Emerging Food–Borne Parasitic Zoonoses: A bird’s eye view

Alok Kumar Singh1, Amit Kumar Verma2, Amit Kumar Jaiswal1, Vikrant Sudan1, Kuldeep Dhama3

1Department of Veterinary Parasitology, 2Department of Veterinary Epidemiology and Preventive Medicine, Uttar Pradesh Pandit Deen Dayal Upadhayaya Padhnik Chikitsa Vigyan Vidwodiyalay Evam Gyan-Aumanish Sansthan (DUVASU), Mathura, India, 3Division of Pathology, Indian Veterinary Research Institute (IVRI), Izatnagar, Bareilly (U.P.) – 243122, India.

Corresponding author: dr_amitverma@sify.com

ABSTRACT

Zoonotic transmission of parasitism is an underreported and under recognized, worldwide distributed entity. Humans acquire these infections either through food, water, soil or close contact with animals. Mostly parasitic zoonoses are those of neglected diseases but with more demand of the food supply, increased travelling and increased ratio of highly susceptible persons coupled with changes in culinary practices with simultaneous improvement in diagnostic tools as well as communication facilities. These conditions are emerging at an alarming rate. Global sourcing of food, coupled with changing consumer vorgues, including the consumption of raw vegetables and undercooking to retain the natural taste and preserve heat-labile nutrients, can increase the risk of foodborne transmission. The increasing demand for raw or under-cooked food is also considered as one of the major reasons causing food borne infections, especially waterborne parasitic diseases, in the last decade. The present review will discuss the factor responsible for transmission and occurrence of zoonotic diseases along with different helminthes and protozoan parasites that are considered to be as important food borne zoonoses. A greater awareness of parasite contamination of our environment and its impact on health has precipitated the development of better detection methods. Overall, there is an urgent need for better monitoring and control of food-borne parasites using new technologies. Robust, efficient detection, viability and typing methods are required to assess risks and to further epidemiological understanding. This paper reviews the most important emerging food-borne parasites, with emphasis on transmission routes.


INTRODUCTION

Food-borne parasitic zoonoses include both helminthic and protozoan infections. Amongst one thousand five hundred known infectious agents for human being, 66 are protozoan and 287 are helminths (Chomel, 2008; Taylor et al., 2001) and amongst them majority (60.3%) of the emerging infectious diseases are zoonotic (Jones et al., 2008). Zoonoses represent a large burden of disease and there are changing patterns of disease burdens with disease emergence (Dhama et al., 2013a,b). Unlike bacteria and viruses, parasites generally have unique features which often make them remarkably suited for survival in the environment and dissemination by water. Many of these parasites are difficult to detect and control. Some have the potential to cause severe public health problems, while others are capable of inflicting considerable losses in livestock. The resulting production and economic losses can be extensive. Human population growth and socioeconomic changes have resulted in the migration of populations into new ecological niches and changes in animal husbandry practices have tremendously impacted on disease emergence and disease burden (Macpherson, 2005). In addition, improved diagnostics are demonstrating that many zoonoses have a higher burden then previously recognized ones. Some new syndromes are also being attributed to parasitic zoonoses and hence add to the disease burden. Environmental changes and ecological disturbances, due to both natural phenomena and human intervention, have exerted and can be expected to continue to exert a marked influence on the emergence and proliferation of zoonotic parasitic diseases. Global warming may change the transmission dynamics of parasitic zoonoses in endemic areas and enable some parasites to transmit in regions where they were previously absent. A range of parasites are well adapted and have coevolved with their hosts so to persist in relationships which may be sub-clinical or even mutualistic in their nature: this would guarantee the survival both of the host and of the parasite populations. This may be true if a population is constantly exposed to a parasite, where young individuals acquire tolerance gradually by, for example, consumption of the “local” contaminated food. Such balance between a foodborne parasitic disease and a host population was usually confined to specific
environments and host populations or geographic areas. Nowadays, due to the increased globalization and movement of people and food commodities, this geographical segregation is not necessarily evident any more. Food and waterborne infections have received considerable attention in the last decade and some of them are considered as emerging diseases (WHO, 2002; Singh et al., 2014). Although humans may serve as host of around 300 species of parasitic worms and over 70 species of protozoa (Cox, 2002), only around 100 species are known to be food borne (Orlandi et al., 2002). Human and society behavior plays a fundamental role in the epidemiology, emergence and spread of parasitic zoonoses. Host-parasite relationships are intricately linked; each component is important and may determine the dynamics and outcome of disease transmission and control (Azim et al., 2008). During the last decades there have been changes in food preferences and eating habits; there is a growing market for more ready-to-eat fresh and healthy food, as well as novel, ethnic food products, which have created new situations where pathogens may be introduced into food and then to populations. The present review will discuss the factor responsible for transmission and occurrence of zoonotic diseases along with different helminthes and protozoan parasites that are considered to be as important food borne zoonoses.

