**Cyclospora cayetanensis**

*Cyclospora cayetanensis* is a protozoan parasite that causes the gastrointestinal illness cyclosporiasis. Infected individuals shed a non-infectious form of the parasite in their faeces which requires an extended period of environmental exposure to develop into the infectious form. In developed countries cyclosporiasis is typically associated with international travel or consumption of imported produce.

**Description of the organism**

*C. cayetanensis* is a protozoan parasite which belongs to the phylum *Apicomplexa*, subclass *Coccidiaina* and family *Eimeriidae*. Many species of *Cyclospora* have been identified in animals. However, *C. cayetanensis* is the only species identified in humans, and appears to be restricted to this host (Arrowood 2003; Ortega and Sanchez 2010). Once sporulated, organisms of the genus *Cyclospora* have an oocyst that contains two sporocysts, and each sporocyst contains two sporozoites. *C. cayetanensis* oocysts are spherical, measuring 8–10µm in diameter, and as such are smaller than many other species of *Cyclospora* (Ortega et al. 1994; Lainson 2005; Smith 2007).

**Growth and survival characteristics**

*C. cayetanensis* can only multiply within the host. Factors that influence the survival of unsporulated and sporulated oocysts in the environment are poorly understood. Available data suggests that the viability of unsporulated oocysts is maintained for up to two months when stored at 4°C (as evidenced by sporulation occurring after storage for one week at 30°C) (Smith et al. 1997). Sathyanarayanan and Ortega (2004) and Ortega et al. (2008) have demonstrated that unsporulated *C. cayetanensis* oocysts are resistant to pesticides commonly used on farms and to sanitizers used by the food industry.

Sporulation of *Cyclospora* oocysts occurs optimally in the temperature range of 22–32°C, with 20–60% of purified oocysts sporulating within 2 weeks. The rate of sporulation slows at temperatures outside of this range (Ortega et al. 1993; Smith et al. 1997; Sathyanarayanan and Ortega 2006). A study by Sathyanarayanan and Ortega (2006) demonstrated that sporulation was prevented after 2 days at -20°C or exposure to extreme temperatures of -70 or 70°C for 15 minutes. Ortega and Liao (2006) showed that microwave heating of *C. cayetanensis* at 96°C for 45 seconds dramatically decreased the level of sporulation but did not completely inhibit sporulation.

**Symptoms of disease**

*Cyclospora* infection has a range of outcomes from no clinical symptoms of disease (asymptomatic infection) to severe diarrhoea resulting in dehydration and weight loss. Other symptoms can include anorexia, nausea, vomiting, abdominal bloating, cramping, fatigue, body aches and low-grade fever. The onset of illness is 2–14 days (average of 7 days). In untreated individuals a cycle of remitting and relapsing symptoms can occur that lasts for weeks to months. Shedding of oocysts occurs during the illness and can continue for several weeks after symptoms have abated (Arrowood 2003; Smith 2007; Hall et al. 2012). Infection with *C. cayetanensis* can lead to longer term sequelae including malabsorption, biliary disease, Reiter’s syndrome (reactive arthritis) and Guillain-Barré syndrome (a peripheral nervous system disorder that causes paralysis) (Herwaldt 2000; Ortega and Sanchez 2010).
Virulence and infectivity

There are currently no animal models or in vitro cultivation methods to determine the infectivity of Cyclospora oocysts and consequently knowledge of factors that influence the virulence of C. cayetanensis is limited (Ortega and Sanchez 2010).

C. cayetanensis oocysts are unsporulated and non-infective when shed in the faeces, and it is thought that a prolonged period outside the host is required for the oocysts to sporulate and become infectious. Factors that affect the sporulation process of C. cayetanensis are not well characterised, however, ambient temperature and the presence of higher concentrations of atmospheric oxygen appear to be involved (Smith 2007).

Cyclospora spp. appear to have a higher binding affinity for particular types of fresh produce. For example the fine hair-like projections on the surface of raspberries are thought to facilitate the attachment of “sticky” Cyclospora oocysts. The adhesins responsible for this strong attachment are unknown (Ortega and Sanchez 2010).

Mode of transmission

C. cayetanensis is transmitted via the faecal-oral route by consumption of contaminated food or water. Direct person-to-person transmission is unlikely as the oocysts shed from individuals are not infectious and require extended periods of time outside the host to sporulate (Ortega and Sanchez 2010; Hall et al. 2012).
(1) When shed in the faeces, *C. cayetanensis* oocysts are unsporulated and non-infective.

(2) Oocysts contaminate the environment.

(3) Oocysts sporulate in the environment and develop sporocysts and sporozoites. The sporulated oocysts are the infectious form of *C. cayetanensis*.

(4) Fresh produce and water can serve as vehicles for transmission.

(5) The sporulated oocysts are ingested (in contaminated food or water).

(6) The oocysts excyst, releasing sporozoites in the gastrointestinal tract. The sporozoites infect the epithelial cells lining the small intestine, in particular the jejunum. Once inside the intestinal cell, sporozoites multiply asexually and produce type I meronts which in turn form type II meronts. The type II meronts infect other intestinal cells and initiate sexual multiplication by producing either microgametocytes or macrogametocytes. The microgametocytes fertilize the macrogametocytes, leading to the production of a zygote.

(7) The zygotes differentiate into unsporulated oocysts, which are released into the lumen of the intestine and shed in the faeces.

