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PREVALENCE AND CLINICAL IMPORTANCE OF *CRYPTOSPORIDIUM* AND *GIARDIA* IN HUMAN AND ANIMALS

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ABSTRACT

The protozoan parasites *Cryptosporidium* and *Giardia duodenalis* are worldwide considered as an important cause of gastrointestinal disease in human patients and in animals. The high number of (oo) cysts excreted shortly after infection, together with the low infectious dose, results in an easy spread of infection. The aim of this literature review is to introduce *Cryptosporidium* and *Giardia* by addressing their taxonomy, life cycle, prevalence and clinical importance for both human and animals.

Key words: Prevalence, *Cryptosporidium*, *Giardia*, Clinical importance

INTRODUCTION

Access to safe drinking water and basic sanitation is a fundamental human right, but currently more than one billion people worldwide do not have access to either safe drinking water or adequate sanitation. It is estimated that almost 60% of deaths following diarrhoeal diseases in developing countries are attributable to lack of access to safe drinking water and basic sanitation, children under 5 being at the highest risk. Important water-borne diarrhoeal diseases are cryptosporidiosis and giardiosis (Xiao and Fayer, 2008; Geurden *et al*., 2009). These diseases are caused by the protozoan parasites *Cryptosporidium* and *Giardia*, respectively, which are able to cause disease in humans and animals. Because of their impact on socio-economic development, especially in developing countries, both *Cryptosporidium* and *Giardia* are since 2004 included in the 'Neglected Disease Initiative' of the World Health Organization (WHO) (Savioli *et al.*, 2006).

However, *Cryptosporidium* and *Giardia* also pose an important risk on the safety of drinking water in developed countries. For example, in 1993 more than 400,000 people were affected by cryptosporidiosis in Milwaukee (Wisconsin, USA) due to an ineffective filtration process in the production of drinking water. Since this outbreak screening of tap water for the presence of *Cryptosporidium* has become compulsory in the UK, The Netherlands and the USA, but water-borne outbreaks are still reported on a regular basis.

The aim of this literature review is to introduce *Cryptosporidium* and *Giardia* by addressing their taxonomy, life cycle, prevalence and clinical importance for both human and animals.

Prevalence of *Cryptosporidium* in humans

In developed countries, the prevalence of *Cryptosporidium* generally is low in asymptomatic people (<1%) and in patients with diarrhoea (1-2%) (Current and Garcia, 1991; Guerrant, 1997; Geurden *et al.*, 2009). In developing countries, high rates of asymptomatic carriage (10-30%) are common in comparison to patients with gastroenteritis (3-20%) (Current and Garcia, 1991; Haque *et al.*, 2003). Among the common *Cryptosporidium* species in humans, *C. parvum* and *C. hominis* are responsible for >90% of human cases of cryptosporidiosis in developed nations (Xiao and Feng, 2008). The distribution of *C. parvum* and *C. hominis* in humans differs between geographic regions. In Europe, both *C. parvum* and *C. hominis* are common in humans (Leoni *et al.*, 2006; Chalmers *et al.*, 2009; Zintl *et al.*, 2009). In the Middle East, *C. parvum* is the dominant species in humans

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(Sulaiman *et al.*, 2005; Pirestani *et al.*, 2008). Geographic variations in the distribution of *C. parvum* and *C. hominis* can also occur within a country. For example, *C. parvum* is more common than *C. hominis* in rural areas in the United States and Ireland (Feltus *et al.*, 2006; Zintl *et al.*, 2009). In the rest of the world, especially developing countries, *C. hominis* is usually the predominant species in humans, responsible for 70-90% of the infections (Xiao and Feng, 2008). This suggests that zoonotic infection is much less common in developing countries than in developed countries.

Temporal and age-associated differences in the distribution of *C. parvum* and *C. hominis* infections have been reported. Peaks in *Cryptosporidium* infections have been observed in spring and late summer (Casemore, 1990). *C. parvum* was more prevalent in spring (in Ireland, the United Kingdom and New Zealand) and *C. hominis* was more prevalent in autumn (in the Netherlands, the United Kingdom and New Zealand) (McLauchlin *et al.*, 2000; Learmonth *et al.*, 2003, 2004; Hunter *et al.*, 2004; Wielinga *et al.*, 2008; Chalmers *et al*., 2009; Zintl *et al.*, 2009). In The Netherlands, *C. hominis* was more commonly found in children and *C. parvum* more in adults (Wielinga *et al.*, 2008). In the UK, *C. hominis* was more prevalent in infants less than one year, females aged 15-44 years and international travelers (Chalmers *et al.*, 2008, 2009). *C. viatorum* was identified among travellers with gastro-intestinal symptoms returning to Great Britain from the Indian subcontinent (Elwin *et al*., 2012). In South American countries, a relatively high proportion of *C. meleagridis* infections has been identified in children and in immunocompromised patients (Cama *et al*., 2007, 2008; Meireles, 2010).

Clinical importance

Cryptosporidium is reported to infect people in at least 106 countries (Fayer, 2008). The most common clinical feature of cryptosporidiosis is diarrhoea. Characteristically, the diarrhoea is profuse and watery; it may contain mucus but rarely blood and leucocytes and it is often associated with weight loss. Other less common clinical features include abdominal pain, nausea, vomiting and low-grade fever. Occasionally, nonspecific symptoms such as myalgia, weakness, malaise, headache and anorexia occur (Current and Garcia, 1991).

The severity of a *Cryptosporidium* infection can vary from an asymptomatic shedding of oocysts to a severe and life-threatening disease. The duration and the severity of the symptoms and the outcome may vary with host factors such as the immune status of the person. Most immunocompetent persons experience a short-term illness with complete and spontaneous recovery (Current and Garcia, 1991). However, for immunocompromised patients, cryptosporidiosis can be a critical illness with persistent symptoms leading to dehydration and wasting (O'Donoghue, 1995; Chen *et al*., 2002; Blackburn *et al*., 2004), and eventually leading to death (Juranek, 1995; Manabe *et al*., 1998). In addition, *Cryptosporidium* infections can cause atypical manifestations in immunocompromised patients, such as biliary tract disease, respiratory tract disease and pancreatitis (Hunter and Nichols, 2002).

The severity of the infection is also related to the age of the patient. Diarrhoea is a leading cause of illness and death among children aged <5 years in developing countries and *Cryptosporidium* is one of the most important diarrhoeal pathogens (Shirley *et al*., 2012). Children are more likely to be infected with *Cryptosporidium,* which can be explained by a lack of an effective immunity at this age. In a study of 191 children with *C. parvum* in Uganda, 13% died, compared with 6% for children without *C. parvum* (Tumwine *et al.*, 2003). Wielinga *et al.* (2008) found that the majority (80%) of the human cases were children aged between 0 and 9 years and >70% of these were caused by *C. hominis*. *C. hominis* is more common than *C. parvum* in children and is associated with heavier infections and greater growth shortfalls, even in the absence of symptoms (Bushen *et al.*, 2007). Patients >25 years of age were infected mainly with *C. parvum.*

The clinical symptoms may also depend on the parasite species involved. Infections with *C. hominis* are associated with diarrhoea, nausea, vomiting, malaise and non-intestinal sequelae such as joint pain, eye pain, recurrent headache and fatigue, whereas infections with *C. parvum*, *C. meleagridis*, *C. canis* and *C. felis* cause only diarrhoea (Bouzid *et al*., 2013).

Prevalence of *Cryptosporidium* in animals

Cattle are commonly infected with *C. parvum*, *C. andersoni, C. bovis* and *C. ryanae* (Xiao, 2010). In dairy cattle, *C. parvum* is mostly found in pre-weaned calves, *C. bovis* and *C. ryanae* in weaned calves and *C. andersoni* in yearlings and adult cattle (Fayer *et al.*, 2006b, 2007; Santín *et al.*, 2008). Parasite prevalence varies from 1% (Kváč *et al.*, 2006) to 59% (Olson *et al.*, 1997) in individual calves and up to 100% on farm level

(Santín *et al.*, 2004). The highest prevalence is observed in calves under the age of 5 weeks (Quílez *et al.*, 1996). The prevalence of *Cryptosporidium* in flocks of small ruminants varies considerably, ranging from 5% to 70% for sheep and from 5% to 35% for goats. This difference in prevalence results can be explained by differences in age of the animals, management, and diagnostic methods applied (Robertson, 2009). *C. xiaoi*,*C. ubiquitum* and *C. parvum*are the predominant species in small ruminants (Ryan *et al.*, 2005; Goma *et al.*, 2007; Santín *et al.*, 2007; Geurden *et al*., 2008a; Mueller-Doblies *et al.*, 2008; Pritchard *et al.*, 2007, 2008; Quílez *et al.*, 2008; Yang *et al.*, 2009; Díaz *et al.*, 2010;Wang *et al*., 2010; Tzanidakis *et al*., 2014).

