

Some foodborne and waterborne protozoa

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ABSTRACT

Pathogenic parasites including helminths and protozoa are responsible for foodborne diseases in developed and developing countries. Reports of foodborne and waterborne protozoan infections are very rare. Food and waterborne zoonotic protozoa and their transmission stages are listed in this review and it is aimed to give brief information about the food-borne zoonotic protozoa.

Keywords: food-borne, parasite, protozoa, water-borne, zoonosis.

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Introduction

Pathogenic parasites including helminths and protozoa are responsible for foodborne diseases in developed and developing countries (Torgerson et al., 2015). Some reports of foodborne and waterborne protozoan infections are found. *Balantidium coli* is one of the most prevalent protozoans in humans (Ronald, 2001). *Giardia intestinalis* has been described more frequently than other pathogens in waterborne outbreaks in the United States (Ronald, 2001). There is also an increase in parasitic foodborne outbreaks in developed and developing countries due to the increasing consumption of fresh vegetables and fruits (Amoah et al., 2007; Dixon, 2015). Various parasites have been detected in ready-to-eat (RTE) food (Caradonna et al., 2017). For example, an outbreak of foodborne cryptosporidiosis was associated with contamination of ready-to-eat salads in the UK in 2012 (McKerr et al., 2015). This case reflects that the infectious stages of the parasite can be highly resistant to cleaning and disinfection processes used in food production (Almeria Seal, 2021). Foodborne parasites can be passed on to new hosts including humans by several ways including consuming some tissues of infected mammals, fish or invertebrates, contaminated fruit and vegetables, and drinking waters

contaminated infectious stages of different parasites (WHO, 2014). Table1 lists food and waterborne protozoan parasites. In this review, it is aimed to give brief information about some food- and waterborne zoonotic protozoa.

Some food- and waterborne zoonotic protozoa and their transmission stages are listed in Table 1.

Toxoplasma gondii

The members of Felidae including cats are the final hosts of *Toxoplasma gondii*. Intermediate hosts consisted of a lot of domestic and wild ruminant animals such as sheep, goat, pigs, cattle, cats, dogs, rodents, poultry, rabbits, marine mammals and humans. *Toxoplasma gondii* is known to have three infectious stages: tachyzoite, bradyzoite (within tissue cyst) and sporozoite (within oocyst) (Dubey, 2010). Sexual development occurs only in the intestinal epithelial cells of Felidae. Oocysts only excrete with the final host's feces. After completed the sporogony stage in a very short time in the outside, the oocyst become infectious for the intermediate hosts (Guy et al., 2012). Asexual development of the parasite occurs in the many tissues of the intermediate hosts. During acute infection, tachyzoites are found in nearly all cells of the organism. Tissue cysts develop in intracellularly in

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Table 1. Parasite species main food sources and infective parasite forms. (WHO, 2014).

Parasite	Food/Water	Stage
<i>Toxoplasma gondii</i>	Ruminant, Pork, Beef, Game Meat (Meat and Organs)	Bradyzoites
<i>Toxoplasma gondii</i>	Water	Oocysts
<i>Toxoplasma gondii</i>	Fresh Produce	Oocysts
<i>Toxoplasma gondii</i>	Milk	Tachyzoites
<i>Cryptosporidium</i> spp.	Water	Oocysts
<i>Cryptosporidium</i> spp.	Fresh Produce	Oocysts
<i>Cryptosporidium</i> spp.	Fruit Juice	Oocysts
<i>Cryptosporidium</i> spp.	Milk	Oocysts
<i>Giardia intestinalis</i>	Water	Cysts
<i>Giardia intestinalis</i>	Fresh Produce	Cysts
<i>Entamoeba histolytica</i>	Water	Cysts
<i>Entamoeba histolytica</i>	Fresh Produce	Cysts
<i>Balantidium coli</i>	Fresh Produce	Cysts
<i>Balantidium coli</i>	Water	Cysts
<i>Cyclospora cayetanensis</i>	Water	Oocyst
<i>Cyclospora cayetanensis</i>	Fresh Produce (Berries)	Oocyst
<i>Sarcocystis</i> spp.	Beef, Pork Meat	Bradyzoites
<i>Trypanosoma cruzi</i>	Fruit Juice	Trypomastigotes

ranged between 5 µm to 100 µm in size. The tissue cysts are responsible for prevalence of toxoplasmosis in humans (Kijlstra and Jongert, 2008). The main transmission route of toxoplasmosis in humans and animals is considered to be carnivorous. Humans and carnivorous animals become infected by consuming the raw or undercooked meat of intermediate host such as sheep and pigs that contain tissue cysts (Kijlstra and Jongert, 2008).

