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Cryptosporidiosis and Giardiasis: Two Common Foodborne Parasitic Infections

AUTHORS DETAIL

Muhammad Arfan Zaman[1], Sana Arif[2], Imaad Rashid[3], Farwa Humak[4], Sobia Amir[5], Ayesha Arif[6], Warda Qamar[7*], Tuba Riaz[8], Ifrah Tahir[7] and Snober Zaib[9]

[1]Section of Parasitology, Department of Pathobiology, College of Veterinary and Animal Sciences, Jhang, Sub-Campus University of Veterinary and Animal Sciences, Lahore, Pakistan
[2]Institute of Home Sciences, University of Agriculture, Faisalabad
[3]Department of Clinical Medicine and Surgery University of Agriculture, Faisalabad
[4]Institute of Microbiology, University of Agriculture, Faisalabad
[5]Veterinary Research Institute, Lahore Cantt
[6]Department of Zoology, Government College Women University, Faisalabad
[7]Department of Parasitology, University of Agriculture, Faisalabad
[8]Department of Animal Nutrition, University of Veterinary and Animal Sciences, Lahore, Pakistan
[9]Department CCU, Government General Hospital, Ghulam Muhammad Abad, Faisalabad, Pakistan
*Corresponding author: wardaqamar17@gmail.com

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INTRODUCTION

Recent times have seen a lot of interest in infections caused by food and water. A group of disorders commonly known as "foodborne disease" arise as a result of eating food that has been tainted by chemicals or microorganisms. The sickness can be spread even by tainted water, utensils, and users' hands. Third-world countries have a greater frequency of food-related problems than developed countries. In rural regions, households still use untreated water for drinking, cooking, washing fruits, bathing, and swimming, exposing residents to diseases other than protozoan parasites. The majority of people in the globe still lack access to clean water and sanitary facilities. (WHO 2014; Javed 2016). As a result, millions of people in developing nations face a major risk from the possibility for protozoan infections being introduced into their water supply. However, this does not imply that these illnesses do not exist in any part of the world. While there are several early warning signs of food-related disorders, gastrointestinal dysfunction is frequently employed to make the diagnosis.

Acute, recurring, and impairing disorders can all be brought on by parasites (Alvi et al. 2020; Štrbac et al. 2020; Kandeel et al. 2022; Mahmood et al. 2022). Almost everywhere in nature, parasitic protozoa may be found. They bear responsibility for epidemics and persistent poverty in both developed and underdeveloped countries (Al-Malki 2021). Since that certain parasites are zoonotic in origin and hence live in animals, their dominance in food and water should be considered to be a public health issue (Thompson 2013). A number of illness outbreaks that have been connected to parasites in the past have caused a rise in the incidence of water- and food-borne parasites throughout time. In 2014, the Food and Agricultural Organization of the United Nations (FAO) and the World Health Organization (WHO) issued their global risk assessment of foodborne parasites (FBPs) (WHO). Although being accepted as substantial foodborne pathogens, parasites are still undervalued when compared to bacterial and viral foodborne pathogens (Torgerson et al. 2015). It was followed in 2015 as a worldwide burden associated with foodborne pathogens (Trevisan et al. 2019).

Cryptosporidium spp and *Giardiaspp* are the important protozoans causing diseases both in livestock and humans (Leung et al. 2019; Gorcea et al. 2020) Across the world these parasites have posed a serious threat. Despite the standard test for the diagnosis of these parasites and different treatment methods, the spread of these parasites is uncontrollable due to other managemental disorders (Siwila et al. 2020). In this study, we summarize etiopathogenesis, epidemiology and preventive measures for zoonotic cryptosporidiosis and giardiasis.

Cryptosporidiosis

Abdominal discomfort, vomiting, and diarrhea are the hallmarks of cryptosporidiosis, a zoonotic protozoan disease caused by the widely distributed *Cryptosporidium* (Dillingham et al. 2002). After consuming food or drink tainted with oocyst-containing feces, this parasite can spread through the faecal-oral route (Tzipori 2000; Tzipori and Ward 2000). About the pathogen's natural reservoir hosts, there is currently no accurate information (Khalil et al.2018).

