and other farm animals, posing a zoonotic risk. This makes it crucial to prevent, accurately diagnose, and manage the causes of abortions to halt the spread of these pathogens. In Switzerland, several diseases such as brucellosis, bovine viral diarrhea virus, chlamydiosis, salmonellosis, and equine arteritis virus are classified as epizootics, underscoring the potential necessity of including SAC in eradication efforts to prevent transmission to other farm animals. Given that SAC have only recently gained popu- larity in the Western world, the lack of economic resources and the extrapolation of information generated from other species, there is a notable gap in veterinary knowledge concerning their specific health issues. This review aims to consolidate all so far known in- fectious and non-infectious causes of abortions in SAC, providing veterinarians, field scientists and SAC owners with a comprehensive knowledge base.

* Corresponding author at: Clinic for Ruminants, Department of Clinical Veterinary Science, Vetsuisse-Faculty, University of Bern, Bern 3012, Switzerland.
E-mail address: hannah.eggimann@unibe.ch (H. Eggimann).
[1] These authors contributed equally to the work.

https://doi.org/10.1016/j.anireprosci.2024.107571
Received 19 June 2024; Received in revised form 26 July 2024; Accepted 27 July 2024
Available online 29 July 2024

2. Material and methods

The review was structured around five key phases: (1) defining the research question, (2) locating relevant studies, (3) selecting appropriate studies, (4) extracting and processing data, and (5) summarizing and presenting the findings, following the methodology proposed by Tricco et al. (2016). The central research question guiding the review was, "What are the known infectious and non-infectious causes of abortions, stillbirths and perinatal mortality in SAC?" To address this, searches were conducted in six medical or agricultural electronic databases through the end of 2023: PubMed, Scopus, Embase, Ovid, Web of Science, and ScienceDirect, without imposing restrictions on publication date, language, or study type. The search utilized terms associated with pregnancy loss and perinatal mortality in SAC such as South American camelids, alpaca, llama, abortion, pregnancy loss, embryonic death, stillbirth, pathologic pregnancy, neonatal loss, perinatal mortality, neonatal death, brucellosis, bovine virus diarrhea virus, equine herpes virus, coxiellosis, salmonellosis, leptospirosis, infectious bovine rhinotracheitis, neosporosis, toxoplasmosis, trace minerals. The search query was tailored to the requirements of each database. All identified citations were imported into the reference manager Mendeley (Elsevier, Amsterdam, Netherlands) and duplicates were manually removed, with additional duplicates identified and eliminated throughout the process. Initial screening involved reviewing titles and abstracts, discarding publications not in English, German, or French, those not focused on SAC, molecular-level studies, non-peer-reviewed documents, research describing diseases in males, conference proceedings, or studies where the death of the cria occurred more than 48 after birth. Additionally, publications prior to 1990 were excluded. Furthermore, studies were excluded if early embryonic loss occurred by the sixth week of pregnancy, adhering to the abortion definitions used in other species where abortion is defined post- 42 days of gestation in cattle (Mee, 2023) and post-40 days in horses (Leon et al., 2023). Subsequent full-text screening excluded manuscripts based on the initial criteria. The remaining studies underwent data extraction, with information complied into a Microsoft Excel spreadsheet (Microsoft Corporation, Redmond, USA).

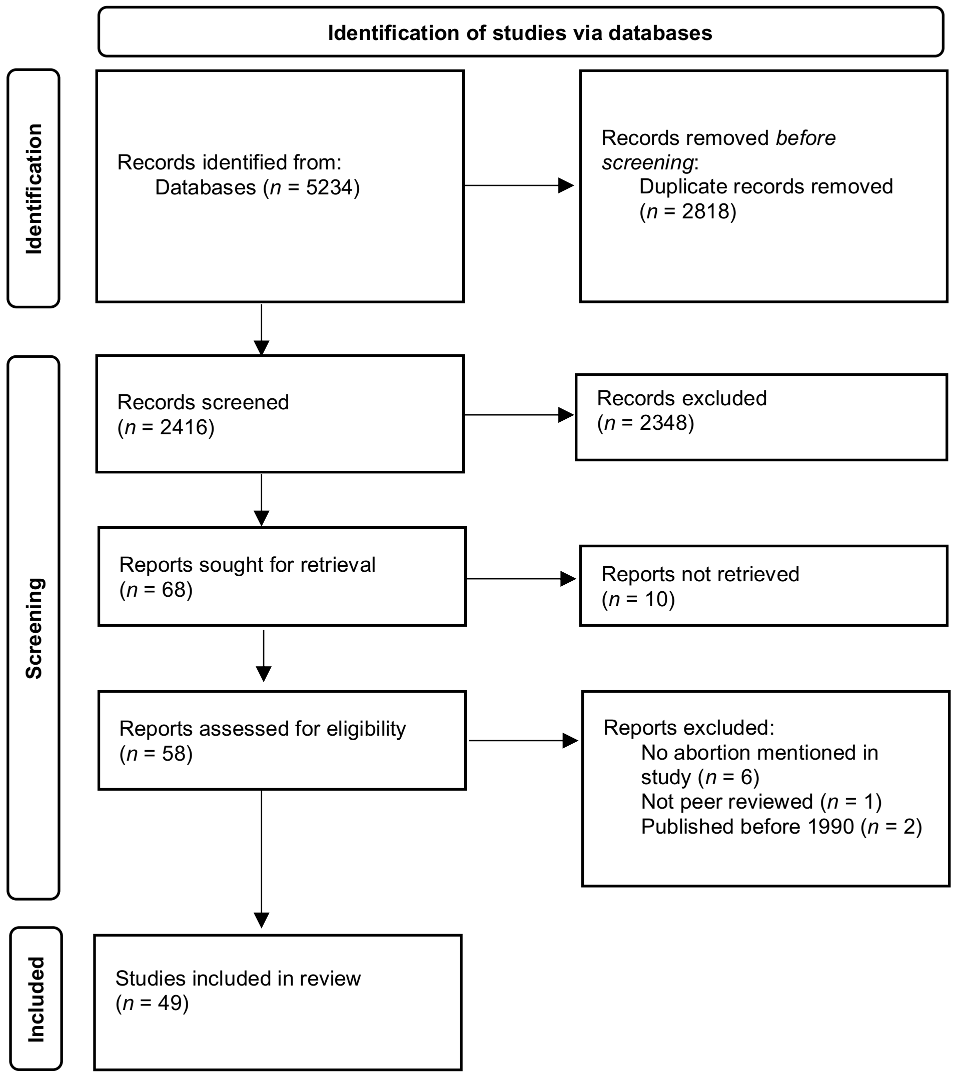

Fig. 1: PRISMA flow chart of study selection process

3. Results

3.1. Search results

The initial search generated 5’234 potentially relevant results. Following duplicate removal, 2’416 citations underwent eligibility screening. From these, 58 records met the inclusion criteria and were subjected to full-text assessment. After thorough examination, 49 publications were retained for inclusion in the review. The progression of citations from identification to final inclusion is shown in Fig. 1.