(Smith 2007; CDC-DPDx 2009; Ortega and Sanchez 2010)
**Incidence of illness and outbreak data**

*C. cayetanensis* has been reported worldwide, however, it is more common in tropical and sub-tropical environments and in many developing countries, particularly in parts of South America, the Caribbean and Asia. The incidence of *C. cayetanensis* is seasonal, with cases most commonly occurring in spring and summer (Ortega and Sanchez 2010; Chacin-Bonilla 2010; Hall et al. 2012).

Infection with *C. cayetanensis* is not a notifiable disease in Australia or New Zealand and hence very little data is available. In the United States (US) the notification rate for cyclosporiasis in 2010 was 0.07 cases per 100,000 population, which was an increase on the 2009 rate of 0.05 cases per 100,000 population (CDC 2012).

Outbreaks of *C. cayetanensis* have largely been associated with fresh produce (refer to Table 1).

**Table 1**: Selected major foodborne outbreaks associated with *C. cayetanensis* (>50 cases and/or ≥1 fatality)

<table>
<thead>
<tr>
<th>Year</th>
<th>No. cases</th>
<th>Food</th>
<th>Country</th>
<th>Comments</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>314</td>
<td>Fresh produce (cantaloupe, chives &amp; lettuce)</td>
<td>Cruise ship (multiple countries)</td>
<td>Food taken on board the cruise ship from south east Asian destinations</td>
<td>Gibbs et al. 2013</td>
</tr>
<tr>
<td>2005</td>
<td>142</td>
<td>Fresh basil</td>
<td>Canada</td>
<td>Fresh basil imported from Mexico, contamination possibly from human handling or irrigation water</td>
<td>Milord et al. 2012</td>
</tr>
<tr>
<td>2004</td>
<td>96</td>
<td>Fresh snow peas</td>
<td>US</td>
<td>Snow peas imported from Guatemala, all from the same batch</td>
<td>CDC 2004</td>
</tr>
<tr>
<td>2000</td>
<td>54</td>
<td>Raspberry filling of a wedding cake</td>
<td>US</td>
<td>Frozen unwashed raspberries were thawed and mixed into the cream filling of the cake. Raspberries were imported from Guatemala</td>
<td>Ho et al. 2002</td>
</tr>
<tr>
<td>1997</td>
<td>93</td>
<td>Mesclun lettuce</td>
<td>US</td>
<td>Lettuce thought to be imported from Peru</td>
<td>Herwaldt 2000</td>
</tr>
<tr>
<td>1996</td>
<td>1465</td>
<td>Raspberries</td>
<td>US and Canada</td>
<td>Raspberries imported from Guatemala. Berries were picked and sorted by hand, well water was used for washing</td>
<td>Herwaldt et al. 1997</td>
</tr>
</tbody>
</table>
Occurrence in food

*C. cayetanensis* has been identified in international surveys of fresh produce. Dixon et al. (2013) detected *Cyclospora* spp. in 1.7% of packaged leafy greens purchased from grocery stores in Canada (n=544). In a study of herbs in Vietnam, 10.4% of basil (n=96), 11.6% of coriander (n=86) and 7.7% of marjoram samples (n=26) were positive for *Cyclospora* spp. oocysts (Tram et al. 2010). Ortega et al. (1997) detected *C. cayetanensis* oocysts in 1.7% of vegetables sampled from markets in Peru (n=172). In Nepal *Cyclospora* spp. have been detected in drinking water and on cabbage and lettuce (Sherchand et al. 1999).

As *C. cayetanensis* infections have only been observed in humans (Ortega and Sanchez 2010), there does not appear to be an animal reservoir. It is likely that the most significant transmission occurs where sewage, or water contaminated by human faeces, has been applied to horticultural crops (Dawson 2005). This could occur via the use of contaminated water for the application of pesticides, sprinkling contaminated water on horticultural produce to maintain freshness, or washing the produce in contaminated water drawn from ponds, lakes or rivers. Contaminated hands of food handlers, baskets and containers in markets could also lead to contaminated produce (Sherchand et al. 1999; Ortega and Sanchez 2010; Tram et al. 2010).

Host factors that influence disease

People of all ages are susceptible to *C. cayetanensis* infection. Young children, the elderly and immunocompromised individuals develop more severe clinical symptoms. In endemic areas, the severity of symptoms and duration of infection tends to decrease after repeated infections, suggesting possible immunity in older children and adults (Ortega and Sanchez 2010).

Dose response

The number of *C. cayetanensis* oocysts required to cause infection is not known, however, it is presumed to be low (possibly as low as 10 oocysts) on the basis of data from outbreak investigations (Smith 2007; RTI International 2009).

Recommended reading and useful links

http://www.fda.gov/Food/FoodborneIllnessContaminants/CausesOfIllnessBadBugBook/ucm206773.htm


References


Lainson R (2005) The genus *Cyclospora* (Apicomplexa: Eimeriidae), with a description of *Cyclospora schneideri* n.sp. in the snake Anilius scytale scytale (Aniliidae) from Amazonian Brazil - A review. Memórias do Instituto Oswaldo Cruz 100(2):103–110


Tram NT, Hoang LMN, Cam PD, Chung PT, Fyfe MW, Issac-Renton JL, Ong CSL (2010) *Cyclospora* spp. in herbs and water samples collected from markets and farms in Hanoi, Vietnam. Tropical Medicine and International Health 13(11):1415–1420

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