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Tyzzer discovered *Cryptosporidium* during the first decade of the 20th century (Tzipori and Widmer 2008), but it wasn't until 1976 that it was revealed to be an opportunistic parasite of humans (Meisel et al.1976; Nime et al.1976). It was discovered in 1982 that *Cryptosporidium* can cause self-limiting diarrhea in people and, in those with impaired immune systems, can even be fatal (Fayer and Ungar, 1986; Majeed et al. 2022). The parasite can complete its life cycle with asexual and sexual reproductive stages on just one host (Tzipori 2002; Tzipori and Widmer 2008). There are currently at least 30 species in the genus *Cryptosporidium*, but from the perspective of zoonotic transmission, *Cryptosporidium parvum* and *Cryptosporidium hominis* are the most significant (Ryan et al. 2014; Thomson et al. 2017). A few members of the *Cryptosporidium* genus are known to infect several species, including mammals, birds, and reptiles (Leitch and He, 2012; Zahedi et al. 2016). Members of the genus are extremely particular to their hosts. The phylum Apicomplexa contains the internal parasite *Cryptosporidium*, which is important for both humans and animals (Suarez et al. 2017). *Cryptosporidium* species cannot be grown in vitro, in contrast to other Protozoa members (Karanis 2018). The only way to reduce the spread of this parasite is to take preventive measures, as there is no commercially licensed vaccination to prevent Cryptosporidium infections and high contagiousness (Thomson et al. 2017).

Life Cycle of Cryptosporidium

Each *Cryptosporidium* oocyst releases four sporozoites into the host's intestine (Tzipori 2000; Tzipori and Ward 2000). After excystation, sporozoites invade a host membrane that has been modified and is now isolated from the cytoplasm. This invasion causes the formation of a parasitophorous vacuole, where schizogony/asexual reproduction takes place, producing 8 merozoites (Bouzid et al. 2013). The infection spreads to additional places in the intestines through the ability of the generated merozoites to penetrate the neighboring epithelial cells. The merozoites go through two distinct cycles after that: an asexual stage during which they reproduce and create thin-walled oocysts that can infect the host on their own, and/or a sexual stage during which type II meront are produced and differentiate into microgametocytes and macrogametocytes. As a result of the union of these microgametocytes and macrogametocytes, a diploid zygote is created, which goes through sporogony to produce four sporozoites inside thick or thin-walled oocysts (Tzipori 2002). The thick-walled oocysts, which are ready to infect a new person, are released in the feces (Bouzid et al. 2013; Jenkins et al. 2010).

Transmission of Cryptosporidiosis

Nearly every region in the world has documented cases of Cryptosporidiosis, however, outbreaks are primarily linked to drinking contaminated water or using unsanitary swimming pools (Fayer et al. 1997 Fayer et al. 2000). The prevalence is probably substantially greater than the number of recorded cases because of the sharp rise in cryptosporidiosis incidence over the world over the past few years, which is well-depicted by clinical signs (Shrivastava et al. 2017). The difference in the prevalence of *Cryptosporidium* in developed and developing nations can be related to the latter's residents' continued lack of access to clean drinking water and adequate sanitary facilities (Bouzid et al. 2018; Shoultz et al. 2016).

It has been determined that at least 30 distinct species of *Cryptosporidium* can cause sickness in both people and animals. The most typical species that harm humans are *C. hominis, C. parvum, C. canis, C. felis,* and *C. meleagridis* (Šlapeta 2013; Ryan et al. 2014; Ayinmode et al. 2018). parvum is the most frequently discovered to be connected to intestinal *Cryptosporidium* infections in people out of these 5 species. Humans and ruminants serve as *C. parvum* hosts, hence it primarily affects people who frequently interact with ruminants (Dixon et al. 2011; Hunter and Thompson 2005). Animals can transmit *Cryptosporidium* to people, however, such cases are extremely rare. According to reports, rats, horses, sheep, goats, and goats are the main sources of human cryptosporidiosis (Hunter and Thompson, 2005; Ehsan et al. 2015; Thomson et al. 2017). When it comes to *C. canis* and *C. felis*, dogs and cats, respectively, carry these parasites without displaying any symptoms of illness (Ehsan et al. 2015; Shrivastava et al. 2017). However, these house pets pose a threat to the spread of *Cryptosporidium* to People (Leitch and He 2011; Ryan et al. 2014).