The publications included in the review originated from four continents, with the majority from North America (*n*=26), followed by Europe (*n*=12), South America (*n*=7), and Australia (*n*=4). The studies primarily focused on alpacas (*n*=24) or both alpacas and llamas (*n*=19), with fewer studies (*n*=6) exclusively involving llamas. Of the total, 36 publications addressed aspects of pregnancy loss, while only six specifically dealt with perinatal mortality and stillbirths. Twelve studies examined both, abortions and perinatal mortality. Research on specific infectious agents causing abortions was limited. A summary of the findings is presented in Table 1, and non-infectious abortifacients are listed in Table 2.

Table 1
Infectious agents causing abortions listed alphabetically.

Group	Infectious agent	Species	Location	Citation
Viruses	*BVDV*	Alpaca, llama	UK, USA, Canada	(Belknap et al., 2000) (Goyal et al., 2002) (Wentz et al., 2003) (Carman et al., 2005) (Evermann, 2006) (Tibary et al., 2006) (Barnett et al., 2008) (Topliff et al., 2009) (Van Amstel and Kennedy, 2010) (Bedenice et al., 2011) (Jarvinen and O’Connor, 2014)
	EAV	Alpaca	Germany	(Weber et al., 2006)
Bacteria	*Brucella ssp.*	Llama	USA	(Gidlewski et al., 2000) (Tibary et al., 2006) (Vaughan and Tibary, 2006)
	Campylobacter fetus ssp. fetus	Alpaca	UK	(Bidewell et al., 2010) (Halsby et al., 2017)
	Chlamydia	Alpaca, llama	USA	(Tibary et al., 2006) (Vaughan and Tibary, 2006)
	Corynebacterium pseudotuberculosis	Alpaca	Sweden	(Bjorklund et al., 2019)
	Coxiella burnetii	Alpaca, llama	Switzerland	(Rüfli et al., 2021)
	Encephalitozoon cuniculi	Alpaca	USA	(Webster et al., 2008)
	Leptospira	Alpaca, llama	UK, USA	(Tibary et al., 2006) (Vaughan and Tibary, 2006) (Halsby et al., 2017)
	Listeria monozytogenes	Alpaca, llama	USA	(McLaughlin et al., 1993) (Tibary et al., 2006) (Vaughan and Tibary, 2006)
	Salmonella ssp.	Alpaca, llama	UK	(Halsby et al., 2017)
	Septicemia (Strep. sanguis type 1)	Llama	USA	(Semalulu and Chirino-Trejo, 1991) (Tibary et al., 2006)
	Strep. pluranimalium	Alpaca, llama	Switzerland	(Rüfli et al., 2021)
	Trueperella pyogenes	Alpaca, llama	USA	(Tibary et al., 2006)
	Yersinia enterocolitica	Alpaca, llama	UK	(Halsby et al., 2017)
	Opportunistic infection - E. coli	Alpaca, llama	Switzerland	(Rüfli et al., 2021)
Parasites	*Neosporin caninum*	Alpaca, llama	Peru, USA	(Chavez-Velasquez et al., 2005) (Serrano-Martinez et al., 2007)
	Sarcocystis ssp.	Alpaca	USA	(La Perle et al., 1999) (Tibary et al., 2006)
	Toxoplasma gondii	Alpaca, llama	USA, Switzerland	(Tibary et al., 2006) (Vaughan and Tibary, 2006) (Dubey et al., 2014) (Rüfli et al., 2021)
Fungi	*Coccidoides posadasii & immitis*	Alpaca, llama	USA	(Diab et al., 2013) (Grayzel et al., 2020)

Abbreviations: Bovine Viral Diarrhea Virus (BVDV), Equine Arteritis Virus (EAV), Streptococcus (Strep.), *Escherichia coli* (E. coli), subspecies (ssp.)

Table 2
Non-infectious reasons for abortions listed alphabetically.

Non-infectious reasons	Species	Location	Citation
Body condition of dam	Alpaca, llama	UK, USA, Continental Europe, Australia	(Brown, 2000)
(poor/ obese)	(Vaughan and Tibary, 2006) (Van Saun, 2008)		
	(Kapustka and Budzyn´ska, 2022)		
Dexamethasone	Alpaca, Llama	USA	(Bravo et al., 1996)
(Vaughan and Tibary, 2006)			
Dystocia	Alpaca, llama	Australia, USA, Switzerland, Germany, Austria	(Brown, 2000)
(Ferrer et al., 2015)			
(Wolfthaler et al., 2020)			
Fetal malformations	Alpaca, llama	UK, USA	(Davis et al., 1998)
(Ferrer et al., 2015)			
Genital abnormalities of dam	Alpaca, llama	USA, Australia	(Brown, 2000)
(Vaughan and Tibary, 2006)			
Alpaca		Peru	(Bravo et al., 2009)
Maternal stress	Alpaca, llama	USA	(Vaughan and Tibary, 2006)
Mineral / vitamin deficiencies	Alpaca, llama	USA	(Van Saun, 2008)
PGF2α	Alpaca, llama	USA, Peru	(Bravo et al., 1996)
(Memon and Stevens, 1997) (Smith et al., 2000) (Vaughan and Tibary, 2006)			
Plant poisoning	Alpaca,	Australia	(McKenzie et al., 2009)
Pregnancy toxemia	Alpaca	Italy	(Sylla and Crociati, 2020)
Twin pregnancy	Alpaca, llama	USA, Germany, UK, Continental Europe	(Vaughan and Tibary, 2006)
(Schaefer et al., 2012) (Hoops and Kauffold, 2013) (Campbell et al., 2015) (Ferrer et al., 2015)			
(Kapustka and Budzyn´ska, (2022)			
Umbilical torsion	Alpaca, llama	USA	(Schaefer et al., 2012)