The clinical picture in *Toxoplasma* infections is related to the immune status of the person. In general, clinical symptoms may cause mild to moderate illness, including low-grade fever, fatigue, sore throat, myalgia, lymphadenopathy, and headache (Petersan et al., 2012). Although clinical symptoms do not develop in latent infections, it has been determined that it can be a factor that contributes or even causes various psychological disorders such as depression, anxiety and schizophrenia (Henriquez et al., 2009; Flegr, 2013).

Considering the situation of the disease in Turkey, in a study conducted in Istanbul, tests were performed in 23,731 cases who applied with the request of *T. gondii* IgM/IgG antibody test between 2013 and 2018. *Toxoplasma gondii* IgG positive rate was 32.5% and IgM positive rate was 2.2% (Demir et al., 2020). Again, in the Black Sea region, the IgG positivity of toxoplasmosis was determined as 14.5% only in pregnant women (Eroglu and Asgin, 2020). As seen in these studies, the parasite, which is not

insignificant in Turkey, is thought to be transmitted by contaminated raw meat, mostly due to eating habits, as mentioned above.

***Cryptosporidium* spp.**

Cryptosporidium species, apicomplexan parasites, possess monoxene life cycle. The parasites inhabit in the gastrointestinal epithelium of numerous vertebrate species, including humans (Egyed et al., 2003). Asexual, sexual development, and also sporogony are observed within the host (Fayer et al., 2008). Infection begins after ingestion of some food or drink water contaminated with oocysts excreted by the feces of infected animals or humans infected with zoonotic *Cryptosporidium* spp. (Ülgen and Balçioğlu, 2007). People working in livestock, veterinarians, laboratory personnel, children and the elderly, and those traveling to endemic areas are risky groups. Development of clinical signs are often related to immunity of the host. The percentage of infection is high in people living in areas with inadequate hygienic conditions and in close contact with infected people. Outbreaks of cryptosporidiosis originating from public swimming pools, communal large meals, well water, and unhygienic drinking water sources have been reported (Miron et al. 1991; Çeliksöz and Çelik, 2003). Disease symptoms; watery diarrhea, abdominal pain, weight loss, nausea, vomiting, fever and malaise (Chalmers and Davies, 2010).

Considering the situation of cryptosporidiosis in Turkey, between 2010 and 2018, 723 samples were

studied in Van Province with the ELISA method with the suspicion of cryptosporidiosis. *Cryptosporidium* spp. antigen positive was detected in 2.8% of the samples (Bayhan and Yilmaz, 2020). In another study conducted in Malatya, the prevalence of *Cryptosporidium* in fungal patients was determined to be 11.4% (Erturk et al., 2021).

Giardia intestinalis

Giardia intestinalis has a wide range of hosts, such as humans, ruminants and other mammals (Thompson, 2004; Ryan and Caccio, 2013; Bilgic et al. 2020). Worldwide, *G. intestinalis* is one of the ten most common enteric parasites in humans (Sulaiman and Cama 2006). The main risk factors are food and water contaminated with *G. intestinalis* cysts. Other associated risk factors are; poor living conditions, polluted environment, low socioeconomic income and poor sewerage systems (Savioli et al. 2006; Naz et al. 2018). Giardiasis is on the "Neglected Diseases" list of the World Health Organization due to its effects on public health, especially in developing countries (Savioli et al. 2006).

Although it is not yet fully understood why some individuals develop clinical giardiasis while others do not, host factors and strain variants are thought to have an effect. *Giardia* causes a disease characterized by diarrhea, abdominal cramps, weight loss and malabsorption (Caeiro et al., 1999; Cantey et al., 2011).

In a study conducted in İzmir, Turkey between 2014-2018, the rate of *G. intestinalis* was determined as 11.4% (Bilman and Yetik, 2019).