Clinical Picture of Cryptosporidiosis

An episode of self-limiting watery diarrhea is brought on by gastroenteritis brought on by a Cryptosporidium infection (Bouzid et al. 2013; Shoultz et al. 2016; Adler et al. 2017; Khalil et al. 2018). Even people who have never previously had contact with animals run the risk of contracting the disease if they mistakenly consume pool water that contains oocysts or drink untreated water (Fayer et al. 1997; Fayer et al. 2000; Bouzid et al. 2018). In people with poor health or impaired immune systems, the condition may progress severely (Bouzid et al. 2013; Florescu et al. 2016; Wang et al. 2018a). According to careful calculations, cryptosporidiosis kills more than 50,000 people per year (Shirley et al. 2012; Wang et al. 2018). Following oocyst consumption and infection, *Cryptosporidium* damages the intestinal membrane, causing increased permeability, decreased absorption, and increased fluid and electrolyte output (Petry et al. 2010; Kumar et al. 2018). The oocysts are particularly resistant to chlorine, chloramines, and chlorine dioxide, which allows them to survive for a very long time in the environment (Shrivastava et al. 2017). Humans can become infected with *Cryptosporidium* by touching objects that have come into contact with contaminated feces. Ingestion of oocysts found in contaminated food, water, or air is the most typical method of transmission (Petry et al. 2010; Shrivastava et al. 2017). Recent data have demonstrated that respiratory secretions can also transfer cryptosporidiosis and cause pulmonary infections (Sponseller et al. 2014). Cryptosporidiosis is more likely to affect hosts with compromised immune systems than immunocompetent individuals. In immunocompromised HIV/AIDS patients, cryptosporidiosis can result in severe outcomes, including death (Samie et al. 2014; Wang et al. 2018). In addition to causing fever and poor food absorption, *Cryptosporidium* causes pancreatitis, sclerosing cholangitis, and biliary tract blockage (Wang et al. 2018).

Diagnosis Tools for Cryptosporidiosis

The primary diagnostic methods used all around the world involve detecting DNA in fecal samples or *Cryptosporidium* oocysts in feces by microscopy. Diarrhea associated with cryptosporidiosis is watery, which is often a symptom of many other illnesses. As a result, infections with rotaviruses, coronaviruses, Salmonella spp., and Escherichia coli are included in the differential diagnosis for *Cryptosporidium* (Mehta 2002 Khurana and Chaudhary, 2008). The diameter of a *Cryptosporidium* oocyst ranges from 4 to 6 µm (Khurana and Chaudhary, 2008; Ahmed and Karanis 2018). Three fecal samples collected on different days should be examined microscopically in order to rule out a *Cryptosporidium* infection in people with severe diarrhea because the detection of *Cryptosporidium* oocysts in fecal challenging (Omoruyi et al. 2014; Khurana and Chaudhary, 2008). Additionally, the fecal sample needs to be concentrated with formalin-ether to increase the likelihood that an oocyst will be seen under a microscope (Pacheco et al 2013).

The Ziehl-Neelsen method and phenol-auramine staining are further options for staining the oocysts. Oocysts are colored red or bright yellow by the stains, respectively (Omoruyi et al. 2014; Khurana and Chaudhary, 2008). Despite being the most often used diagnostic tool and being simple to use and inexpensive, the microscopic diagnosis of Cryptosporidia oocysts has a low sensitivity (up to 30%). Furthermore, accurate diagnosis by microscopy heavily depends on the microscopist’s training. According to some reports, staining oocysts with a modified acid-fast stain can boost sensitivity by up to 55%. The two highly sensitive and specific procedures to diagnose Cryptosporidiosis are the immuno-chromatographic test and enzyme-linked immunosorbent assay (ELISA) (Agnamey et al. 2011; Hawash 2014). Additionally, these antigen/antibody-based detection techniques are thought to be ineffective in patients whose oocyst load is below the cutoff (Hawash 2014). Additionally, these techniques are costlier than polymerase chain reaction (PCR), the industry-standard method for finding *Cryptosporidium* in stool samples. Microscopy, ELISA, and immunochromatographic tests have been found in earlier studies to be inferior to PCR in terms of sensitivity, specificity, and cost (Autier et al. 2018; Friesen et al. 2018). Along with being superior to other oocyst detection techniques, PCR is not always available in all laboratories. Additionally, this technology cannot be used in developing nations due to issues like cost and the requirement for technical skills.