3.2. *Infectious agents*

3.2.1. *Viral pathogens*

3.2.1.1. *Bovine viral diarrhea virus.* South American camelids are susceptible to bovine viral diarrhea virus (BVDV), but an experimental study has shown that acutely infected animals show few or no clinical signs (Wentz et al., 2003). Since BVDV isolates from llamas and bovines are very similar, it has been concluded that cattle are the most likely source of BVDV infection in SAC (Wentz et al., 2003). Bovine viral diarrhea virus causes early embryonic loss, abortions and stillbirths (Belknap et al., 2000; Goyal et al., 2002; Carman et al., 2005; Barnett et al., 2008). Persistent infections with BVDV type 1b are possible in SAC, as was first described in 2005 (Carman et al., 2005). Persistently infected (PI) alpaca crias experience a high degree of morbidity and mortality associated with various clinical manifestations of disease. Clinical signs of PI animals include stillbirth, chronic wasting, low-grade pyrexia, atypical fleece, lethargy, inappetence, low birth weight, stunted growth and weight gain, diarrhea, joint swelling, opportunistic dental, intestinal and respiratory diseases (Belknap et al., 2000; Carman et al., 2005; Foster et al., 2005, 2007; Bedenice et al., 2011). Opportunistic infections and reduced immune responses can contribute to the early death of PI alpacas (Bedenice et al., 2011). Because of their high viral shedding, PI animals are an important source of infection for other healthy ruminants (Carman et al., 2005).

3.2.1.2. *Equine arteritis virus.* In a zoo in western Germany, an alpaca had an abortion in the late stages of gestation. In organs of the aborted fetus PCR isolation confirmed Equine Arteritis Virus (EAV). All five remaining alpacas at the zoo tested positive for EAV antibodies. Five donkeys in the same zoo were tested for antibodies against EAV. Two of these donkeys were seropositive for EAV. There was no direct contact to equids, but visitors had the possibility to feed the alpacas and equids, and the same caretakers were responsible for the donkeys and the alpacas, so EAV could have been transmitted to the alpacas (Weber et al., 2006). The case report of Weber et al. is so far the only publication on EAV infection in SAC.

3.2.2. *Bacterial pathogens*

3.2.2.1. *Brucella abortus.* Spontaneous *Brucella abortus* infections have not been described in SAC, but were experimentally induced in a llama by inoculation into the conjunctival sac (Gidlewski et al., 2000). After 43 days, the dam aborted an eight-month-old fetus. The lesions caused by *Brucella abortus* in the llama dam were comparable to those seen in cattle, as *Brucella abortus* was isolated from the mammary gland, lymph nodes and placenta of the dam when the llama was necropsied after abortion. *Brucella abortus* was also identified in the fetal kidney and lung (Gidlewski et al., 2000).

3.2.2.2. Campylobacter fetus subspecies fetus. Late gestation abortions due to *C. fetus ssp. fetus* were reported in a herd of alpacas in England. The potential sources of infection in the study of Bidewell et al. were direct or indirect exposure to contaminated feces of carrier sheep, alpacas, wildlife or wild birds. The alpacas had direct and indirect contact with a flock of sheep living on the same farm with no history of fetal loss. There were four abortions and one birth of a premature, non-viable cria over a six-week period. The abortion rate in the described alpaca herd was 6.25 %. Abortions occurred two to four weeks before term. The pathogen was isolated from fetal stomach contents and the placenta. Nine out of 25 fecal samples from pregnant alpacas contained *C. fetus ssp. fetus*. Therefore, it was concluded that fecal shedding also occurs in SAC (Bidewell et al., 2010).

3.2.2.3. Coxiella burnetii. Recently, *Coxiella burnetii* was identified as an abortion pathogen in alpacas and llamas (Rüfli et al., 2021). Eight aborted or stillborn fetuses were necropsied and examined for infectious causes leading to abortion. In five out of eight fetuses *Coxiella burnetii* was isolated from fetal organs or the placenta. In three cases, corresponding placentitis was identified. As *Coxiella burnetii* has zoonotic potential and is highly infectious, precautions should be taken to protect owners and other susceptible animals (Rüfli et al., 2021).

3.2.2.4. Listeria monocytogenes. Only one case of late gestation abortion due to *Listeria monocytogenes* was reported in a llama dam (McLaughlin et al., 1993). The dam appeared slightly lethargic but was otherwise in good condition. The placenta showed scattered areas of congestion with edema and many necrotic neutrophils and mononuclear cells extending from the chorionic epithelium into the underlying connective tissue. No significant gross lesions were discovered in the aborted fetus. *Listeria monocytogenes* was isolated in pure culture from the liver and lungs of the fetus. The dam remained healthy (McLaughlin et al., 1993).

3.2.2.5. Streptococcus sanguinis type 1. An abortion was reported in one llama after an estimated 270 days pregnancy. A pure culture of *Streptococcus sanguinis* type-1 was isolated from samples of gastric fluid, liver, lung and spleen of the aborted fetus. The large number of *Streptococcus sanguinis* isolated support the etiologic role of septicemia and subsequent abortion (Semalulu and Chirino-Trejo, 1991).

3.2.2.6. Salmonella typhimurium and Salmonella dublin. A salmonella infection can lead to abortion in animals. The Animal and Plant Health Agency in England confirmed 23 cases of salmonella infections in SAC between 2000 and 2015, including two abortions. One was caused by *S. dublin* and one by *S. typhimurium* (Halsby et al., 2017).

3.2.2.7. Leptospira. Leptospira can infect many animal species, including livestock and domestic mammals, and can lead to asymptomatic or mild disease through to severe, fatal hepatorenal failure. In England, *Leptospira ssp.* have been detected in the kidneys of an aborted alpaca fetus (Halsby et al., 2017). *Leptospira ssp.* has also been described as possible cause of abortion in SAC in North and South America (Tibary et al., 2006; Vaughan and Tibary, 2006).

3.2.2.8. Opportunistic coinfections (Escherichia coli and Streptococcus pluranimalium). In the study by Rüfli et al. (2021), one aborted SAC fetus showed histological signs of severe bronchopneumonia. Severe growth of *Escherichia coli* (*E. coli*) was detected in bacterial cultures from the liver, lungs, C3 and placenta. *Coxiella burnetii* was also detected in the placenta. This suggests that *E. coli* was only involved as an opportunistic secondary pathogen (Rüfli et al., 2021). A co-infection of *Coxiella burnetii* and *Streptococcus pluranimalium* was found in one abortion in the same study. The affected dam had already suffered an abortion in a previous pregnancy (Rüfli et al., 2021).