Table 1: Some important food-borne parasitic zoonoses

<table>
<thead>
<tr>
<th>Type</th>
<th>Protozoa</th>
<th>Helminths</th>
<th>References</th>
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<tbody>
<tr>
<td>Meat borne</td>
<td>Toxoplasma gondii</td>
<td>Taenia solium, T.saginata</td>
<td>Dubey et al., 2005, Bhatia et al., 2006, Kijlstra and Jongert, 2009, Moro and Schantz, 2009, Gottstein et al., 2009</td>
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<td></td>
<td>Sarcocystis suihominis</td>
<td>Echinococcus granulosus</td>
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<td></td>
<td>Sarcocystis hominis</td>
<td>Trichinella spiralis</td>
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<td>Fish-borne</td>
<td>-----</td>
<td>Anisakis sp.</td>
<td>Vuylstek et al., 2004, Keiser and Utzinger, 2005, Chai et al., 2005, Scholz et al., 2009,</td>
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<td></td>
<td></td>
<td>Diphyllobothrium latum</td>
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<td>Opisthorchis sp.</td>
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<td>Clonorchis sp.</td>
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<td>Heterophyes sp.</td>
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<td>Spirometra sp.</td>
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<td>Arthropod-borne</td>
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<td>Paragonimus sp.</td>
<td>Liu et al., 2008</td>
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<td>Cryptosporidium sp.</td>
<td>Cryptosporidium sp.</td>
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<td>Entamoeba histolytica</td>
<td>Paragonimus westermani</td>
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<td>Spirometra sp.</td>
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<td></td>
<td>Cryptosporidium sp.</td>
<td>Fasciolopsis huski</td>
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<td></td>
<td>Entamoeba histolytica</td>
<td>Echinococcus granulosus</td>
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<td></td>
<td>Toxoplasma gondii</td>
<td>Echinococcus multilocularis</td>
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<td>Trypanosoma cruzi</td>
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<td>Reptile and amphibian-borne</td>
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<td>Spirometra sp. (sparganosis)</td>
<td>Vuylstek et al., 2004, Wiwanitkit, 2005, Bhatia et al., 2006, Scholz et al., 2009</td>
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<td>Gnathostoma sp.</td>
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<td>Diphyllobothrium sp.</td>
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<td>Alaria sp.</td>
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FACTORS RESPONSIBLE FOR TRANSMISSION AND OCCURRENCE OF PARASITIC ZOONOSES
1. Lack of personal hygiene viz., improper or non-washing of hands before meal and after defecation, long nails fingers.
2. Consumption of raw or under cooked food.
3. Defecation in open area near water bodies
4. Lack of education, poor living standards and poverty
5. Unavailability of clean potable water
6. Environmental factors facilitating the survival of parasites and their development stages

PARASITES TRANSMITTED BY CONTAMINATED FOOD AND WATER
Water is one of the major sources for parasites and their different environmental stages, which contaminate the food stuffs viz., fruits and vegetables (Mahima et al., 2013; Rahal et al., 2014). It is difficult to associate an outbreak with a particular food item, and therefore, if the food-borne route is suspected, it means how, identify the food implicated became contaminated (Slifko et al., 2000). Due to these difficulties, the acquisition of parasitic infections via the food-borne route is almost certainly poorly detected by a factor 10 or more (Casemore, 1990). Of the emerging waterborne parasitic infections that may be acquired by food are Cyclospora cayetanensis, Cryptosporidium spp., Fasciol sp. and Faschiolops spp.