Giardiasis

Food-borne giardiasis is a disease caused by the ingestion of food or water contaminated with the *Giardia* spp (Mozer et al. 2022). *Giardia* species have a typical life cycle that consists of two active trophozoite and cystic forms. By directly or indirectly ingesting infected cysts, this parasite spreads through the fecal-oral pathway. After eating cysts, the incubation period lasts somewhere between 9 and 15 days. The symptoms of this illness include diarrhea, abdominal pain, nausea, and vomiting, which can last for several days (Linscott 2011). In some cases, the symptoms may persist for several weeks, leading to severe dehydration and weight loss. According to Rendtorff (1954), the infective dosage might be as little as 10 cysts, making host-to-host transmission easier. *Giardias pp* spreads to new hosts via the faecal-oral pathway, which involves oral contact with cyst-containing food or drink or direct contact with human or animal feces. *Giardia is* not considered as an opportunistic infection that causes persistent symptoms and enteritis in immunocompromised persons. Giardiasis symptoms in HIV-positive people are comparable to those in HIV-negative people.

Life Cycle of Giardia

Giardiasis is an intestinal infection caused by the protozoan parasite, *Giardia spp* (Einarsson et al. 2016). The life cycle of *Giardia* involves two stages: the cyst and the trophozoite (Bernander et al. 2011). The cyst is the infectious stage of the parasite. It is a hardy, environmentally-resistant form that is shed in the feces of infected animals and humans (Gerba 2009). The cyst is capable of surviving outside of a host for several months, making it highly transmissible through contaminated food and water sources. Once the cyst is ingested by a host, it transforms into the trophozoite stage (Evans-Osses et al. 2017). The trophozoite is the active, motile form of the parasite. It attaches to the lining of the small intestine and begins to reproduce by binary fission (Ikbal et al. 2022). The trophozoite stage is responsible for the symptoms of giardiasis, which include diarrhea, abdominal pain, and bloating. After several days in the host's small intestine, the trophozoites undergo a process called encystation (Mendoza Cavazos et al. 2023). During this process, the trophozoites transform back into cysts, which are then passed out of the host in the feces (Smoguła et al. 2023). The cysts are shed into the environment through the feces of infected hosts. They can survive in water, soil, and on surfaces for several months, allowing for transmission to new hosts through contaminated food and water sources (Carmena 2010). Once ingested by a new host, the cysts transform back into the active trophozoite form, continuing the life cycle of the parasite. Overall, the life cycle of *Giardia spp* is characterized by the alternation between the cyst and trophozoite stages, which allows the parasite to survive in a range of environments and infect new hosts (Ehrenkaufer et al. 2018).

Transmission of Giardiasis

Giardiasis is an intestinal infection caused by a microscopic parasite called *Giardiaspp*. This infection is usually transmitted through contaminated water, food, or surfaces (Balderrama-Carmona et al. 2017). The most common source of transmission of giardiasis is through the ingestion of water that has been contaminated with *Giardia*cysts (Daly et al. 2010). The cysts can survive in water for weeks, making it possible for people to become infected by drinking water from contaminated sources such as streams, lakes, or poorly maintained water systems (Karanis et al. 2007). People can also become infected by consuming food that has been contaminated with Giardia, such as raw or undercooked meat, fruits, or vegetables that have been washed with contaminated water (Moreira et al. 2005). Giardiasis can also be transmitted from person to person through the fecal-oral route (Bui et al. 2016). This means that people can become infected by coming into contact with the feces of an infected person, such as when caring for someone who is sick or changing the diaper of an infected child. People can also become infected by touching surfaces that have been contaminated with *Giardia*and then touching their mouths or face (De France et al. 2022). It's important to practice good hygiene, such as washing your hands regularly and thoroughly, avoiding drinking untreated water from natural sources, and properly preparing and cooking food, to reduce the risk of contracting giardiasis (Yakubovna et al. 2022).