3.2.2.9. Necrotizing placentitis / uterine infection with unknown pathogens. In a study done by Schaefer et al. (2012), 85 placentae were histologically examined to characterize the microanatomy and histopathology of placentae of aborted, stillborn and normally delivered SAC. Placentitis was diagnosed in 11.8 % of the aborted placentae of llamas and alpacas examined. In five out of ten cases, bacteria were identified as the sole infectious cause of the placentitis. In the other five cases, the etiology remained undetermined (Schaefer et al., 2012). The same finding was made in one case of necrotizing placentitis following an abortion, in which no pathogen could be identified either (Bjorklund et al., 2019).

3.2.2.10. Miscellaneous bacterial abortifacients. Abortions due to *Chlamydia ssp.* have been described in SAC (Tibary et al., 2006; Vaughan and Tibary, 2006). In a single known case in Sweden, one abortion was found to be due to abscesses of *Corynebacterium pseudotuberculosis* in the gravid uterine horn (Bjorklund et al., 2019). *Trueperella pyogenes* has been found in biopsies of the genital tract of llamas and has therefore been mentioned as potential abortifacient in SAC (Tibary et al., 2006). One abortion in SAC in the United Kingdom was caused by *Yersinia enterocolitica*. Infections in animals are usually asymptomatic, rarely leading to diarrhea and abortions (Halsby et al., 2017).

3.2.3. Parasitic pathogens

3.2.3.1. Toxoplasma gondii. Dubey et al. (2014) reported a spontaneous abortion associated with toxoplasmosis in an alpaca in the USA: an alpaca fetus was stillborn two days before the expected date of delivery. The fetus had a hydrocephalus and an enlarged liver. Protozoan cysts were discovered in the brain and kidney tissue and identified as *Toxoplasma gondii*. The dam's antibody titer against *Toxoplasma gondii* was increased (Dubey et al., 2014). In Switzerland, *Toxoplasma gondii* antibodies were detected in the body fluids of an aborted fetus and a stillborn cria. No *Toxoplasma gondii* cysts were detected, but the presence of antibodies in fetal material clearly suggested an infection with *Toxoplasma gondii* because maternal antibodies cannot cross the placental barrier in SAC. The dams had also developed antibodies against *Toxoplasma gondii* (Rüfli et al., 2021).

3.2.3.2. Neospora. *Neospora caninum* has been shown to be the cause in 14 out of 50 mid to late trimester abortions in SAC (Serrano-Martinez et al., 2007), and in three mid to late trimester of pregnancy abortions mentioned by Serrano-Martinez et al., (2004). Protozoal infection was found in 38 % of the fetuses examined. Characteristic histopathological lesions are non-suppurative multifocal encephalitis and meningoencephalitis. These typical lesions were present in only three of 13 (26 %) aborted fetuses that had protozoan-associated lesions in brain tissue (Serrano-Martinez et al., 2007). Other ways of detecting *Neospora ssp*. are immunohistochemical analysis or specific PCR, in which 28 % of the aborted fetuses showed signs of protozoal infection (Serrano-Martinez et al., 2007).

3.2.3.3. Sarcocystis. A severe disease caused by *Sarcocystis aucheniae* was described in an alpaca, which led to recumbency, abortion and ultimately death. At necropsy, numerous cysts and hemorrhagic lesions were found in skeletal muscles of the entire body of the dam. The alpaca dam showed signs of both acute and chronic disease, which is unusual. No cysts or hemorrhages were found in the aborted fetus and placenta (La Perle et al., 1999).

3.2.3.4. Enzephalitozoon cuniculi. Webster et al. (2008) reported a case of placentitis, premature birth and perinatal death of a 290-day pregnant alpaca cria in Purdue, USA, caused by *Encephalitozoon cuniculi.* The dam remained clinically normal. DNA of *Encephalitozoon cuniculi* was extracted from placental tissue. *Enzephalitozoon cuniculi* should be considered as a potential cause of sporadic abortions and perinatal deaths in SAC (Webster et al., 2008).

3.2.4. Fungal pathogens

3.2.4.1. Coccidoides posadasii and immitis. Diab et al. (2013) report an abortion caused by *Coccidoides posadasii* in the ninth month of pregnancy in California, USA. The serum of the dam was positive for coccidioidal IgG antibodies. The high titer (1:256), determined by quantitative immunodiffusion, was interpreted as an indicator of disseminated coccidiomycosis. The dam was subsequently euthanized and a necropsy was performed. Disseminated coccidiomycosis was found, severely affecting the lungs and serosal membranes of thoracic cavities. The placenta and the fetus showed multifocal pyogranulomatous nodules in many organs. This suggests that hematogenous spread or aspiration of contaminated amniotic fluid led to subsequent placental insufficiency and / or fetal disease resulting in abortion (Diab et al., 2013). Grayzel et al. documented four additional cases of miscarriage or neonatal mortality in alpacas due to coccidiomycosis and showed that SAC living in California are at higher risk for developing coccidiomycosis than SAC living in other states of the USA. Pregnant alpacas infected with *Coccidoides* ssp. appear to be predisposed to abortion, even in the absence of other clinical signs of disease (Grayzel et al., 2020).

3.3. Non-infectious agents

3.3.1. Iatrogenic causes

3.3.1.1. PGF2α. Prostaglandins have been shown to safely induce birth within 24 h in alpacas (Bravo et al., 1996; Vaughan and Tibary, 2006). In the study by Bravo et al. (1996), crias born after PGF2α (40µg fluprostenol IM) treatment took a longer time from birth to standing than crias after spontaneous delivery, but otherwise showed no differences in regard to mean time from birth to first suckling, body weight or mean IgG serum concentration 24 h postpartum and vital parameters (Bravo et al., 1996). In unwanted cases of pregnancies (e.g. in possibly related animals or animals accidentally bred too young), the prostaglandin analogue cloprostenol can be used to induce abortion through luteolysis (Memon and Stevens, 1997). In the study of Memon and Stevens (1997) an intramuscular dosage of 150µg cloprostenol was used, while Smith et al. (2000) used a higher dosage of intramuscular cloprostenol (250µg). The majority of abortions (82.9 %) happen within three or four days (Smith et al., 2000). In rare cases, a second injection of cloprostenol may be required (Smith et al., 2000). Induction of abortion with cloprostenol does not appear to have a negative effect on the future fertility of the dam (Memon and Stevens, 1997; Smith et al., 2000).