In pigs, herd prevalences range from 8% to 100% with individual animal infection rates of between 1% and 34%. *C. suis* (36-83%) and *C. scrofarum (*formerly *Cryptosporidium* pig genotype II) (9-61%) are the major *Cryptosporidium* spp. (Kváč *et al.*, 2009; Chen *et al.*, 2011; Budu-Amoako *et al.*, 2012). *C.suis* preferentially infects suckling piglets, whereas *C. scrofarum* is more frequently found in weaners (Langkjaer *et al.*, 2007; Johnson *et al.*, 2008; Kváč *et al.*, 2009; Yin *et al*., 2013; Zhang *et al*., 2013). Occasionally, *C. muris* (Kváč *et al*., 2009; Budu-Amoako *et al.*, 2012; Němejc *et al*., 2013) or *C. tyzzeri* (Kváč *et al.*, 2012) are found in pigs. With the exception of one study where *C. parvum* was the predominant species (Farzan *et al*., 2011), this speciesis less frequently found in pigs, suggesting that pigs are not an important source of zoonotic transmission (Chen and Huang, 2007; Zintl *et al.*, 2009; Budu-Amoako *et al.*, 2012; de la Fé Rodríguez *et al*., 2013; Němejc *et al*., 2013).

Low prevalences of *Cryptosporidium* have been reported in horses in the USA (7%) and Italy (8%) (Burton *et al.*, 2010; Veronesi *et al.*, 2010). Both *C. parvum* and *Cryptosporidium* horse genotype were found in horses (Ryan *et al.*, 2003; Chalmers *et al.*, 2005; Grinberg *et al.*, 2008; Veronesi *et al.*, 2010) and rarely the hedgehog genotype (Laatamna *et al*., 2013). These findings support a potential role of infected horses in zoonotic transmission.

A *Cryptosporidium* prevalence ranging from 0% to 13% has been reported in privately owned and stray dogs (Chermette and Blondel, 1989; Grimason *et al.*, 1993; Diaz *et al.*, 1996; Giangaspero *et al.*, 2006; Claerebout *et al*., 2009; Yoshiuchi *et al.*, 2010; Bajer *et al.*, 2011). Most infections in dogs are caused by the host-specific *C. canis*. In addition to *C. canis*, other *Cryptosporidium* spp. were detected occasionally in dogs such as *C. Muris* (Lupo *et al*., 2008; Ellis *et al*., 2010), *C. Parvum* (Hajdušek *et al*., 2004; Giangaspero *et al*., 2006; Sotiriadou *et al*., 2013) and *C. Meleagridis* (Hajdušek*et al*., 2004). Thus the risk of zoonotic transmission from *Cryptosporidium*-infected dogs is low (Lucio-Foster *et al.*, 2010; Uehlinger *et al*., 2013).

Cryptosporidium has been detected in cats with a range of 2% to 25% (Rambozzi, *et al*., 2007; Hoopes *et al*., 2013). In addition to the cat specific species, *C. felis, C. parvum* and *C. muris* were also identified (Palmer *et al*., 2008; Yoshiuchi *et al*., 2010; FitzGerald *et al*., 2011; Scorza *et al*., 2011; Sotiriadou et *al*., 2013).

Veterinary importance

C. parvum is a well-known cause of diarrhoea in neonatal ruminants. Clinical symptoms are most frequently observed in calves between the age of 5 days and 1 month and include profuse watery diarrhoea with acute onset, lethargy, anorexia and dehydration, which is usually self-limiting within 2 weeks (O'Handley *et al.*, 1999, Schnyder *et al*., 2009). Mortality is variable and is most often observed in calves with multiple infections and in certain beef breeds, such as the Belgian Blue and White (de Graaf *et al.*, 1999) and it can be as high as 30% (Olson *et al.*, 2004). However, morbidity in endemic herds can be as high as 100% (Santín *et al*., 2008). Abomasal cryptosporidiosis, caused by *C. andersoni*, does not result in any visible clinical signs (Kváč *et al*., 2008). Infections with *C. andersoni* do not cause diarrhoea and follow a more chronic course than infections with *C. parvum* (Kváč and Vitovec, 2003). *C. andersoni* infections may result in a decrease in daily weight gain, decreased feed efficiency and less milk production (Anderson, 1987; Esteban and Anderson, 1995; Ralston *et al.*, 2003).

Cryptosporidium is a major cause of neonatal diarrhoea in lambs, usually within the first 2 weeks of life and diarrhoea can be mild to severe. Cryptosporidiosis outbreaks in lambs are most common in crowded flocks and are associated with a decrease in liveweight, dressing percentage, growth rate and carcass productivity (Angus *et al*., 1982; Alonso-Fresán *et al*., 2005; Sweeny *et al*., 2011; de Graaf *et al*., 1999; Sari *et al*., 2009). Caprine cryptosporidiosis is characterised by diarrhoea and mortality in kids. Morbidity can reach 100% and mortality 50% in some herds (Vieira *et al*., 1997; Johnson *et al*., 1999; Sevinc¸ *et al*., 2005; Paraud *et al*., 2010; Santín, 2013).

Diarrhoea is the major clinical sign in foals affected by cryptosporidiosis. Foals are more susceptible to the infection than older animals (Grinberg *et al*., 2003; 2009; Veronesi *et al*., 2010) and most *Cryptosporidium* infections in adult horses are asymptomatic (Majewska *et al*., 2004; Sturdee *et al*., 2003).
Inappetance, depression, vomiting and/or diarrhoea developed in piglets experimentally infected with *C. parvum,* whereas mild or no clinical signs developed with *C. suis* (Enemark *et al*., 2003). However, an association between diarrhoea and infections with *C. suis*and *C. scrofarum* in nursing piglets has been described (Hamnes *et al*., 2007). In contrast, other studies did not find any significant association between diarrhoea and cryptosporidial infections (Quilez *et al*., 1996; Maddox-Hyttel *et al*., 2006, Vitovec *et al*., 2006).

Cryptosporidiosis in dogs has been reported in both asymptomatic and diarrhoeic dogs (Santín and Trout, 2008). Infections with *C. canis* are usually asymptomatic but severe diarrhoea, malabsorption, weakness and weight loss have been reported (Irwin, 2002; Miller *et al*., 2003). Dogs infected with *C. muris* showed chronic vomiting and profuse diarrhoea in one study (Ellis *et al*., 2010) but in another study no gastrointestinal signs were observed (Lupo *et al*., 2008).

Cryptosporidium oocysts were detected more frequently in cats without diarrhoea than in cats with diarrhoea (Sabshin *et al*., 2012) and shedding of *Cryptosporidium* oocysts without the presence of clinical signs was reported in experimentally and naturally infected cats (Mtambo *et al*., 1991; Nash *et al*., 1993; Fayer *et al*., 2006c). However, oocysts were also detected in the faeces of cats with persistent diarrhoea (Goodwin and Barsanti, 1990; Lent *et al*., 1993; Morgan *et al*., 1998).

Prevalence of *Giardia* in humans

In developed countries *Giardia* is detected in up to 14% of symptomatic patients and 2% in asymptomatic humans (Geurden *et al.*, 2009; Homan and Mank, 2001). In developing countries, the prevalence of giardiosis in patients with diarrhoea is around 20%, ranging from 5-43% (Islam, 1990; Haque *et al.*, 2005). *Giardia* infections are very common in children in developing countries (Farthing, 1994; Rabbani and Islam, 1994). *Giardia* assemblages A and B are considered more infectious for humans, with the latter being more prevalent. Sub-assemblage AII is more prevalent in humans than AI and is distributed globally, except in Asia and Australia. Assemblage AIII has not yet been detected in humans (Sprong *et al.*, 2009). The geographic distribution of sub-assemblages BIII and BIV in human shows marked difference between continents. In Africa, infection with BIII is more prevalent (81%) than with BIV, whereas the opposite is found in North America where 86% of infections are associated with BIV and 14% with BIII. A more balanced distribution was found in Australia and Europe (Sprong *et al.*, 2009). To a much lesser extent, assemblage C, D, E and F were identified in human samples (Gelanew *et al.*, 2007; Foronda *et al.*, 2008). However, it remains unclear whether the presence of these assemblages in human stool is due to patent infections or merely represents passage through the intestinal tract.

Clinical importance

Approximately 200 million people in Asia, Africa and Latin America have symptomatic infections with about 50,000 cases reported each year (Xiao and Fayer, 2008). In symptomatic patients, mostly children, the severity of symptoms and the duration of *Giardia* infection are highly variable. In some patients, symptoms last for only 3 or 4 days, while in others the symptoms last for months. Higher prevalence of chronic *Giardia* infection in patients with immunodeficiency supports that the failure to develop an effective immune response against *Giardia* may account for the chronicity of the infections (O'Handley *et al*., 2003). In developed countries, the incidence rate peaks at the age of 1-4 years (Flannagan, 1992); a second peak is observed at the 20-40 age groups, partly due to the care for the young children and partly due to travelling (Medema, 1999). The main symptoms include diarrhoea, abdominal pain, nausea, vomiting, flatulence, anorexia and fever (Nash *et al*., 1987; Farthing, 1996; Katz *et al*., 2006). In most instances the diarrhoeal illness is short-lived and self-limited. However, a proportion of individuals develop persistent diarrhoea (Farthing, 1996; Katz *et al*., 2006), sometimes accompanied by malabsorption of sugars and fat and by weight loss. There is evidence that infection with *Giardia* results in 'failure to thrive' in children, by impairment of the uptake of nutrients (Farthing, 1994; Hall, 1994). A high prevalence of chronice fatigue syndrome has been reported as a post-infection sequel in patients (Naess *et al*., 2012; Wensaas *et al*., 2012; Mørch *et al*., 2013).