Entamoeba histolytica

Entamoeba histolytica is an intestinal protozoan that has been identified as a secondary cause of protozoan death worldwide (Haque et al., 2003; Stanley, 2003). The parasite possess monoxene life cycle. Humans and some primates act as hosts in the life cycle. Infection is generally developed after ingestion of water or food contaminated with *E. histolytica* cysts (Weinke et al., 1990; Nozaki, 2000).

Less than 10% of *E. histolytica* infections in humans develop symptoms (Haque et al., 2003; Stanley, 2003; Ali and Nozaki, 2007). Clinical symptoms of amoebic colitis; mucoid stools, bloody diarrhea, abdominal pain and tenderness. Fulminant amoebic colitis is characterized by severe bloody diarrhea, fever, severe abdominal pain and marked leukocytosis. Amoebic liver abscess is the most common extraintestinal manifestation. Symptoms associated with amoebic liver abscess; right upper abdomen pain, fever, hepatic tenderness and sometimes cough, loss of appetite and weight loss.

Occasionally, pleuropulmonary amoebiasis, amoebic brain abscess, and amoebic skin abscess may also occur (IASR, 2007).

In a study conducted in İzmir, Turkey between 2014-2018, *E. histolytica* was found to be positive with a rate of 12.9% (Bilman and Yetik, 2019).

Balantidium coli

Balantidium coli is a species of protozoan parasite that is pathogenic in humans (CDC, no date; Anon., 2003a). *Balantidium coli* is localized in the caecum and colon. *Balantidium coli* has two developmental stages; trophozoite and cyst. Trophozoites proliferate and become cysts in the intestines. Humans are infected consuming food or water contaminated with the cysts. If the balance develops between the parasite and host, clinical signs may not be seen in infected humans. The infection is most likely to occur in people who are malnourished, with low stomach acid, or in people with weakened immune systems (Anon., 2003b; Schuster and Ramirez-Avila, 2008).

Common symptoms of infection; chronic diarrhea, nausea, occasional dysentery (diarrhea with the passage of blood and mucus), halitosis, colitis, abdominal pain, weight loss, deep intestinal ulcers and possibly intestinal perforation. Bleeding may occur in fulminant acute balantidiasis, which can lead to shock and death. It is reported that there is a 30% mortality rate in untreated acute diseases. If the disease is left untreated, diarrhea leads to high fluid loss and dehydration, and if abdominal bleeding occurs it can lead to death (Schuster and Ramirez-Avila, 2008).

In the study conducted in Hatay province between 2006 and 2010, the positive rate of *Balantidium coli* was determined as 0.1% (Culha and Gulhan, 2011).

Cyclospora cayetanensis

Cyclospora cayetanensis, a coccidian, can be transmitted by ingestion through contaminated raw products (vegetables, herbs and fruits) and drinking water. Asexual and sexual development occur in the epithelium of the small intestine and oocysts excreted with feces (Ortega and Sanchez, 2010). The oocysts have been identified in some waters that used for human consumption (Rabold et al., 1994). Moreover, foodborne contamination has been reported more frequently than waterborne transmission. Foodborne contamination has been associated with basil, snow peas, strawberries (raspberries and blackberries) and lettuce (Shields and Olson, 2003).

The disease is characterized by watery diarrhea, abdominal pain, nausea and anorexia. Biliary disease, Reiter's Syndrome and Guillain-Barré Syndrome have been reported to develop after *Cyclospora* infections

(Ortega and Sanchez, 2010). In the study conducted in Van Province in Turkey 2018-2019, the detection rate of *C. cayetanensis* was found to be 12% (Ekici et al., 2021).

Sarcocystis spp.

Protozoans of the genus *Sarcocystis* are obligate intracellular parasites, with two-host life cycles. The final hosts of this parasite are carnivores and humans, intermediate hosts are usually cattle, sheep, goats, poultry, pigs whose meat is consumed by the final host. Intestinal sarcocytosis in humans is known to be caused by the species *Sarcocystis hominis* and *S. suihominis*, in which humans are the final hosts of the parasites (Fayer et al., 2004; Saki et al., 2010). In intermediate hosts, sarcocytes are mostly found in striated muscles, oesophagus, diaphragm, tongue, pharynx, larynx and skeletal muscles (Lindsay et al., 1995). Infection in humans occurs by consuming raw or undercooked beef and pork containing cysts (Fayer et al., 2004).

As a conclusion, food- and waterborne parasitic diseases are most important for humans in the world.

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