3.3.1.2. Dexamethasone. Dexamethasone administered in high doses (e.g. 0.5 mg) causes intrauterine death of alpaca fetuses. In an experimental study by Bravo et al. (2009), the fetuses were expelled six to nine days after administration of dexamethasone. Two dams in the same study developed dystocia and had to be assisted in labor. The stillborn crias and fetal membranes were in a necrotic state. This shows that dexamethasone cannot be used to safely induce parturition in alpacas. Administered at lower doses (0.0005 mg, 0.005 mg, 0.05 mg IV), dexamethasone had no adverse effects on the pregnancies (Bravo et al., 1996; Vaughan and Tibary, 2006).

3.3.2. Influence of dam, management and housing conditions

3.3.2.1. Age of dam. Body weight of crias at birth and placental efficiency (body weight of cria divided by placenta weight at birth) increase with dam's age. Dams older than six years give birth to heavier crias, reaching a peak of cria birth weight in nine-year-old dams. Stillborn crias and crias that died shortly after birth were significantly lighter than surviving crias. The inability to ingest sufficient colostrum due to weakness or lack of colostrum production can lead to death. In a study by Bravo et al., the weight of the crias was put in relation with the survival of the newborns. This study showed that 11.3 % of crias from dams at the age of two to three years died. In contrast, only 5.9 % of crias born to dams aged four to 12 years died. The increased quantity and quality of colostrum could have an influence, as could the more experienced mothering ability of multiparous females (Bravo et al., 2009).

3.3.2.2. Vitamin / mineral deficiencies. Deficiencies in trace minerals (copper, selenium, zinc) are likely to lead to reproductive losses, as these are important nutrients supporting the immune function of the dam and neonate. This hypothesis has not yet been confirmed in SAC, but seems likely as reproductive losses occur in cattle that are deficient in trace minerals (Hostetler et al., 2003; Van Saun, 2008). Fat soluble vitamins (Vitamin A and E) may also play a role in early embryonic death, but this has not yet been proven (Tibary et al., 2006; Van Saun, 2008). In a recent study, crias from dams receiving mineral supplements had higher birth weights, than those from dams that did not receive mineral supplements. But in regard of miscarriages, stillbirth or neonatal death, no difference was found (Kapustka and Budzyn´ska, 2022).

3.3.2.3. Pregnancy toxemia. Inappetence due to many diseases or stress factors can lead to increased mobilization of body fat and subsequently to liver lipidosis and ketonemia. This has been reported in two alpacas in late gestation. Pregnancy toxemia can lead to intrauterine death of the fetus or to prematurely born crias. In this study, one fetus of a dam suffering from pregnancy toxemia died intrauterinely and was later iatrogenically aborted with prostaglandins, after which the condition of the dam improved rapidly (Sylla and Crociati, 2020). Another prematurely born cria of a dam with pregnancy toxemia was euthanized after 36 h of life after its general condition declined due to failure of passive transfer and non-responsiveness to the applied therapy (Sylla and Crociati, 2020).

3.3.2.4. Dystocia. Anatomy and constitution of the dam can lead to dystocia, possibly leading to stillbirth of the cria. Incorrect positioning of cria or malformations can lead to dystocia, although malformations of the fetus rarely appear to be a problem (Ferrer et al., 2015; Wolfthaler et al., 2020). Most birth difficulties are due to an abnormal presentation or position of the fetus. Dystocia can also be due to genital abnormalities of the dam, infections, poor nutrition or obesity (Brown, 2000).

3.3.2.5. Nutritional status of the dam. Nutritional deficiencies, particularly in maiden females can lead to abortions (Brown, 2000; Vaughan and Tibary, 2006). A recent study showed a close correlation between scabies infestation in a herd and an increased rate of abortions and stillbirths of unknown etiology. Sarcoptes mites have no direct influence on the fetus, but infestation with this parasite leads to weight loss and impaired reproductive performance of the dam due to reduced general health condition (Kapustka and Budzyn´ska, 2022). Nowadays obesity poses more often a problem regarding birth, as fat deposits in the birth canal can lead to dystocia (Belknap et al., 2000). Obese animals are also more susceptible to hepatic lipidosis. Clinical observations suggest lower progesterone concentrations in obese animals and therefore a higher risk for early embryonic loss (Van Saun, 2008).

3.3.2.6. Plant poisoning. Nitrate-nitrite poisoning after consumption of oat hay *(Avena sativa)* resulted in the death of four alpacas and induced abortion of a full-term fetus, shortly before the dam died as well. The clinical signs in the adult alpacas were cyanosis, tachycardia, weakness and finally collapse. No lesions were noted at necropsy of the fetus. Necropsy of the adult animals revealed cyanosis of the carcass, edematous congested lungs and very dark blood suggestive of methemoglobinemia. The aqueous humor of the fetus contained 10 mg NO_3/L, whilst the aqueous humor of the adults contained 25 mg NO_3/L. In cattle, aqueous humor concentrations greater than 25 mg NO_3/L are regarded as diagnostic of intoxication (Osweiler et al., 1985). The abortion of the fetus is believed to be due to fetal hypoxia as a result of maternal methemoglobinemia (McKenzie et al., 2009).

3.3.3. Influence of fetus

3.3.3.1. Twins (Placental Insufficiency). Conception of twins is not uncommon in alpacas, but two viable twins are almost never born (Schaefer et al., 2012). An incidence of twin pregnancies below 1 % has been suggested (Vaughan and Tibary, 2006). A very high rate of spontaneous reductions of twin pregnancies occurs before Day 45 of pregnancy. A significant number of twin pregnancies may even result in the loss of both embryos. Unilaterally ovulating females carrying twins may be at higher risk of losing both embryos than bilaterally ovulating females (Campbell et al., 2015). In the study of Kapustka and Budzyn´ska (2022), 81 % of twin pregnancies ended in miscarriage. Placental insufficiency is believed to play a major role in this phenomenon. Areas of villous hypoplasia have been detected in placentae of alpaca abortions due to twinning. This leads to placental insufficiency, which can result in fetal distress syndrome due to hypoxia (Schaefer et al., 2012). Abortion of twins can furthermore lead to dystocia from incorrect positioning in the birth canal (Ferrer et al., 2015).

3.3.3.2. Fetal malformations. Fetal anomalies rarely appear to be a problem in SAC. Some cases of spina bifida (Davis et al., 1998), hydrocephalus (Dubey et al., 2014; Ferrer et al., 2015) and brachygnathia superior (Ferrer et al., 2015) have been reported. These malformations can lead to dystocia.