The relation between clinical symptomatology and the *Giardia* genotype is controversial. In a study in The Netherlands, assemblage A isolates were solely detected in patients with intermittent diarrhoeal complaints, while assemblage B isolates were present in patients with persistent diarrhoeal complaints (Homan and Mank, 2001). A strong correlation between infection with assemblage B and diarrhoea was observed in Saudi children (Al-Mohammed, 2011). An association between assemblage B and flatulence in children was reported by Lebbad *et al*. (2011). In contrast, Read *et al.* (2002) found that assemblage B genotypes were more prevalent in asymptomatic children than those of assemblage A and according to Haque *et al*. (2005, 2009) only assemblage A was an important cause of diarrhoea in children in Bangladesh. A systematic review and meta-analysis confirmed that *Giardia* infections of both assemblages A and B can cause acute or persistent diarrhoea (Muhsen and Levine, 2012).

However, *Giardia* infections are often asymptomatic. In some studies no significant association between *Giardia* and diarrhoea was found (Guerrant *et al*., 1983; Schorling *et al*., 1990; Hollm-Delgado *et al*., 2008; Boeke *et al*., 2010). In both volunteers and outbreak situations, a sizable proportion of the infected subjects are asymptomatic, often exceeding the proportion with manifest clinical illness (Muhsen and Levine, 2012). It has been estimated that between 50% and 75% of *Giardia*-infected persons may be asymptomatic (USEPA, 1998a). Children with asymptomatic *Giardia* infection serve as unidentified carriers and may be responsible for transmission of the infection. Secondary transmission among family members may occur. Asymptomatic infections may last for months or years (ICAIR, 1984).

Prevalence of *Giardia* in animals

In calves younger than six months, the prevalence varies between 17% (Muhid *et al*., 2012) and 73% (Olson *et al.*, 1997) and on farm level it can be as high as 100% (Olson *et al.*, 1997; Hunt *et al.*, 2000; Geurden *et al.*, 2010, 2012). In cattle the livestock specific assemblage E is most prevalent, although up to 59% zoonotic assemblage A isolates and mixed infection with both A and E have been reported (Geurden *et al.*, 2008b; Sprong *et al.*, 2009). This suggests that calves should be considered as a potential reservoir for human infections. However, within assemblage A, sub-assemblage AI is predominantly found in livestock and companion animals, while assemblage AII is more prevalent in humans (Sprong *et al.*, 2009). The prevalence of *Giardia* in sheep and goats is reported to range from 10% to 40% with assemblage E detected in 75%, assemblage A in 27% and assemblage B in 2% of cases (Robertson, 2009).

The prevalence of *Giardia* in pigs ranges from 1% to 51% (Armson *et al*., 2009; Farzan *et al*., 2011; Budu-Amoako *et al*., 2012). The herd prevalence was 18%, 22% and 84% for sows, piglets and weaners in Denmark (Maddox-Hyttel *et al*., 2006) and 12% in Zambia (Siwila and Mwape *et al*., 2012). DNA sequencing demonstrated that assemblage E was the most common genotype in Australia and the UK (Armson *et al*., 2009; Minetti *et al*., 2013), while in Canada assemblage B was predominant (Farzan *et al*., 2011). Assemblage A was found in both weaners and piglets in Denmark (Langkjaer *et al*., 2007) and in pigs in Australia (Armson *et al*., 2009). Unexpectedly, the canine-specific assemblages C and D and the feline-specific assemblage F were also found occasionally in pigs in different countries (Langkjaer *et al*., 2007; Armson *et al*., 2009; Minetti *et al*., 2013). As for humans, it remains unclear whether the presence of these assemblages represents a patent infection or merely indicates carriage.

The prevalence of *Giardia* in horses was 1% in Brazil (De Souza *et al*., 2009), 9%-23% in Italy (Veronesi *et al*., 2010; Traversa *et al*., 2012) and 17% in Colombia (Santín *et al*., 2013). *G. duodenalis* isolates from horses belonged predominantly to the zoonotic assemblages A and B (Traub *et al*., 2005; Traversa *et al*., 2012; Santín *et al*., 2013) and to a lesser extent to assemblage E (Veronesi *et al*., 2010; Traversa *et al*., 2012).

In dogs, the prevalence of *Giardia* infections varies from 1% to 55% (Itoh *et al*., 2005; Jafari Shoorijeh *et al*., 2008). The most prevalent assemblages in dogs are the dog-specific assemblages C and D (Beck *et al*., 2012) but other sub-assemblages such as AI, AII, BIII and BIV are also detected in dogs worldwide (Souza *et al.*, 2007; Palmer *et al*., 2008; Claerebout *et al*., 2009; Sprong *et al.*, 2009), sometimes in higher frequencies than the dog-specific assemblages (*e.g.* Leonhard *et al*., 2007; Claerebout *et al*., 2009; Covacin *et al*., 2011).

Worldwide the prevalence of *Giardia* in cats ranges from 1%-40% (De Santis-Kerr *et al*., 2006; Itoh *et al*., 2006; Gow *et al*., 2009; Mohsen and Hossein, 2009; Mircean *et al*., 2011; Sabshin *et al*., 2012). Assemblage F and sub-assemblage AI are predominant but assemblage D and sub-assemblages AII, AIII were also detected in cats (Papini *et al.*, 2007; Souza *et al.*, 2007; Palmer *et al*., 2008; Sprong *et al.*, 2009).

Veterinary importance

Although *G. duodenalis* is recognised worldwide as the most common parasitic cause of gastrointestinal disorder in human patients, the relevance of infection in production animals is open to debate (Geurden *et al.*, 2010). The clinical signs may vary considerably between animals and animal species due to the involvement in the pathogenesis of giardiosis of both parasite and host factors. This lack of consistency in clinical outcome resulted in the perception that *Giardia* is not a major cause of clinical disease in ruminants. However, several studies reported clinical signs caused by *Giardia* both in natural infections (St. Jean, 1987; O'Handley *et al.*, 1999; Aloisio *et al.*, 2006; Geurden *et al.*, 2006b) and in experimental infections (Olson *et al.*, 1995; Geurden *et al.*, 2006a). Infection can result in diarrhoea that does not respond to antibiotic or coccidiostatic treatment. The excretion of pasty to fluid faeces with a mucoid appearance may be indicative for giardiosis, especially when the diarrhoea occurs in young animals.

A study in dairy calves showed that calves did not begin to excrete *Giardia* cysts until approximately 1 month of age. Passive immunity through colostrum may have the potential to provide initial protection against *Giardia* infections as colostrum contains a high level of anti-*Giardia* antibodies. Failure to develop a humoral immune response from natural infections by these calves could account for the high prevalence and chronic duration of the infections (O'Handley *et al*., 2003).

In pigs, a significant association was found between the presence of assemblage E and soft to diarrhoeic stool, whereas assemblage A was not correlated with diarrhoea (Armson *et al*., 2009). This is in contrast to previous studies that have reported no association between *Giardia* infections in pigs and diarrhoea (Maddox-Hyttel *et al*., 2006, Hamnes *et al*., 2007; Langkjaer *et al*., 2007).Next to diarrhoea, there is an economic impact of giardiosis for farmers. In goat kids and lambs an experimental infection resulted in a decreased feed efficiency and subsequently a decreased weight gain (Olson *et al.*, 1995; Sweeney *et al*., 2011, 2012). Infections with *Giardia* in dogs and cats are common. Clinical signs vary from asymptomatic to small bowel diarrhoea and associated discomfort (Fiechter *et al.*, 2012).