CYCLOSPORA SP.
Cyclospora cayetanensis is a coccidian parasite that can infect small intestine and clinically leads to watery diarrhoea ranging 4-8 stools per day, nausea and vomition in man. In Unites States and Canada, approximately 1500 cases were reported by consuming raspberries from Guatemala (Herwaltdt and Ackers, 1997, CDC, 1997). Cyclospora...
organisms have also been isolated from patients suffering with AIDS and chronic diarrhoea (Long et al., 1990; Ortega et al., 1993; Pape et al., 1994; Cox, 2002; Orlandi et al., 2002; Vuong et al., 2007).

CRYPTOSPORIDIUM SP.
Cryptosporidium is also major cause of diarrhoeic disorders in man all over the world. Water-borne, food-borne and infected animals may act as the major routes of transmission of this zoonotic disease (Silikto et al., 2000; Smith et al., 2007) especially in patients that were immune-suppressed, suffering with HIV, chronic diseases and sometimes infection may become fatal too. In immune-competent patients, cryptosporidiosis is usually a self-limiting disease. Till there are 16 species of Cryptosporidium species and 33 genotypes, but only few of them are zoonotic (Xiao and Fayer, 2008). Cryptosporidium parvum is the major zoonotic species, whose reservoir is calves. Water-borne outbreaks and infections occur through handling of infected animals, contact with children and through contaminated recreational waters. Oocysts may also contaminate soft fruits, salad, vegetables, shell fish viz., oysters and mussels (Anh et al., 2007; Schets et al., 2007). In an epidemiological survey in UK, about 38.5% of human cryptosporidiosis cases were due to C. parvum out of these 25% is through direct contact with cattle, while in France 54% of cryptosporidiosis were reported due to C. parvum (Derouin et al., 2010). These zoonotic Cryptosporidium cases were more in high income countries as compared to low income countries. Children and HIV patients have a higher prevalence of Cryptosporidium especially C. meleagridis, C. canis, C. felis, and C. muris. But most human infections reported with C. canis from low income countries. Moreover, other interesting feature is that most human infections are due to the anthroponotic of C. parvum. Thus, where C. parvum does occur in such countries it is more likely to be of anthroponotic rather than zoonotic in origin (Xiao and Feng, 2008). The burden of disease in high income countries due to zoonotic cryptosporidiosis is low. Although there are a small number of fatalities (Scallan et al., 2011), the disease generally has an acute, non fatal and outcome with few number of fatalities (Scallan et al., 2011). The disease transmission is uncertain and known to affect at least 40 species of vertebrates, including humans. Due to host specificity of G. duodenalis, its role in zoonoses is controversial. Only two assemblages (A and B) appears to be zoonotic (Monis et al., 2009). The clinical signs of giardiasis in man vary greatly (Thompson, 2011) and some of them are acute short-lasting diarrhoea or chronic syndromes associated with nutritional disorders, malabsorption of fat and weight loss. A chronic syndrome is more common and supposed to cause more harm. In low and middle income countries about 200 million persons have symptomatic giardiasis and new cases are added at the rate of 500,000 cases per year (Savioli et al., 2006). Various studies supported that direct transmission is more important than water-borne, food-borne or zoonotic transmission (Hunter and Thompson, 2005). Livestock such as cattle are frequently infected with giardiasis, but molecular evidence suggests its zoonotic transmission useless. However, molecular studies support the zoonotic transmission of giardia from dog (Leonhard et al., 2007).

ENTAMOEBA SP.
Entamoeba histolytica is of highest clinical importance and considered as the only amoeba parasitic in the intestine of human beings (Schuster and Visvesvara, 2004). Dogs are considered to be an important source of infections to human beings (Barr, 1998). E. histolytica is also found in non-human primates (Schuster and Visvesvara, 2004). Other potentially zoonotic but nonpathogenic and commensals in nature of Entamoeba are E. coli, E. polecki and E. hartmanni (Meloni et al., 1993; Stensvold et al., 2011). Of these, E. coli is one of the most commonly reported human protozoa (Chunge et al., 1991; Youn, 2009; Boeke et al., 2010). It has also been recovered dogs, nonhuman primates (Howells et al., 2011), and marsupials (Campos-Filho et al., 2008; Youn, 2009). Previous report suggested that E. polecki to be zoonotic but recent molecular diagnosis suggested that this species is restricted to humans only whereas E. hartmanni is potentially zoonotic and reported in non-human primates (Stensvold et al., 2011).