3.3.4. Miscellaneous non-infectious abortifacients

Placental insufficiency due to villous hypoplasia can result in a fetal distress syndrome due to hypoxia and therefore lead to abortion. If considered as possible cause of abortion, the percentage of idiopathic abortions in alpacas in the study of Schaefer et al. (2012) is reduced from 66.2 % to 47.9 % of the microscopically examined cases. In the same study one abortion was caused by an umbilical torsion. Inbreeding is a factor that is also associated with embryonic loss (Brown, 2000). Furthermore, maternal stress, e.g. due to transport, can lead to abortion (Vaughan and Tibary, 2006).

4. Discussion

Abortions in SAC significantly impact animal welfare and biosafety. Many infectious diseases have zoonotic potential or can be transmitted to other species. Furthermore, recurrent abortions can lead to substantial economic losses in SAC herds. Despite this, the field remains under-researched, with a few studies available, many of which are dated or rely on limited sources. Some studies are based on hypotheses or single case reports, while other potential causes for abortions have only been mentioned in personal communications from authors without further investigation. In most examined cases, the reason of the abortion remains unidentified, and no causative agent can be found. With the increasing accuracy of modern diagnostics and the availability of more diagnostic options, there is a pressing need for new studies to gain a better understanding of the possible causative diseases. Many infectious diseases that cause abortions in SAC are transmissible to humans or other species, often resulting in similar symptoms, including abortions. Hence, it is crucial to raise awareness about this potential risk and implement appropriate biosafety measures. These measures should include testing and isolation new animals before introducing them into a herd, isolation and providing veterinary care for sick animals, and ensuring that pregnant women do not come into contact with abortion material. Some infectious diseases, such as brucellosis, BVDV, chlamydiosis, salmonellosis, and EAV, are listed in the terrestrial animal health code of the World Organization for Animal Health (World organization for animal health, 2024). Consequently, special regulations regarding epizootics of individual countries must be considered when these diseases occur.

In addition to infectious causes, there are numerous non-infectious reasons for abortions in SAC, many of which are influenced by management and housing conditions. Proper nutrition is crucial, requiring high-quality basic feed and mineral supplements in appropriate quantities. Regular assessment of body condition scores is necessary to prevent malnourishment or obesity, keeping in mind that large amount of fibers can mask the actual body condition. Additionally, effective monitoring of births and close supervision of pregnant animals can help identify and correct potential dystocia due to incorrect positioning of the cria, thereby reducing perinatal mortality.

5. Conclusion

As the popularity of SAC continues to rise, conducting further research becomes increasingly crucial for enhancing our under- standing and mitigating the occurrence of abortions. We strongly advocate for SAC owners and attending veterinarians to thoroughly investigate any instances of abortion, as each case contributes valuable insights that can advance our collective knowledge in this field.

Funding

This review did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Hannah Eggimann: Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Isabelle Rediger:** Writing – original draft, Data curation. **Gaby Hirsbrunner:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Patrik Zanolari:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of Competing Interest

The authors declare no potential conflicts of interest.

References

Aller, J.F., Rebuffi, G.E., Cancino, A.K., Alberio, R.H., 2003. Fetal mortality diagnosis by ultrasound in the vicun˜a (Vicugna vicugna). Reprod. Fertil. Dev. 15, 125–128. https://doi.org/10.1071/rd02097.

Barnett, J., Twomey, D.F., Miller, M.F., Bell, S., Bradshaw, J., Higgins, R.J., Scholes, S.F.E., Errington, J., Bromage, C.G., Oxenham, G.J., 2008. BVDV in British alpacas. Vet. Rec. 162, 795. https://doi.org/10.1136/VR.162.24.795-A.

Bedenice, D., Dubovi, E., Kelling, C., Henningson, J., Topliff, C., Parry, N., 2011. Long-term clinicopathological characteristics of Alpacas naturally infected with bovine viral diarrhea virus type Ib. J. Vet. Intern. Med. 25, 605–612. https://doi.org/10.1111/j.1939-1676.2011.0719.x.

Belknap, E.B., Collins, J.K., Larsen, R.S., Conrad, K.P., 2000. Bovine viral diarrhea virus in New World camelids. J. Vet. Diagn. Invest. 12, 568–570. https://doi.org/10.1177/104063870001200614.

Bidewell, C.A., Woodger, N.G.A., Cook, A.J.C., Carson, T.V., Gale, S.L., Chanter, J.I., Williamson, S.M., 2010. Campylobacter fetus subspecies fetus abortion in alpacas (Vicugna pacos). Vet. Rec. 167, 457–458. https://doi.org/10.1136/VR.C4461.

Bjorklund, C., Bage, R., Morrell, J., de Verdier, K., Nisu Hartzell, L., Kjellinbro, N., Belak, K., Bernodt, K., Gavier-Widen, D., 2019. Diseases and causes of death among alpacas in Sweden: a retrospective study. Vet. Rec. Open 6. https://doi.org/10.1136/vetreco-2017-000239.

Bravo, P.W., Bazan, P.J., Troedsson, M.H.T., Villalta, P.R., Garnica, J.P., 1996. Induction of parturition in alpacas and subsequent survival of neonates. J. Am. Vet. Med. Assoc. 209, 1760–1762

Bravo, P.W., Garnica, J., Puma, G., 2009. Cria alpaca body weight and perinatal survival in relation to age of the dam. Anim. Reprod. Sci. 111, 214–219. https://doi.org/10.1016/j.anireprosci.2008.03.001.

Bravo, P.W., Diaz, D., Alarco´n, V., Ordon˜ez, C., 2010. Effect of the reproductive state of female alpacas on embryonic mortality rate. Am. J. Vet. Res. 71, 1096–1099. https://doi.org/10.2460/ajvr.71.9.1096.

Brown, B.W., 2000. A review on reproduction in South American camelids. Anim. Reprod. Sci. 58, 169–195. https://doi.org/10.1016/S0378-4320(99)00081-0.

Campbell, A.J., Pearson, L.K., Spencer, T.E., Tibary, A., 2015. Double ovulation and occurrence of twinning in alpacas (Vicugna pacos). Theriogenology 84, 421–424. https://doi.org/10.1016/j.theriogenology.2015.03.027.

Carman, S., Carr, N., DeLay, J., Baxi, M., Deregt, D., Hazlett, M., 2005. Bovine viral diarrhea virus in alpaca: abortion and persistent infection. J. Vet. Diagn. Invest. 17, 589–593.