REFERENCES

1. Aloisio F, Filippini G, Antenucci P, Lepri E, Pezzotti G, Cacciò SM and Pozio E (2006). Severe weight loss in lambs infected with *Giardia duodenalis* assemblage B. *Veterinary Parasitology* 142: 154-158.
2. Al-Mohammed HI (2011). Genotypes of *Giardia intestinalis* clinical isolates of gastrointestinal symptomatic and asymptomatic Saudi children. *Parasitology Research* 108: 1375-1381.
3. Alonso-Fresán MU, García-Alvarez A, Salazar-García F, Vázquez-Chagoyán JC, Pescador-Salas N and Saltijeral-Oaxaca J (2005). Prevalence of *Cryptosporidium* spp. in asymptomatic sheep in family flocks from Mexico State. *Journal of Veterinary Medicine. B, Inectious Diseases and Veterinary Public Health* 52: 482-483.
4. Anderson BC (1987). Abomasal cryptosporidiosis in cattle. *Veterinary Pathology* 24: 235-238.
5. Angus KW, Tzipori S, Gray EW (1982). Intestinal lesions in specific-pathogen-free lambs associated with a *Cryptosporidium* from calves with diarrhoea. *Veterinary Pathology* 19: 67-78.
6. Armson A, Yang R, Thompson J, Johnson J, Reid S and Ryan UM (2009). *Giardia* genotypes in pigs in Western Australia: prevalence and association with diarrhoea. *Experimental Parasitology* 121: 381-3.
7. Bajer A, Bednarska M and Rodo A (2011). Risk factors and control of intestinal parasites infections in sled dogs in Poland. *Veterinary Parasitology* 175: 343-50.
8. Blackburn BG, Craun GF, Yoder JS, Hill V, Calderon RL, Chen N, Lee SH, Levy DA and Beach MJ (2004). Surveillance for waterborne-disease outbreaks associated with drinking water-United States, 2001-2002.*MMWR Surveillance Summaries* 53: 23-45.
9. Boeke CE, Mora-Plazas M, Forero Y and Villamor E (2010). Intestinal protozoan infections in relation to nutritional status and gastrointestinal morbidity in Colombian school children. *Journal of Tropical Paediatrics* 56: 299-306.
10. Bouzid M, Hunter PR, Chalmers RM and Tyler KM (2013). *Cryptosporidium* pathogenicity and virulence. *Clinical Microbiology Reviews* 26: 115-134.
11. Budu-Amoako E, Greenwood SJ, Dixon BR, Barkema HW, Hurnik D, Estey C and McClure JT (2012). Occurrence of *Giardia* and *Cryptosporidium* in pigs on Prince Edward Island, Canada. *Veterinary Parasitology* 184: 18-24.
12. Burton AJ, Nydam DV, Dearen TK, Mitchell K, Bowman DD and Xiao L (2010). The prevalence of *Cryptosporidium*, and identification of the *Cryptosporidium* horse genotype in foals in New York State. *Veterinary Parasitology* 174: 139-144.

13. Bushen OY, Kohli A, Pinkerton RC, Dupnik K, Newman RD, Sears CL, Fayer R, Lima AA and Guerrant RL (2007)**.** Heavy cryptosporidial infections in children in northeast Brazil: comparison of *Cryptosporidium hominis* and *Cryptosporidium parvum*. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 1001: 378-384.
14. Cama VA, Ross JM, Crawford S, Kawai V, Chavez-Valdez R, Vargas D, Vivar A, Ticona E, Navincopa M, Williamson J, Ortega Y, Gilman RH, Bern C and Xiao L (2007). Differences in clinical manifestations among *Cryptosporidium* species and subtypes in HIV-infected persons. *Journal of Infectious Diseases* 196: 684-691.
15. Cama VA, Bern C, Roberts J, Cabrera L, Sterling CR, Ortega Y, Gilman RH and Xiao L (2008). *Cryptosporidium* species and subtypes and clinical manifestations in children, Peru. *Emerging Infectious Diseases* 14: 1567-1574.
16. Casemore DP (1990). Epidemiological aspects of human cryptosporidiosis. *Epidemiology and Infection* 104:1-28.
17. Chalmers RM, Sturdee AP, Bull SA, Miller A and Wright SE (1997). The prevalence of *Cryptosporidium parvum* and *C. Muris* in Mus domesticus, Apodemus sylvaticus and Clethrionomys glareolus in an agricultural system. *Parasitology Research* 83: 478-482.
18. Chalmers RM, Thomas AL, Butler BA and Morel MC (2005). Identification of *Cryptosporidium parvum* genotype 2 in domestic horses. *Veterinary Record* 156: 49-50.
19. Chalmers RM, Hadfield SJ, Jackson CJ, Elwin K, Xiao L and Hunter P (2008). Geographic linkage and variation in *Cryptosporidium hominis*. *Emerging Infectious Diseases* 14: 496-498.
20. Chalmers RM, Elwin K, Thomas AL, Guy EC and Mason B (2009). Long-term *Cryptosporidium* typing reveals the aetiology and species-specific epidemiology of human cryptosporidiosis in England and Wales, 2000 to 2003. *EuroSurveillance* 4: pii: 19086.
21. Chen F and Huang K (2007). Prevalence and phylogenetic analysis of *Cryptosporidium* in pigs in eastern China. *Zoonoses and Public Health* 54: 393-400.
22. Chen X, Keithly JS, Paya CV and LaRusso NF (2002). Cryptosporidiosis. *The New England Journal of Medicine* 346:1723-1731.
23. Chen Z, MI R, Yu H, Shi Y, Huang Y, Chen Y, Zhou P, Cai Y and Lin J (2011). Prevalence of *Cryptosporidium* spp. in pigs in Shanghai, China. *Veterinary Parasitology* 181: 113-9.
24. Chermette R and Blondel S (1989). Cryptosporidiose des Carnivores domestiques, resultats preliminairesen France. *Bulletin de la Société française de parasitologie* 7: 31-36.
25. Claerebout E, Casaert S, Dalemans AC, De Wilde N, Levecke B, Vercruysse J and Geurden T (2009). *Giardia* and other intestinal parasites in different dog populations in Northern Belgium. *Veterinary Parasitology* 161: 41-6.
26. Current WL and Garcia LS (1991). Cryptosporidiosis. *Clinical Microbiology Reviews* 4: 325-258.
27. de Graaf DC, Vanopdenbosch E, Ortega-Mora LM, Abbassi H and Peeters JE (1999). A review of the importance of cryptosporidiosis in farm animals. *International Journal of Parasitology* 29: 1269-1287.
28. de la Fé Rodríguez PY, Martin LO, Muñoz EC, Imberechts H, Butaye P, Goddeeris BM and Cox E (2013). Several enteropathogens are circulating in suckling and newly weaned piglets suffering from diarrhoea in the province of Villa Clara, Cuba. *Tropical Animal Health and Production* 45: 435-440.
29. De Santis-Kerr AC, Raghavan M, Glickman NW, Caldanaro RJ, Moore GE, Lewis HB, Schantz PM and Glickman LT (2006). Prevalence and risk factors for *Giardia* and coccidia species of pet cats in 2003-2004. *Journal Feline Medicine and Surgery* 8: 292-301.
30. De Souza PN, Bomfim TC, Huber F, Abboud LC and Gomes RS (2009). Natural infection by *Cryptosporidium* sp.; *Giardia* sp. and *Eimeria leuckarti* in three groups of equines with different handlings in Rio de Janeiro, Brazil. *Veterinary Parasitology* 160: 327-333.
31. Díaz P, Quílez J, Robinson G, Chalmers RM, Díez-Baños P and Morrondo P (2010). Identification of *Cryptosporidium xiaoi* in diarrhoeic goat kids (*Capra hircus*) in Spain. *Veterinary Parasitology* 172: 132-134.
32. Diaz V, Campos M, Lozano J, Manas I and Gonzalez J (1996). Aspects of animal giardiasis in Granada province (southern Spain). *Veterinary Parasitology* 64: 171-176.
33. Dieter RA, Jr. Dieter RS, Dieter RA and 3rd. Gulliver G (2001). Zoonotic diseases: health aspects of Canadian geese. *International Journal of Circumpolar Health* 60: 676-684.
34. Enemark HL, Ahrens P, Bille-Hansen V, Heegaard PM, Vigre H, Thamsborg SM and Lind P (2003). *Cryptosporidium parvum*: infectivity and pathogenicity of the 'porcine' genotype. *Parasitology* 126: 407-416.
35. Ellis AE, Brown CA and Miller DL (2010). Diagnostic exercise: chronic vomiting in a dog. *Veterinary Pathology* 47: 991-993.
36. Elwin K, Hadfield SJ, Robinson G, Crouch ND and Chalmers RM (2012). *Cryptosporidium viatorum* n. sp. (Apicomplexa: Cryptosporidiidae) among travellers returning to Great Britain from the Indian subcontinent, 2007-2011. *International Journal for Parasitology* 42: 675-682.