FASCIOLA SPP.
Fasciolosis is caused by two species of liver fluke i.e. Fasciola hepatica and Fasciola gigantica. Among these, F. hepatica is cosmopolitan in distribution and has the capacity to infect variety of host species. Its intermediate host (snail) is adapted to a wide range of ecological niches (Bhatta et al., 2006). F. gigantica has a more restricted distribution because of reduced ability of the aquatic snail to invade new niches and is generally found in tropical regions of Africa, South and East Asia and the Middle East continents. Man is always acquiring the infection with local affected animals, although the distribution of infection in man and level of prevalence may not always correlate with that observed in animals (Mas-Coma, 2004; Mas-Coma et al., 1999a). Infection is usually acquired by the ingestion of various freshwater aquatic plants, such as watercress, on which the metacercariae have settled. Farm management practices and the culturing of edible aquatic plants in greenhouses has limited the extent of human infection in industrialized regions, but in some developing countries wild aquatic plants or plants grown in fields where infected animals can easily roam form a regular part of the daily diet. Metacercariae may also associate with floating in water and, therefore, infection can be acquired through drinking water. The importance of human fasciolosis has recently been recognized. Earlier in 1992 total cases of human fasciolosis was estimated to be less than 3000, but recently this data have reached to 2.4 million (Rim et al., 1994; Curtaile et al., 2005) and 17 million (Hopkins, 1992). Clinically disease occurs due to

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migration of the young or immature flukes through the liver parenchyma leading to abdominal discomfort, diarrhoea, weight loss and malaise. Sometimes, erratic migrations of Fasciola may also occur (Le et al., 2007). Fasciolosis is emerging as a major plantborne zoonotic disease in high altitude Andean rural regions of Bolivia and Peru (Mas-Coma et al., 1999b), northern provinces of Iran bordering Caspian sea (Rokni et al., 2002; Moghaddam et al. 2004), Nile Delta region of Egypt (Esteban et al., 2003) and Central provinces of Vietnam (De et al., 2003).

**FASCIOLOPSIS SPP**

*Fasciolopsis bukhari* is commonly known as ‘giant intestinal fluke’ and present in small intestine of man and pigs, transmitted by consumption or handling of metacercariae infected aquatic plants viz., water chestnut, water hyacinth and water morning glory etc or by drinking or using untreated water (Bhatia, 2003). Man may be infected when peeling off the hull or skin of infected plants using their teeth. Pigs are the only prevalent reservoir, although they harbor few flukes. The infection occurs locally and linked to freshwater habitats with stagnant or slow moving waters, and is associated with common social and agricultural practices and promiscuous defecation. The disease may lead to erosions of intestine, abdominal pain, yellow offensive stools, ulceration, haemorrhage, abscesses and catarrhal inflammation (Mas-Coma et al., 2005).

**PARASITES TRANSMITTED BY Fecal contamination of food and drinks**

Infected stages of some parasites come out through faeces and contaminate foodstuffs such as vegetables, fruits of fruit juices and edible raw materials. Human infection with *Toxoplasma gondii*, a cosmopolitan zoonotic protozoan parasite may be congenital or acquired (Flegr et al., 2002, 2009). Infection can be acquired either through ingestion of raw or under-cooked meat containing tissue cyst or ingestion of sporulated oocysts along with food or water. Several studies have found that Echinococcosis increases public health concern (Moro and Schantz, 2009). Dogs are increasingly recognized as important animal reservoirs for *Trypanosoma cruzi* (Hotez et al., 2008) and transmitted through oral infection via fruit juices, contaminated with faeces from infected bugs (Rodriguez-Morales, 2008).

**TRYPANOSOMA CRUZI**

It causes chagas disease in man, affecting young ones and neonates. Disease is prevalent in South America, United State of America and Canada and transmitted by blood-sucking Reduvid bugs living in cracks, crevices and roofs of poor quality dwellings in rural and unhygienic areas. Disease may also be transmitted by blood transfusion, organ transplantation and congenital infection. Various animals may be infected and serve as reservoirs like dogs, cats, pigs, foxes, serrets, squirlers, opossum and monkey (Hotez et al., 2008). Recent outbreaks in Brazil and Venezuela suggested its transmission through consumption of fruit juices contaminated with faeces of infected bugs. These outbreaks are of significant importance in periurban areas of non-endemic regions (Rodriguez-Morales, 2008). The chronic Chagas disease is the usual form seen in adults and clinical manifestations depend on the location of the organisms but cardiac form is more common.