Chavez-Velasquez, A., Alvarez-Garcia, G., Gomez-Bautista, M., Casas-Astos, E., Serrano-Martinez, E., Ortega-Mora, L.M., 2005. Toxoplasma gondii infection in adult llamas (Lama glama) and vicunas (Vicugna vicugna) in the Peruvian Andean region. Vet. Parasitol. 130, 93–97.

Clarke, L.L., Breuer, R.M., 2022. Postmortem diagnoses in South American camelids and factors influencing diagnostic rate in the Upper Midwest USA, 2009–2019. J. Vet. Diagn. Invest. 34, 727–732. https://doi.org/10.1177/10406387221091733.

Davis, R., Keeble, E., Wright, A., Morgan, K.L., 1998. South American camelids in the United Kingdom: Population statistics, mortality rates and causes of death. Vet. Rec. 142, 162–166. https://doi.org/10.1136/vr.142.7.162.

Diab, S., Johnson, S.M., Garcia, J., Carlson, E.L., Pappagianis, D., Smith, J., Uzal, F.A., 2013. Case report: Abortion and disseminated infection by Coccidioides posadasii in an alpaca (Vicugna pacos) fetus in Southern California. Med. Mycol. Case Rep. 2, 159–162. https://doi.org/10.1016/j.mmcr.2013.10.002.

Dubey, J.P., Johnson, J.E., Hanson, M.A., Pierce, V., 2014. Toxoplasmosis-associated abortion in an alpaca (Vicugna pacos) fetus. J. Zoo. Wildl. Med. 45, 461–464.

Evermann, J.F., 2006. Pestiviral infection of llamas and alpacas. Small Rumin. Res. 61, 201–206. https://doi.org/10.1016/j.smallrumres.2005.07.010.

Ferrer, M.S., Schulz, K.L., Anderson, D.E., 2015. Theriogenology question of the month. J. Am. Vet. Med. Assoc. 247, 889–891. https://doi.org/10.2460/javma.247.8.889.

Foster, A.P., Houlihan, M., Higgins, R.J., Errington, J., Ibata, G., Wakeley, P.R., 2005. BVD virus in a British alpaca. Vet. Rec. 156, 718–719.

Foster, A.P., Houlihan, M.G., Holmes, J.P., Watt, E.J., Higgins, R.J., Errington, J., Ibata, G., Wakeley, P.R., 2007. Bovine viral diarrhoea virus infection of alpacas (Vicugna pacos) in the UK. Vet. Rec. 161, 94–99. https://doi.org/10.1136/vr.161.3.94.

Gidlewski, T., Cheville, N.F., Rhyan, J.C., Miller, L.D., Gilsdorf, M.J., 2000. Experimental Brucella abortus induced abortion in a llama pathologic effects. Vet. Pathol. 37, 77–82. https://doi.org/10.1354/vp.37-1-77.

Goyal, S.M., Bouljihad, M., Haugerud, S., Ridpath, J.F., 2002. Isolation of bovine viral diarrhea virus from an Alpaca. J. Vet. Diagn. Invest. 14, 523–525. https://doi.org/10.1177/104063870201400616.

Grayzel, S.E., Thompson, G.R., Martinez-Lopez, B., Dechant, J.E., McHardy, I., Sykes, J.E., 2020. Coccidioidomycosis in llamas and alpacas diagnosed at the University of California, Davis (1990-2016). Med. Mycol. https://doi.org/10.1093/mmy/myaa082.

Halsby, K., Twomey, D.F., Featherstone, C., Foster, A., Walsh, A., Hewitt, K., Morgan, D., 2017. Zoonotic diseases in South American camelids in England and Wales. Epidemiol. Infect. 145, 1037–1043. https://doi.org/10.1017/S0950268816003101.

Hoops, M., Kauffold, J., 2013. Physiology and pathology of reproduction in domesticated New World camelids with special emphasis on ultrasonography. Tierarztl. Prax. Ausg. G 41, 166–175. https://doi.org/10.1055/s-0038-1623166.

Hostetler, C.E., Kincaid, R.L., Mirando, M.A., 2003. The role of essential trace elements in embryonic and fetal development in livestock. Vet. J. 166, 125–139. https://doi.org/10.1016/S1090-0233(02)00310-6.

Jarvinen, J.A., O'Connor, A.M., 2014. Seroprevalence of bovine viral diarrhea virus in alpacas in the United States and assessment of risk factors for exposure, 2006- 2007. J. Am. Vet. Med. Assoc. 245, 696–703. https://doi.org/10.2460/javma.245.6.696.

Kapustka, J., Budzyn´ska, M., 2022. Reproductive losses and their causes in Alpacas—a survey-based study. Animals 12. https://doi.org/10.3390/ani12213030.

La Perle, K.M.D., Silveria, F., Anderson, D.E., Blomme, E.A.G., 1999. Dalmeny disease in an alpaca (Lama pacos): Sarcocystosis, eosinophilic myositis and abortion. J. Comp. Pathol. 121, 287–293. https://doi.org/10.1053/jcpa.1999.0321.

Leon, A., Pillon, C., Tebourski, I., Bruyas, J.F., Lupo, C., 2023. Overview of the causes of abortion in horses, their follow-up and management. Reprod. Domest. Anim. 58 (Suppl 2), 93–101. https://doi.org/10.1111/rda.14406.

McKenzie, R., Gordon, A., Burren, B., Gibson, J., Gardner, M., 2009. Alpaca plant poisonings: nitrate-nitrite and possible cyanide. Aust. Vet. J. 87, 113–115. https://doi.org/10.1111/j.1751-0813.2009.00400.x.

McLaughlin, B.G., Greer, S.C., Singh, S., 1993. Listerial abortion in a llama. J. Vet. Diagn. Invest. 5, 105–106.

Mee, J.F., 2023. Invited review: Bovine abortion—Incidence, risk factors and causes. Reprod. Domest. Anim. 58, 23–33. https://doi.org/10.1111/rda.14366.

Memon, M.A., Stevens, D.K., 1997. Termination of unwanted pregnancy in a llama with cloprostenol and subsequent pregnancy: a case report. Theriogenology 47, 615–618.

Osweiler, G.D., Carson, T.L., Buck, W.B., Van, Gelder, G.A., 1985. Clinical and diagnostic veterinary toxicology, third ed. Kendall/Hunt Publishing Company, Dubuque, Iowa, pp. 460–467.

Ridland, M., Knight, T.W., Wyeth, T.K., Death, A.F., 1993. Brief Communication - Time and incidence of foetal mortality in alpacas. Proc. NZ Soc. Anim. Prod. 53, 437–438.