37. Esteban E and Anderson BC (1995). *Cryptosporidium muris*: prevalence, persistency, and detrimental effect on milk production in a dry lot dairy. *Journal of Dairy Science* 78: 1068-1072.
38. Farthing MJG (1994). Giardiasis as a disease. In: Thompson RCA, Reynoldson JA, Lymbery AJ (eds.). *Giardia* from molecules to disease, CAB Int.; Wallingford, UK. pp. 15-37.
39. Farthing MJG (1996). Giardiasis. *Gastroenterology Clinics of North America* 25: 493- 515.
40. Farzan A, Parrington L, Coklin T, Cook A, Pintar K, Pollari F, Friendship R, Farber J and Dixon B (2011). Detection and characterization of *Giardia duodenalis* and *Cryptosporidium* spp. on swine farms in Ontario, Canada. *Foodborne Pathogens and Disease* 8: 1207-1213.
41. Fayer R (2008). Biology. In: Fayer, R.; Xiao, L. (Eds.), *Cryptosporidium* and Cryptosporidiosis, second ed. CRC Press and IWA Publishing, Boca Raton, FL, pp. 1-42.
42. Fayer R, Santín M and Trout JM (2007). Prevalence of *Cryptosporidium* species and genotypes in mature dairy cattle on farms in eastern United States compared with younger cattle from the same locations. *Veterinary Parasitology* 145: 260-266.
43. Fayer R, Santín M, Trout JM and Dubey JP (2006c). Detection of *Cryptosporidium felis* and *Giardia duodenalis* Assemblage F in a cat colony. *Veterinary Parasitology* 140: 44-53.
44. Fayer R, Santín M, Trout JM and Greiner E (2006b). Prevalence of species and genotypes of *Cryptosporidium* found in 1-2-year-old dairy cattle in the eastern United States. *Veterinary Parasitology* 135: 105-12.
45. Feltus DC, Giddings CW, Schneck BL, Monson T, Warshauer D and McEvoy JM (2006). Evidence supporting zoonotic transmission of *Cryptosporidium* spp. In Wisconsin. *Journal of Clinical Microbiology* 44: 4303-4308.
46. Fiechter R, Deplazes P and Schnyder M (2012). Control of *Giardia* infections with ronidazole and intensive hygiene management in a dog kennel. *Veterinary Parasitology* 187: 93-98.
47. FitzGerald L, Bennett M, Ng J, Nicholls P, James F, Elliot A, Slaven M and Ryan U (2011). Morphological and molecular characterization of a mixed *Cryptosporidium muris*/ *Cryptosporidium felis* infection in a cat. *Veterinary Parasitology* 175: 160-164.
48. Flannagan PA (1992). *Giardia* - Diagnosis, clinical course and epidemiology - A review. *Epidemiology and Infection* 109: 1-22.
49. Foronda P, Bargues MD, Abreu-Acosta N, Periago MV, Valero MA, Valladares B and Mas-Coma S (2008). Identification of genotypes of *Giardia intestinalis* of human isolates in Egypt. *Parasitology Research* 103: 1177-1181.
50. Gelanew T, Lalle M, Hailu A, Pozio E and Cacciò SM (2007). Molecular characterization of human isolates of *Giardia duodenalis* from Ethiopia. *Acta Tropica* 102: 92-99.
51. Geurden T, Claerebout E, Dursin L, Deflandre A, Bernay F, Kaltsatos V and Vercruysse J (2006a). The efficacy of an oral treatment with paromomycin against an experimental infection with *Giardia* in calves. *Veterinary Parasitology* 135: 241-247.
52. Geurden T, Vercruysse J and Claerebout E (2006b). Field testing of a fenbendazole treatment combined with hygienic and management measures against a natural *Giardia* infection in calves. *Veterinary Parasitology* 142: 367-371.
53. Geurden T, Thomas P, Casaert S, Vercruysse J and Claerebout E (2008). Prevalence and molecular characterisation of *Cryptosporidium* and *Giardia* in lambs and goat kids in Belgium. *Veterinary Parasitology* 155: 142-145.
54. Geurden T, Geldhof P, Levecke B, Martens C, Berkvens D, Casaert S, Vercruysse J and Claerebout E (2008). Mixed *Giardia duodenalis* assemblage A and E infections in calves. *International Journal for Parasitology* 38: 259-264.
55. Geurden T, Levecke B, Cacció SM, Visser A, De Groote G, Casaert S, Vercruysse J and Claerebout E (2009). Multilocus genotyping of *Cryptosporidium* and *Giardia* in non-outbreak related cases of diarrhoea in human patients in Belgium. *Parasitology* 36: 1161-1168.
56. Geurden T, Vercruysse J and Claerebout E (2010). Is *Giardia* a significant pathogen in production animals? *Experimental Parasitology* 124: 98-106.
57. Geurden T, Vanderstichel R, Pohle H, Ehsan A, von Samson-Himmelstjerna G, Morgan ER, Camuset P, Capelli G, Vercruysse J and Claerebout E (2012). A multicentre prevalence study in Europe on *Giardia duodenalis* in calves, with molecular identification and risk factor analysis. *Veterinary Parasitology* 190: 383-390.
58. Giangaspero A, Iorio R, Paoletti B, Traversa D and Capelli G (2006). Molecular evidence for *Cryptosporidium* infection in dogs in Central Italy. *Parasitology Research* 99: 297-299.
59. Goma FY, Geurden T, Siwila J, Phiri IGK, Gabriel S, Claerebout E and Vercruysse J (2007). The prevalence and molecular characterisation of *Cryptosporidium* spp. in small ruminants in Zambia. *Small Ruminant Research* 22: 77-80.

60. Goodwin MA and Barsanti JA (1990). Intractable diarrhoea associated with intestinal cryptosporidiosis in a domestic cat also infected with feline leukaemia virus. *Journal of the American Veterinary Medical Association* 26: 365-368.
61. Gow AG, Gow DJ, Hall EJ, Langton D, Clarke C and Papasouliotis K (2009). Prevalence of potentially pathogenic enteric organisms in clinically healthy kittens in the UK. *Journal Feline Medicine and Surgery* 11: 655-62.
62. Grimason AM, Smith HV, Parker JF, Jackson MH, Smith PG and Girdwood RW (1993). Occurrence of *Giardia* spp. cysts and *Cryptosporidium* sp oocysts in faeces from public parks in the west of Scotland. *Epidemiology and Infection* 110: 641-645.
63. Grinberg A, Oliver L, Learmonth JJ, Leyland M, Roe W and Pomroy WE (2003). Identification of *Cryptosporidium parvum* ''cattle'' genotype from a severe outbreak of neonatal foal diarrhoea. *Veterinary Record* 153: 628-631.
64. Grinberg A, Learmonth J, Kwan E, Pomroy W, Lopez Villalobos N, Gibson I and Widmer G (2008). Genetic diversity and zoonotic potential of *Cryptosporidium parvum* causing foal diarrhoea. *Journal of Clinical Microbiology* 46: 2396-2398.
65. Grinberg A, Pomroy WE, Carslake HB, Shi Y, Gibson IR and Drayton BM (2009). A study of neonatal cryptosporidiosis of foals in New Zealand. *New Zealand Veterinary Journal* 57: 284-289.
66. Guerrant RL (1997). Cryptosporidiosis: an emerging, highly infectious threat. *Emerging Infectious Diseases* 3:51-57.
67. Guerrant RL, Kirchhoff LV, Shields DS, Nations MK, Leslie J, de Sousa MA, Araujo JG, Correia LL, Sauer KT, McClelland KE, Trowbridge FL and Hughes JM (1983). Prospective study of diarrheal illnesses in northeastern Brazil: patterns of disease, nutritional impact, etiologies, and risk factors. *Journal of Infectious Diseases* 148: 986-997.
68. Hajdušek O, Ditrich O and Slapeta J (2004). Molecular identification of *Cryptosporidium* spp. in animal and human hosts from the Czech Republic. *Veterinary Parasitology* 122: 183-192.
69. Hall A (1994). *Giardia* infections: epidemiology and nutritional consequences. In: Thompson RCA, Reynoldson JA, Lymbery AJ (eds.). *Giardia* from molecules to disease, CAB Int.; Wallingford, UK. pp. 251-279.
70. Hamnes IS, Gjerde BK, Forberg T and Robertson LJ (2007). Occurrence of *Cryptosporidium* and *Giardia* in suckling piglets in Norway. *Veterinary Parasitology* 144: 222-233.
71. Haque R, Mondal D, Kirkpatrick BD, Akther S, Farr BM, Sack RB, Petri WAJr (2003). Epidemiologic and clinical characteristics of acute diarrhea with emphasis on *Entamoeba histolytica* infections in preschool children in an urban slum of Dhaka, Bangladesh. *The American Journal of Tropical Medicine and Hygiene* 69: 398-405.
72. Haque R, Roy S, Kabir M, Stroup SE, Mondal D and Houpt ER (2005). *Giardia* assemblage A infection and diarrhea in Bangladesh. *Journal of Infectious Diseases* 192: 2171-2173.
73. Haque R, Mondal D, Karim A, Molla IH, Rahim A, Faruque ASG, Ahmad N, Kirkpatrick BD, Houpt E, Snider C, Petri WA Jr (2009). Prospective case-control study of the association between common enteric protozoal parasites and diarrhea in Bangladesh. *Clinical Infectious Diseases* 48:1191-1197.
74. Hollm-Delgado MG, Gilman RH, Bern C, Cabrera L, Sterling CR, Black RE and Checkley W (2008). Lack of an adverse effect of *Giardia intestinalis* infection on the health of Peruvian children. *American Journal of Epidemiology* 168: 647-55.
75. Homan WL and Mank TG (2001). Human giardiosis: genotype linked differences in clinical symptomatology. *International Journal for Parasitology* 31: 822-826.
76. Hoopes JH, Polley L, Wagner B and Jenkins EJ (2013). A retrospective investigation of feline gastrointestinal parasites in western Canada. *Canadian Veterinary Journal* 54: 359-362.
77. Hunt CL, Ionas G and Brown TJ (2000). Prevalence and strain differentiation of *Giardia intestinalis* in calves in the Manawatu and Waikato regions of North Island, New Zealand. *Veterinary Parasitology* 91: 7-13.
78. Hunter PR, Hughes S, Woodhouse S, Syed Q, Verlander NQ, Chalmers RM, Morgan K, Nichols G, Beeching N and Osborn K (2004). Sporadic cryptosporidiosis case-control study with genotyping. *Emerging Infectious Diseases* 10: 1241-1249.
79. Hunter P and Nichols G (2002). Epidemiology and clinical features of *Cryptosporidium* infection in immunocompromised patients. *Clinical Microbiology Reviews* 15: 145-154.
80. ICAIR Life Systems Inc (1984). Criteria Document on *Giardia*, U.S. EPA, Washington, DC.
81. Irwin PJ (2002). Companion animal parasitology: a clinical perspective. *International Journal for Parasitology* 32:581-593.
82. Islam A (1990). Giardiasis in developing countries. In: Meyer EA (ed). Human Parasitic Diseases, Vol. 3, Giardiasis. Elsevier Science Publ.; Amsterdam, the Netherlands, pp. 235-266.