**ECHINOCOCCUS**

Echinococcosis in humans occurs as a result of infection by accidental ingestion of contaminated food and water with eggs of the taeniid cestodes of the genus *Echinococcus*. These eggs may contaminate raw vegetables and fruits resulting in a food-borne infection. Four species viz., *Echinococcus granulosus* (causes cystic echinococcosis), *Echinococcus multilocularis* (causes alveolar echinococcosis), *Echinococcus oligarthus* and *Echinococcus vogeli* (causes polycystic echinococcosis) have been considered as important from public health point of view (Moro and Schantz, 2009). Humans are accidental intermediate and dead end host. Liver is the most prevalent site for the hydatid cyst development, followed by lungs or any other part of the body of unglulates such as spleen, kidneys, heart, bone and central nervous system. Cysts may reach up to 80cm in diameter per year, and may take many years before showing any clinical signs. If a cysts ruptures, the sudden release of its contents causes serious allergic or immunological reactions from mild to fatal anaphylaxis (Das et al., 2003, Moro and Schantz, 2009). Control of stray dog populations, treatment of dogs with anti-cestodal drugs, prohibition of home slaughter of sheep and correct slaughter practices and disposal of carcass, supported by health education programmes, are some of effective ways to break its life cycle.

**MEAT-BORNE PARASITE INFECTIONS**

Meatborne parasitic zoonoses are important cause of illness and economic loss, globally (Roberts et al., 1994, Murrell, 1995, Gamble et al., 1998). Among the meat-borne parasitic infections *Toxoplasma gondii*, *Taenia* spp., *Sarcocystis* spp., and *Trichinella* spp are of significant socio-economic importance. Man get infection by eating raw or undercooked meat infected with cyst of these parasites. Meat inspection for cystercocerosis has very low sensitivity, so that resulting in a high number of infected carcasses entering the food chain. However, in developing countries a large proportion of the carcass escapes meat inspection because it is not a routine practice or the animals are not slaughtered in abattoirs. For sarcocystosis and toxoplasmosis no any specific meat inspection is done. Cooking is effective criteria for killing the parasites if the appropriate temperature is reached in the core of the meat product. Freezing, drying, smoking and curing are other effective process to reduce the risk of infection by consuming contaminated meat, except for some species of *Trichinella*, which show resistance upto some extent. Recently, all *Trichinella* infections occurring in animals and humans were associated to *Trichinella spiralis*. Presently, 8 species and 4 genotypes within two clades i.e encapsulated and nonencapsulated, are recognized (Pozio and Murrell, 2006; Zarlenia et al., 2006; Krivokapich et al., 2008).

**TOXOPLASMA GONDII**

Toxoplasmosis is a protozoan parasite caused by *T. gondii* is still a neglected and underreported cases, despite having
a disease similar to that of salmonellosis and campylobacteriosis (Kijlstra and Jongert, 2009). Disease is transmitted to man by accidental ingestion of sporulated oocysts shed with the faeces by other cats, or by eating raw or undercooked meat contaminated with tissue cysts. In Western and Asian countries the consumption of undercooked meat is a prominent source of infections (Cook et al., 2000; Fallah et al., 2008; Han et al., 2008) with significant public health impact (Kijlstra and Jongert, 2009). However, the eating of uncleaned raw vegetables or fruits is an important risk factor in various studies (Antoniou et al., 2007; Cavalante et al., 2006; Fallah et al., 2008; Liu et al., 2009). It is a serious health problem in pregnant women leading to abortions. Encephalitis is the main clinical symptom in immunocompromised patient. Clinical manifestations are more common in boys than girls and in young woman than in young man possibly due to hormonal reasons and condition is accompanied by myalgia which may proceed to myositis and headache may develop in encephalitis (Dubey and Beattie, 1988). The proper heating and freezing meat are the most efficient method to kill T. gondii tissue cysts. However, interventions to prevent mixing of infected meat into the food chain would be technically feasible in countries where the meat chain is well organized. Monitoring of farms and farm management can play an important role in the control of Toxoplasma infection (Kijlstra and Jongert, 2009).