Rüfli, I., Gurtner, C., Basso, W.U., Vidondo, B., Hirsbrunner, G., Zanolari, P., 2021. Causes of abortions in South American Camelids in Switzerland-cases and questionnaire. Animals (Basel) 11. https://doi.org/10.3390/ani11071956.

Schaefer, D.L., Bildfell, R.J., Long, P., Lohr, C.V., 2012. Characterization of the microanatomy and histopathology of placentas from aborted, stillborn, and normally delivered alpacas (Vicugna pacos) and llamas (Lama glama). Vet. Pathol. 49, 313–321. https://doi.org/10.1177/0300985811406889.

Semalulu, S., Chirino-Trejo, M., 1991. Streptococcus sanguis Type-1 Associated with Abortion in a Llama (Lama glama). J. Zoo. Wildl. Med. 22.

Serrano-Martinez, E., Collantes-Fernandez, E., Rodriguez-Bertos, A., Casas-Astos, E., Alvarez-Garcia, G., Chavez-Velasquez, A., Ortega-Mora, L.M., 2004. Neospora species-associated abortion in alpacas (Vicugna pacos) and llamas (LLama glama). Vet. Rec. 155, 748–749.

Serrano-Martinez, E., Collantes-Fernandez, E., Chavez-Velasquez, A., Rodriguez-Bertos, A., Casas-Astos, E., Risco-Castillo, V., Rosadio-Alcantara, R., Ortega-Mora, L. M., 2007. Evaluation of Neospora caninum and Toxoplasma gondii infections in alpaca (Vicugna pacos) and llama (Lama glama) aborted foetuses from Peru. Vet. Parasitol. 150, 39–45.

Smith, B.B., Timm, K.I., Reed, P.J., Christensen, M., 2000. Use of cloprostenol as an abortifacient in the llama (Lama glama). Theriogenology 54, 497–505.

Sylla, L., Crociati, M., 2020. Pregnancy toxemia and lipid mobilization syndrome in two alpaca (Vicugna pacos) at 6 and 10 months of gestation. Large Anim. Rev. 26, 317–320.

Tibary, A., Fite, C., Anouassi, A., Sghiri, A., 2006. Infectious causes of reproductive loss in camelids. Theriogenology 66, 633–647. https://doi.org/10.1016/j.theriogenology.2006.04.008.

Topliff, C.L., Smith, D.R., Clowser, S.L., Steffen, D.J., Henningson, J.N., Brodersen, B.W., Bedenice, D., Callan, R.J., Reggiardo, C., Kurth, K.L., Kelling, C.L., 2009. Prevalence of bovine viral diarrhea virus infections in alpacas in the United States. J. Am. Vet. Med. Assoc. 234, 519–529. https://doi.org/10.2460/ javma.234.4.519.

Van Amstel, S., Kennedy, M., 2010. Bovine viral diarrhea infections in new world camelids-a review. Small Rumin. Res. 91, 121–126. https://doi.org/10.1016/j.smallrumres.2010.03.018.
Van Saun, R.J., 2008. Effect of nutrition on reproduction in llamas and alpacas. Theriogenology 70, 508–514. https://doi.org/10.1016/j.theriogenology.2008.04.025.
Vaughan, J.L., Tibary, A., 2006. Reproduction in female South American camelids: a review and clinical observations. Small Rum. Res. 61, 259–281. https://doi.org/10.1016/j.smallrumres.2005.07.015.
Weber, H., Beckmann, K., Haas, L., 2006. Case report: equine arteritis virus (EAV) as the cause of abortion in alpacas? Dtsch. Tierarztl. Wochenschr. 113, 162–163.
Webster, J.D., Miller, M.A., Vemulapalli, R., 2008. Encephalitozoon cuniculi-associated placentitis and perinatal death in an alpaca (Lama pacos). Vet. Pathol. 45, 255–258. https://doi.org/10.1354/vp.45-2-255
Wentz, P.A., Belknap, E.B., Brock, K.V., Collins, J.K., Pugh, D.G., 2003. Evaluation of bovine viral diarrhea virus in New World camelids. J. Am. Vet. Med. Assoc. 223, 223–228.
Wolfthaler, J., Franz, S., Dadak, A., Steiner, K., Drillich, M., 2020. A survey among breeders of South American camelids concerning breeding and reproduction management. Tierarztl. Prax. Ausg. G 48, 386–397. https://doi.org/10.1055/A-1287-3282.
World organization for animal health, 2024, Terrestrial Animal Health Code 〈https://www.woah.org/en/what-we-do/standards/codes-and-manuals/terrestrial-code-online-access/?id=169&L=1&htmfile=chapitre_oie_listed_disease.html〉 (accessed 20 February, 2024)

Danksagung

An dieser Stelle möchte ich mich herzlich bei Prof. Dr. med. vet. Gaby Hirsbrunner und Prof. Dr. med. vet. Patrik Zanolari für die professionelle Betreuung, hilfreichen Anregungen und stete Unterstützung bedanken.

Ein besonderer Dank gilt Dr. med. vet. Stefan Hutter, für die Möglichkeit, diese Dissertation parallel zu meiner Tätigkeit als praktizierende Tierärztin ausführen zu können.

Universität Bern | Universität Zürich
vetsuisse-fakultät

Eigenständigkeitserklärung

Ich, erkläre hiermit, dass ich die vorliegende Dissertation selbständig verfasst habe und keine anderen als die angegebenen Quellen benutzt habe. Alle Stellen, die wörtlich oder sinngemäss aus Quellen entnommen wurden, habe ich als solche gekennzeichnet.
Mir ist bekannt, dass andernfalls der Senat gemäss Artikel 36 Absatz 1 Buchstabe r des Gesetzes über die Universität vom 5. September 1996 und Artikel 69 des Universitätsstatuts vom 7. Juni 2011 zum Entzug des Doktortitels berechtigt ist. Für die Zwecke der Begutachtung und der Überprüfung der Einhaltung der Selbständigkeitserklärung bzw. der Reglemente betreffend Plagiate erteile ich der Universität Bern das Recht, die dazu erforderlichen Personendaten zu bearbeiten und Nutzungshandlungen vorzunehmen, insbesondere die Dissertation zu vervielfältigen und dauerhaft in einer Datenbank zu speichern sowie diese zur Überprüfung von Arbeiten Dritter zu verwenden oder hierzu zur Verfügung zu stellen.

Messen, 01.09.2024

Ort, Datum

Unterschrift Doktorandin

Universität Bern | Universität Zürich
vetsuisse-fakultät