83. Itoh N, Muraoka N, Saeki H, Aoki M and Itagaki T (2005). Prevalence of *Giardia intestinalis* infection in dogs of breeding kennels in Japan. *Journal of Veterinary Medical Science* 67: 717-718.
84. Itoh N, Muraoka N, Kawamata J, Aoki M and Itagaki T (2006). Prevalence of *Giardia intestinalis* infection in household cats of Tohoku district in Japan. *Journal of Veterinary Medical Science* 68: 161-163.
85. Jafari Shoorijeh S, Sadjjadi SM, Asheri A and Eraghi K (2008). *Giardia* spp. and *Sarcocystis* spp. status in pet dogs of Shiraz, Southern part of Iran. *Tropical Biomedicine* 25: 154-159.
86. Johnson EH, Muirhead DE, Windsor JJ, King GJ, Al-Busaidy R and Cornelius R (1999). Atypical outbreak of caprine cryptosporidiosis in the Sultanate of Oman. *Veterinary Record* 145: 521-524.
87. Johnson J, Buddle R, Reid S, Armson A and Ryan UM (2008). Prevalence of *Cryptosporidium* genotypes in pre and post-weaned pigs in Australia. *Experimental Parasitology* 119: 418-421.
88. Juranek D (1995). Cryptosporidiosis: sources of infection and guidelines for prevention. *Clinical Infectious Diseases* 22: S57-S61.
89. Katz DE, Heisey-Grove D, Beach M, Dicker RC and Matyas BT (2006). Prolonged outbreak of giardiasis with two modes of transmission. *Epidemiology and Infection* 134: 935-941.
90. Kváč M, Hanzlikova D, Sak B and Kvetonová D (2009). Prevalence and age-related infection of *Cryptosporidium suis*, *C. muris* and *Cryptosporidium* pig genotype II in pigs on a farm complex in the Czech Republic. *Veterinary Parasitology* 160: 319-322.
91. Kváč M, Kestřánová M, Květoňová D, Kotková M, Ortega Y, McEvoy J and Sak B (2012). *Cryptosporidium tyzzeri* and *Cryptosporidium muris* originated from wild West-European house mice (*Mus musculus domesticus*) and East-European house mice (*Mus musculus musculus*) are non-infectious for pigs. *Experimental Parasitology* 131: 107-10.
92. Kváč M, Kouba M and Vítovec J (2006). Age-related and housing-dependence of *Cryptosporidium* infection of calves from dairy and beef herds in South Bohemia, Czech Republic. *Veterinary Parasitology* 137: 202-209.
93. Kváč M, Sak B, Kvetonová D, Ditrich O, Hofmannová L, Modry D, Vítovec J and Xiao L (2008). Infectivity, pathogenicity, and genetic characteristics of mammalian gastric *Cryptosporidium* spp. in domestic ruminants. *Veterinary Parasitology* 153: 363-367.
94. Kváč M and Vítovec J (2003). Prevalence and pathogenicity of *Cryptosporidium andersoni* in one herd of beef cattle. *Journal of Veterinary Medicine. B, Infectious Diseases and Veterinary Public health* 50: 451-457.
95. Laatamna AE, Wagnerová P, Sak B, Květoňová D, Aissi M, Rost M and Kváč M (2013). Equine cryptosporidial infection associated with *Cryptosporidium* hedgehog genotype in Algeria. *Veterinary Parasitology* pii: S0304-4017(13)00276-8.
96. Langkjaer RB, Vigre H, Enemark HL and Maddox-Hyttel C (2007). Molecular and phylogenetic characterization of *Cryptosporidium* and *Giardia* from pigs and cattle in Denmark. *Parasitology* 134: 339-350.
97. Learmonth JJ, Ionas G, Pita AB and Cowie RS (2003). Identification and genetic characterisation of *Giardia* and *Cryptosporidium* strains in humans and dairy cattle in the Waikato Region of New Zealand. *Water Science Technology* 47: 21-26.
98. Learmonth JJ, Ionas G, Ebbett KA and Kwan ES (2004). Genetic characterization and transmission cycles of *Cryptosporidium* species isolated from humans in New Zealand. *Applied and Environmental Microbiology* 70:3973-3978.
99. Leonhard S, Pfister K, Beelitz P, Wielinga C and Thompson RC (2007). The molecular characterisation of *Giardia* from dogs in southern Germany. *Veterinary Parasitology* 150: 33-38.
100. Lent SF, Burkhardt JE and Bolka D (1993). Coincident enteric cryptosporidiosis and lymphosarcoma in a cat with diarrhoea. *Journal of the American Veterinary Medical Association* 29: 492-496.
101. Leoni F, Amar C, Nichols G, Pedraza-Diaz S and McLauchlin J (2006). Genetic analysis of *Cryptosporidium* from 2414 humans with diarrhoea in England between 1985 and 2000. *Journal of Medical Microbiology* 55: 703-707.
102. Lucio-Forster A, Griffiths JK, Cama VA, Xiao L and Bowman DD (2010). Minimal zoonotic risk of cryptosporidiosis from pet dogs and cats. *Trends in Parasitology* 26: 174-179.
103. Lupo PJ, Langer-Curry RC, Robinson M, Okhuysen PC and Chappell CL (2008). *Cryptosporidium muris* in a Texas canine population. *The American Journal of Tropical Medicine and Hygiene* 78: 917-921.
104. Maddox-Hyttel C, Langkjaer RB, Enemark HL and Vigre H (2006). *Cryptosporidium* and *Giardia* in different age groups of Danish cattle and pigs--occurrence and management associated risk factors. *Veterinary Parasitology* 141: 48-59.
105. Majewska AC, Solarczyk P, Tamang L and Graczyk TK (2004). Equine *Cryptosporidium parvum* infections in western Poland. *Parasitology Research* 93:274-178.