TAENIA SPP. There are two most common tapeworms in human beings i.e. T. saginata and T. solium. The terms cysticercosis refer to food-borne zoonotic infections with larvae and adult tapeworms, respectively. Their life cycles depend on the association between humans and cattle (Taenia saginata) or pigs (Taenia solium) (Flisser et al., 2005). Humans acquire infection by eating raw or undercooked meat containing cysticerci. Among these tapeworms, Taenia solium is unique because the cysticercic stage can also infect humans. Cysticerci may lodge in the brain and cause neurocysticercosis (Garcia et al., 2003). Other signs are headache, dimness of vision, vomition, and cysticercus present in anterior chamber of eye or outer part of the eyelid, convulsions, acute suppurative dacrcoedinitis and cystic nodules on neck. Human cysticercosis is not acquired by eating meat but through accidental ingestion of food or drinks contaminated with Taenia eggs through infected hands. Infection of Taenia solium is eradicated in most developed countries, mainly due to general socio-economic development and intensification of pig husbandry systems, but it is still present in tropical countries where pigs are rare for food purpose. It is associated with poverty and unhygienic condition allowing pigs to have access to human faeces. Increased immigration and travelling are major causes for spreading this parasitic infection. Estimation about millions of persons worldwide is infected with Taenia solium, mainly in Latin America, Sub-Saharan Africa and South and South-East Asia. In Africa, the rapid expansion of smallholder pig production has led to a significant increase of cysticercosis in pigs and humans (Phiri et al., 2003). Control measure based on public health education, improvement of sanitation, pig husbandry systems, meat inspection and mass treatment of humans, while conventional method include single dose treatment with oxendazole in pigs and vaccination of pigs with recombinant antigens (Gonzales et al., 1996; Lightowlers et al., 2000). The beef tapeworm is found in developed as well as in developing countries. Cysticerci easily destroy with high temperatures, dietary habits and culinary practices which readily affect the transmission. Taeniosis is more common where consumption of raw or undercooked beef (Murrell, 2005). Intestinal taeniosis may be associated with abdominal discomfort, irritation of intestinal mucosa, obstruction, nausea, weight loss and anal pruritis (Jongwutiwes et al., 2004). However, bovine cysticercosis may lead to serious economic losses to the dairy industry due to condemnation, poor storage, refrigeration and downgrading of infected carcasses (Yoder et al., 1994; Giesecke, 1997).

SARCOCYSTIS SP. Sarcocystis involves pig-man cycle (Sarcocystis suihominis) and cattle-man cycle (Sarcocystis hominis), in which man act as definitive host. The sporulated oocysts are passed out through faeces and intermediate host (pig) gets the infection through ingestion of contaminated food and water. Sarcocystis suihominis is worldwide in distribution but mainly occurs in Egypt, Sudan, West Africa, South America and Mediterranean region. The life cycle in pigs includes two generations of schizogony and mature microsarcocysts. In man parasite causes digestive disturbances, nausea, abdominal pain and diarrhea within 6-8 days of consumption of raw or undercooked pork (Banerjee et al., 1994). Sarcocystis hominis found throughout the world, but especially found in Australia, Brazil, Germany, New Zealand and India. Cattle act as intermediate host in which microsarcocysts settle in striated muscles by 98 days after the infection. In man, there are symptoms of diarrhea, vomition and respiratory distress (Jain and Shah, 1987).

TRICHINELLA SPP. This is an only example of auto-heteroxenous nematodes parasites and one of the most widespread zoonotic pathogens in the world. Infection by Trichinella spp. has been detected in domestic as well as wild animals of all continents, with the exception of Antarctica (Pozio and Murrell, 2006). Trichinellosis or trichinosis in man occurs by the ingestion of Trichinella larvae encysted in muscular tissue of domestic or wild animal. The domestic pig play important source of human infection worldwide. However, meats of wild boars and horses have played a significant role during outbreaks within the past decades (Gottstein et al., 2009). The occurrence of trichinosis in humans is strictly related to cultural food practices, including the consumption of raw or undercooked meat. Globally, average yearly incidence of the disease in humans is around 10,000 cases with a mortality rate of about 0.2%: however, the number of infections is underreported in many nations due to the lack of appropriate diagnosis and knowledge (Pozio, 2007). Clinically the disease in man is characterized by an intestinal phase followed by a muscular phase, which is associated with heavy muscle pains, myocardiitis,
encephalitis, fever, eosinophilia and calcium may be deposited in the muscle fibres and eventually the larvae die. Trichinosis is not only an economic problem but also a public health hazard in porcine animal production and food safety. With the zoonotic importance of infection, the main strategies of many countries have focused on the control of Trichinella or the elimination of Trichinella from the food chain (Gottstein et al., 2009).