Clinical Picture of Giardiasis

The clinical picture of Giardiasis can vary widely, with some people experiencing no symptoms, while others may have severe symptoms (Choutka et al. 2022). The symptoms of Giardiasis usually appear 1-3 weeks after infection and can last for several weeks to months. The most common symptoms of Giardiasis include Diarrhea - which can be watery or greasy, abdominal cramps and bloating, nausea and vomiting, loss of appetite and weight loss, fatigue, Excessive gas or flatulence, foul-smelling stools that may be pale or greasy, fever (low grade) (Sengupta and Chakraborty, 2023). In severe cases, symptoms can include, dehydration, anemia, malnutrition, and chronic diarrhea. In some cases, people with Giardiasis may experience recurring symptoms even after the infection has been treated (Beiting and John 2022). It is important to note that not everyone infected with *Giardia*will have symptoms, but they can still spread the infection to others. The risk of death from giardiasis is generally low, but it can occur in severe cases. The parasite can cause dehydration and malnutrition, which can be life-threatening if not treated promptly (Weil et al. 2020). Additionally, in rare cases, the parasite can cause complications such as pancreatitis or a bowel obstruction, which can also be life-threatening. Foodborne giardiasis can result in significant economic losses due to its impact on human health and productivity (Mateusa et al. 2023). The direct costs of giardiasis can include medical treatment, hospitalization, and lost productivity due to illness. Indirect costs can include lost income and decreased economic activity due to decreased productivity (Collier et al. 2012). In addition, outbreaks of foodborne giardiasis can have a significant impact on the food industry, resulting in decreased consumer confidence and reduced demand for affected products (Slifko et al. 2000). This can lead to decreased sales and revenue for food producers and retailers. Overall, the production losses caused by foodborne giardiasis can be significant and can have both short- and long-term impacts on individuals, businesses, and the economy as a whole (Daniel et al. 2020).

Diagnostic Tools for Giardiasis

The diagnosis of foodborne giardiasis can be made through a combination of clinical symptoms, laboratory tests, and epidemiological investigations (Smith et al. 2007). Some of the diagnostic tools used to identify giardiasis include, the use of stool examination to identify the presence of Giardia cysts or trophozoites. It is the most commonly used diagnostic tool for giardiasis and has high sensitivity and specificity Goka et al. 1990; Hooshyar et al. 2019). Antigen detection tests are also used to detect the presence of Giardia antigens in stool samples using immunological methods. They are typically used when the microscopic examination is inconclusive or when there is a need for rapid diagnosis (Gonçalves et al. 2002). Other techniques include PCR which is a molecular diagnostic tool that can detect the presence of Giardia DNA in stool samples. PCR has high sensitivity and specificity and can detect the parasite even in low concentrations. However, it is more expensive and requires specialized laboratory equipment (Stark et al. 2011; Laude et al. 2016). Serological tests detect the presence of antibodies against Giardia in blood samples (Gilpin et al. 2022). In addition to these diagnostic tests, epidemiological investigations can help identify the source of the outbreak and the food or waterborne transmission of the disease. This may involve interviewing patients and collecting information about their recent food and water consumption.

Prevention of Giardiasis

Prevention is key in controlling the spread of food-borne giardiasis (Hosseinian 2022). Proper food handling, preparation, and storage practices can help to prevent the contamination of food with the *Giardia*parasite. Here are some prevention strategies that can be employed. Cleanliness practices such as hand washing and cleaning of surfaces used in food preparation can prevent contamination (Osafo et al. 2022). Safe food handling e.g Foods should be cooked at the appropriate temperature, refrigerated promptly, and reheated properly to avoid the growth of bacteria. Water purification like Drinking water should be treated, boiled or filtered to remove parasites and bacteria (Malan and Sharma 2023). Proper sewage disposal systems and regulations can reduce the risk of contamination of water sources. Safe agricultural practices in which the use of clean water for irrigation and the use of appropriate pesticides and herbicides can reduce contamination. Overall, food-borne giardiasis can be prevented through proper food handling, water purification, and safe agricultural practices (Desalegn et al. 2022). Awareness campaigns and education can also play a significant role in preventing the spread of this disease. By practicing good hygiene and following proper food handling practices, we can help to reduce the incidence of food-borne giardiasis and promote good health in our communities (Agbalaka et al. 2019).

Conclusion

Giardia and *Cryptosporidium* are two parasites that frequently go unnoticed and undiagnosed yet represent serious problems for public health globally. Despite the widespread occurrence and severe effects of these parasitic diseases, which are mostly seen in immunocompromised patients, there are significant flaws in the present control programs, particularly with regard to the diagnostic resources available. The majority of diagnostic procedures also frequently misdiagnose the illness in endemic regions. In order to more accurately detect infections and outbreaks and lessen the burden that these parasites place on the public health system, more evidence-based advancements in the diagnosis and treatment of giardiasis and cryptosporidiosis are necessary. It is necessary to create molecular approaches that are sensitive, specific, straightforward to use, affordable, and high throughput because early detection is the most effective way to combat the illness.

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