106. Manabe YC, Clark DP, Moore RD, Lumadue JA, Dahlman HR, Belitsos PC, Chaisson RE and Sears CL (1998). Cryptosporidiosis in patients with AIDS: correlates of disease and survival. *Clinical Infectious Diseases* 27: 536-542.
107. McLauchlin J, Amar C, Pedraza-Diaz S and Nichols GL (2000). Molecular epidemiological analysis of *Cryptosporidium* spp. in the United Kingdom: results of genotyping *Cryptosporidium* spp. in 1,705 fecal samples from humans and 105 fecal samples from livestock animals. *Journal of Clinical Microbiology* 38: 3984-3990.
108. Medema GJ (1999). *Cryptosporidium* and *Giardia*: new challenges to the water industry. Thesis Universiteit Utrecht. *igiturarchive.library.uu.nl/dissertations/1883822/full.pdf.*
109. Meireles MV (2010). *Cryptosporidium* infection in Brazil: implications for veterinary medicine and public health. *Revista Brasileira de Parasitologia Veterinária* 19: 197-204.
110. Miller DL, Liggett A, Radi ZA and Branch LO (2003). Gastrointestinal cryptosporidiosis in a puppy. *Veterinary Parasitology* 115: 199-204.
111. Minetti C, Taweenan W, Hogg R, Featherstone C, Randle N, Latham SM and Wastling JM (2013). Occurrence and diversity of *Giardia duodenalis* assemblages in livestock in the UK. *Transboundary and Emerging Diseases* 61: e60-7.
112. Mircean V, Györke A, Jarca A and Cozma V (2011). Prevalence of *Giardia* species in stool samples by ELISA in household cats from Romania and risk factors. *Journal of Feline Medicine and Surgery* 13: 479-482.
113. Mohsen A and Hossein H (2009). Gastrointestinal parasites of stray cats in Kashan, Iran. *Tropical Biomedicine* 26: 16-22.
114. Mørch K, Hanevik K, Rivenes AC, Bødtker JE, Næss H, Stubhaug B, Wensaas KA, Rortveit G, Eide GE, Hausken T and Langeland N (2013). Chronic fatigue syndrome 5 years after giardiasis: differential diagnoses, characteristics and natural course. *BMC Gastroenterology* 13: 28.
115. Morgan UM, Sargent KD, Desplazes P, Forbes DA, Spano F, Hertzberg H, Elliot A and Thompson RCA (1998). Molecular characterization of *Cryptosporidium* from various hosts. *Parasitology* 117: 31-37.
116. Mtambo MM, Nash AS, Blewett DA, Smith HV and Wright S (1991). *Cryptosporidium* infection in cats: prevalence of infection in domestic and feral cats in the Glasgow area. *Veterinary Record* 129: 502-504.
117. Mueller-Doblies D, Giles M, Elwin K, Smith RP, Clifton-Hadley FA and Chalmers RM (2008). Distribution of *Cryptosporidium* species in sheep in the UK. *Veterinary Parasitology* 154: 214-219.
118. Muhid A, Robertson I, Ng J, Yang R and Ryan U (2012). Prevalence of *Giardia* spp. infection in pre-weaned and weaned calves in relation to management factors. *Veterinary Journal* 191: 135-137.
119. Muhsen K and Levine MM (2012). A systematic review and meta-analysis of the association between *Giardia lamblia* and endemic pediatric diarrhea in developing countries. *Clinical Infectious Diseases* 55: S271-93.
120. Naess H, Nyland M, Hausken T, Follestad I and Nyland HI (2012). Chronic fatigue syndrome after *Giardia* enteritis: clinical characteristics, disability and long-term sickness absence. *BMC Gastroenterology* 12: 13.
121. Nash TE, Herrington DA, Losonsky GA and Levine MM (1987). Experimental human infections with *Giardia lamblia*. *Journal of Infectious Diseases* 156: 974-984.
122. Nash AS, Mtambo MMA and Gibbs HA (1993). *Cryptosporidium* infection in farm cats in the Glasgow area. *Veterinary Record* 133: 576-577.
123. Němejc K, Sak B, Květoňová D, Kernerová N, Rost M, Cama VA and Kváč M (2013). Occurrence of *Cryptosporidium suis* and *Cryptosporidium scrofarum* on commercial swine farms in the Czech Republic and its associations with age and husbandry practices. *Parasitology Research* 112: 1143-1154.
124. O'Donoghue P (1995). *Cryptosporidium* and cryptosporidiosis in man and animals. *International Journal for Parasitology* 25:139-195.
125. O'Handley RM, Cockwill C, McAllister TA, Jelinski M, Morck DW and Olson ME (1999). Duration of naturally acquired giardiosis and cryptosporidiosis in dairy calves and their association with diarrhea. *Journal of the American Veterinary Medical Association* 214: 391-396.
126. O'Handley RM, Ceri H, Anette C and Olson ME (2003). Passive immunity and serological immune response in dairy calves associated with natural *Giardia duodenalis* infections. *Veterinary Parasitology* 113: 89-98.
127. Olson ME, McAllister TA, Deselliers L, Morck DW, Cheng KJ, Buret AG and Ceri H (1995). Effects of Giardiasis on production in a domestic ruminant (lamb) model. *American Journal of Veterinary Research* 56: 1470-1474.
128. Olson ME, Guselle NJ, O'Handley RM, Swift ML, McAllister TA, Jelinski MD and Morck DW (1997). *Giardia* and *Cryptosporidium* in dairy calves in British Columbia. *Canadian Veterinary Journal* 38: 703-706.
129. Olson ME, O'Handley RM, Ralston BJ, McAllister TA and Thompson RC (2004). Update on *Cryptosporidium* and *Giardia* infections in cattle. *Trends in Parasitology* 20: 185-191.

130. Palmer CS, Traub RJ, Robertson ID, Devlin G, Rees R and Thompson RC (2008). Determining the zoonotic significance of *Giardia* and *Cryptosporidium* in Australian dogs and cats. *Veterinary Parasitology* 154: 142-147.
131. Papini R, Cardini G, Paoletti B and Giangaspero A (2007). Detection of *Giardia* assemblage A in cats in Florence, Italy. *Parasitology Research* 100: 653-656.
132. Paraud C, Pors I and Chartier C (2010). Evaluation of oral tilmicosin efficacy against severe cryptosporidiosis in neonatal kids under field conditions. *Veterinary Parasitology* 170: 149-152.
133. Pirestani M, Sadraei J, Dalimi Asl A, Zavvar M and Vaeznia H (2008). Molecular characterization of *Cryptosporidium* isolates from human and bovine using 18s rRNA gene in Shahriar county of Tehran, Iran. *Parasitology Research* 103: 467- 472.
134. Pritchard GC, Marshall JA, Giles M, Chalmers RM and Marshall RN (2007). *Cryptosporidium parvum* infection in orphan lambs on a farm open to the public. *Veterinary Record* 161: 11-14.
135. Pritchard GC, Marshall JA, Giles M, Mueller-Doblies D, Sayers AR, Marshall RN, Elwin K and Chalmers RM (2008). *Cryptosporidium* species in lambs submitted for diagnostic post-mortem examination in England and Wales. *Veterinary Record* 163: 688-689.
136. Quílez J, Sánchez-Acedo C, del Cacho E, Clavel A and Causapé AC (1996). Prevalence of *Cryptosporidium* and *Giardia* infections in cattle in Aragón (northeastern Spain). *Veterinary Parasitology* 66: 139-46.
137. Quílez J, Torres E, Chalmers RM, Hadfield SJ, Del Cacho E and Sanchez-Acedo C (2008). Genotype and subtype characterization of *Cryptosporidium* in lambs and goat kids in Spain. *Applied and Environmental Microbiology* 74: 6026-6031.
138. Rabbani GH and Islam A (1994). Giardiasis in humans: populations most at risk and prospects for control. In: Thompson RCA, Reynoldson JA and Lymbery AJ (eds.). *Giardia* from molecules to disease, CAB Int.; Wallingford, UK. pp. 217-249.
139. Ralston BJ, Cockwill C, Guselle N, Van Herk FH, McAllister TA and Olson ME (2003). Prevalence of *Giardia* and *Cryptosporidium andersoni* and their effect on performance in feedlot beef calves. *Canadian Journal of Animal Science* 83: 153-159.
140. Rambozzi L, Menzano A, Mannelli A, Romano S and Isaia MC (2007). Prevalence of cryptosporidian infection in cats in Turin and analysis of risk factors. *Journal of Feline Medicine and Surgery* 9: 392-396.
141. Read C, Walters J, Robertson ID and Thompson RC (2002). Correlation between genotype of *Giardia duodenalis* and diarrhea. *International Journal for Parasitology* 32: 229-231.
142. Robertson L (2009). *Giardia* and *Cryptosporidium* infections in sheep and goats: a review of the potential for transmission to humans via environmental contamination. *Epidemiology and Infection* 137: 913-921.
143. Ryan U, Xiao L, Read C, Zhou L, Lal AA and Pavlasek I (2003). Identification of novel *Cryptosporidium* genotypes from the Czech Republic. *Applied and Environmental Microbiology* 69: 4302-4307.
144. Ryan UM, Bath C, Robertson I, Read C, Elliot A, McInnes L, Traub R and Besier B (2005). Sheep may not be an important zoonotic reservoir for *Cryptosporidium* and *Giardia* parasites. *Applied and Environmental Microbiology* 71: 4992-4997.
145. Sabshin SJ, Levy JK, Tupler T, Tucker SJ, Greiner EC and Leutenegger CM (2012). Enteropathogens identified in cats entering a Florida animal shelter with normal faeces or diarrhea. *Journal of the American Veterinary Medical Association* 241: 331-337.
146. Santín M (2013). Clinical and subclinical infections with *Cryptosporidium* in animals. *New Zealand Veterinary Journal* 61: 1-10.
147. Santín M, Trout JM, Xiao L, Zhou L, Greiner E and Fayer R (2004). Prevalence and age related variation of *Cryptosporidium* species and genotypes in dairy calves. *Veterinary Parasitology* 122: 103-117.
148. Santín M, Trout JM and Fayer R (2007). Prevalence and molecular characterization of *Cryptosporidium* and *Giardia* species and genotypes in sheep in Maryland. *Veterinary Parasitology* 146: 1724.
149. Santín M and Trout JM (2008). Companion animals. In: Fayer R, Xiao L (eds). *Cryptosporidium* and Cryptosporidiosis. CRC Press, Boca Raton,FL, USA. Pp. 437-450.
150. Santín M, Trout JM and Fayer R (2008). A longitudinal study of cryptosporidiosis in dairy cattle from birth to 2 years of age. *Veterinary Parasitology* 155:15-23.
151. Santín M, Cortés Vecino JA and Fayer R (2013). A large scale molecular study of *Giardia duodenalis* in horses from Colombia. *Veterinary Parasitology* 196: 31-36.
152. Sari B, Arslan MO, Gicik Y, Kara M and Taşçi GT (2009). The prevalence of *Cryptosporidium* species in diarrhoeic lambs in Kars province and potential risk factors. *Tropical Animal Health and Production* 41: 819-826.
153. Savioli L, Smith H and Thompson A (2006). *Giardia* and *Cryptosporidium* join the 'Neglected Diseases Initiative'. *Trends in Parasitology* 22: 203-208.

154. Schnyder M, Kohler L, Hemphill A and Deplazes P (2009). Prophylactic and therapeutic efficacy of nitazoxanide against *Cryptosporidium parvum* in experimentally challenged neonatal calves. *Veterinary Parasitology* 160: 149-154.
155. Schorling JB, Wanke CA, Schorling SK, McAuliffe JF, de Souza MA and Guerrant RL (1990). A prospective study of persistent diarrhea among children in an urban Brazilian slum. Patterns of occurrence and etiologic agents. *American Journal of Epidemiology* 132: 144-156.
156. Scorza AV, Duncan C, Miles L and Lappin MR (2011). Prevalence of selected zoonotic and vector-borne agents in dogs and cats in Costa Rica. *Veterinary Parasitology* 183: 178- 83.
157. Sevinç F, Şımşek A and Uslu U (2005). Massive *Cryptosporidium parvum* infection associated with an outbreak of diarrhoea in neonatal goat kids. *Turkish Journal of Veterinary and Animal Sciences* 29: 1317-20.
158. Shirley DAT, Moonah SN and Kotloff KL (2012). Burden of disease from Cryptosporidiosis. *Current Opinion of Infectious Diseases* 25: 555-563.
159. Siwila J and Mwape KE (2012). Prevalence of *Cryptosporidium* spp. and *Giardia duodenalis* in pigs in Lusaka, Zambia. *Onderstepoort Journal of Veterinary Research* 79: E1-5.
160. Sotiriadou I, Pantchev N, Gassmann D and Karanis P (2013). Molecular identification of *Giardia* and *Cryptosporidium* from dogs and cats. *Parasite* 20: 8.
161. Souza SL, Gennari SM, Richtzenhain LJ, Pena HF, Funada MR, Cortez A, Gregori F and Soares RM (2007). Molecular identification of *Giardia duodenalis* isolates from humans, dogs, cats and cattle from the state of Sao Paulo, Brazil, by sequence analysis of fragments of glutamate dehydrogenase (GDH) coding gene. *Veterinary Parasitology* 149: 258-264.
162. Sprong H, Cacciò SM, van der Giessen JW, ZOOPNET network and partners (2009). Identification of zoonotic genotypes of *Giardia duodenalis*. *PLoS Neglected Tropical Diseases* 3: e558.
163. St Jean G (1987). Diagnosis of *Giardia* infection in 14 calves. *Journal of the American Veterinary Medical Association* 191: 831-832.
164. Sturdee AP, Bodley-Tickell AT, Archer A and Chalmers RM (2003). Long-term study of *Cryptosporidium* prevalence on lowland farm in the United Kingdom. *Veterinary Parasitology* 116: 97-113.
165. Sulaiman IM, Hira PR, Zhou L, Al-Ali FM, Al-Shelahi FA, Shweiki HM, Iqbal J, Khalid N and Xiao L (2005). Unique endemicity of cryptosporidiosis in children in Kuwait. *Journal of Clinical Microbiology* 43: 2805-2809.
166. Sweeny JP, Ryan UM, Robertson ID and Jacobson C (2011). *Cryptosporidium* and *Giardia* associated with reduced lamb carcass productivity. *Veterinary Parasitology* 182: 127-139.
167. Sweeny JP, Robertson ID, Ryan UM, Jacobson C and Woodgate RG (2012). Impacts of naturally acquired protozoa and strongylid nematode infections on growth and faecal attributes in lambs. *Veterinary Parasitology* 184: 298-308.
168. Traub R, Wade S, Read C, Thompson A and Mohammed H (2005). Molecular characterization of potentially zoonotic isolates of *Giardia duodenalis* in horses. *Veterinary Parasitology* 130: 317-21.
169. Traversa D, Otranto D, Milillo P, Latrofa MS, Giangaspero A, Di Cesare A and Paoletti B (2012). *Giardia duodenalis* sub-Assemblage of animal and human origin in horses. *Infection Genetics and Evolution* 12: 1642-1646.
170. Tumwine JK, Kekitiinwa A, Nabukeera N, Akiyoshi DE, Rich SM, Widmer G, Feng X and Tzipori S (2003). *Cryptosporidium parvum* in children with diarrhea in Mulago Hospital, Kampala, Uganda. *The American Journal of Tropical Medicine and Hygiene* 68: 710-715.
171. Tzanidakis N, Sotiraki S, Claerebout E, Ehsan A, Voutzourakis N, Kostopoulou D, Casaert S, Vercruysse J and Geurden T (2014). Occurrence and molecular characterization of *Giardia duodenalis* and *Cryptosporidium* spp. in sheep and goats reared under dairy husbandry systems in Greece. *Parasite* 21: 45. doi: 10.1051/parasite/2014048.
172. USEPA (1998). Drinking water criteria document on *Giardia*. Environmental Protection Agency, Washington, DC.
173. Uehlinger FD, Greenwood SJ, McClure JT, Conboy G, O'Handley R and Barkema HW (2013). Zoonotic potential of *Giardia duodenalis* and *Cryptosporidium* spp. and prevalence of intestinal parasites in young dogs from different populations on Prince Edward Island, Canada. *Veterinary Parasitology* 196: 509-514.
174. Veronesi F, Passamonti F, Cacciò S, Diaferia M and Piergili Fioretti D (2010). Epidemiological survey on equine *Cryptosporidium* and *Giardia* infections in Italy and molecular characterization of isolates. *Zoonoses Public Health* 57: 510-517.
175. Vieira LS, Silva MB, Tolentino AC, Lima JD and Silva AC (1997). Outbreak of cryptosporidiosis in dairy goats in Brazil. *Veterinary Record* 140: 427-428.

176. Vítovec J, Hamadejová K, Landová L, Kváč M, Kvetonová D and Sak B (2006). Prevalence and pathogenicity of *Cryptosporidium suis* in pre- and post-weaned pigs. *Journal of Veterinary Medicine. B, Infectious Diseases and Veterinary Public health* 53: 239-243.
177. Wang Y, Feng Y, Cui B, Jian F, Ning C, Wang R, Zhang L and Xiao L (2010). Cervine genotype is the major *Cryptosporidium* genotype in sheep in China. *Parasitology Research* 106: 341-347.
178. Wensaas KA, Langeland N, Hanevik K, Mørch K, Eide GE and Rortveit G (2012). Irritable bowel syndrome and chronic fatigue 3 years after acute giardiasis: historic cohort study. *Gut* 61: 214-219.
179. Wielinga PR, de Vries A, van der Goot TH, Mank T, Mars MH, Kortbeek LM and van der Giessen JW (2008). Molecular epidemiology of *Cryptosporidium* in humans and cattle in the Netherlands. *International Journal for Parasitology* 38: 809-817.
180. Xiao L (2010). Molecular epidemiology of cryptosporidiosis: an update. *Experimental Parasitology* 124: 80-89.
181. Xiao L and Fayer R (2008). Molecular characterization of species and genotypes of *Cryptosporidium* and *Giardia* and assessment of zoonotic transmission. *International Journal for Parasitology* 38: 1239-1255.
182. Xiao L and Feng Y (2008). Zoonotic cryptosporidiosis. *FEMS Immunology and Medical Microbiology* 52: 309-323.
183. Yang R, Jacobson C, Gordon C and Ryan U (2009). Prevalence and molecular characterisation of *Cryptosporidium* and *Giardia* species in pre-weaned sheep in Australia. *Veterinary Parasitology* 161: 19-24.
184. Yin JH, Yuan ZY, Cai HX, Shen YJ, Jiang YY, Zhang J, Wang YJ and Cao JP (2013). Age-related infection with *Cryptosporidium* species and genotype in pigs in China. *Biomedical and Environmental Sciences* 26: 492-495.
185. Yoshiuchi R, Matsubayashi M, Kimata I, Furuya M, Tani H and Sasai K (2010). Survey and molecular characterization of *Cryptosporidium* and *Giardia* spp. in owned companion animal, dogs and cats, in Japan. *Veterinary Parasitology* 174: 313-316.
186. Zhang W, Yang F, Liu A, Wang R, Zhang L, Shen Y, Cao J and Ling H (2013). Prevalence and genetic characterizations of *Cryptosporidium* spp. in pre-weaned and post-weaned piglets in Heilongjiang Province, China. *PLoS One* 8: e67564.
187. Zintl A, Proctor AF, Read C, Dewaal T, Shanaghy N, Fanning S and Mulcahy G (2009). The prevalence of *Cryptosporidium* species and subtypes in human faecal samples in Ireland. *Epidemiology and Infection* 137: 270-277.