PARASITES TRANSMITTED BY FISH, REPTILES, AMPHIBIAN, CRUSTACEANS AND SNAILS
The recognition of the public health significance linked to poverty, cultural traditions, intensification of agriculture, environmental degradation, and lack of tools for control is increasing (World Health Organization, 1995, 2004). Meat of reptiles, amphibians and fish can also be infected with a wide range of parasites viz., trematodes (Opisthorchis spp., Clonorchis sinensis), cestodes (Diphyllobothrium spp., Spirometra), nematodes (Gnathostoma, spp., Anisakidae), and pentastomids, causing zoonotic infections, when consumed raw or poorly cooked. Freezing, cooking and salting when properly applied may reduce the transmission of disease (Abollo et al., 2001). However, smoking or pickling may not always be effective to eliminate these infective larvae (Toro et al., 2004). Diphyllobothriasis, is contracted by consuming raw or undercooked fish (Dupouy-Camet and Peduzzi, 2004, Chai et al., 2005), and most common species infecting humans (Scholz et al., 2009). Traditionally, it is more common in Asia because of the particular food practices and the importance of aquaculture (Keiser and Utzinger, 2005). Moreover, some of these parasites may emerge in other continents through aquaculture, improved transportation and distribution systems to bring aquatic foods for local and international markets, increased tourism and changing culinary habits (Keiser and Utzinger, 2005).

CESTODES
Sparganosis is a zoonotic disease, caused by larval stage of the genus Spirometra of dogs and cats. The disease is reported in many countries but most common in eastern Asia. Migrations of parasite larvae occur in the eye, subcutaneous tissues, the central nervous system or other organs. Humans also get infections through consumption of contaminated water, frog, snake or meat infected with copepods (Wiw檀ikits, 2003). Another parasite Diphyllobothrium latum (broad fish tapeworm) is the largest tapeworm of fish eating mammals and transmitted to man by consuming raw or undercooked fish (Dupouy-Camet and Peduzzi, 2004). These parasites are found in Europe, Russia, Japan, Korea, France, Italy, Ireland, Finland, Switzerland, North and South America and Asia. About 20 million people are infected worldwide (Chai et al., 2005). Prolonged infection causes macrocytic hypochromic anaemia or pernicious anaemia resulting from a competition between parasite and host for vitamin B12 that makes vitamin B12 unavailable to the host (Vuylsteke et al., 2004).

NEMATODES
Angiostrongylus cantonensis is a zoonotic parasite, causes eosinophilic meningitis in humans after accidental ingestion of raw or under-cooked snails or fresh water crustaceans which act as intermediate host containing larvae in their slime or contaminated vegetables (Sharma et al., 1981). Rats are the natural hosts. The larvae migrate to the meninges of brain and may be found in spinal cord causing acute inflammatory reaction, mild meningeal irritation, paresthesia and cranial nerve abnormalities. With the rise in income, living standards; and dependency of exotic and delicate soft foods, populations around the world particularly in Asia have observed Angiostrongyliasis as food-borne parasitic zoonosis (Alicata, 1991; Zhang et al., 2008). The consumption of either raw or undercooked sea-fish may lead to infection with several nematodes belonging to the family Anisakidae. The nematodes commonly involved in human infections are Anisakis simplex, Anisakis physeteris and Contracaecum osculatum (Audicana and Kennedy, 2008). Humans may be accidental hosts by eating raw or undercooked fish that contains the third-stage larvae of Anisakis simplex. After ingestion larvae penetrate the digestive tract and produce a disease, known as Anisakiasi (herring worm disease). The life cycle involves larval stages with several intermediate, paratenic hosts and adult stage, during which the worm may, parasitize the stomach of marine mammals such as seals and dolphins. Generally symptom appears within a few hours after the ingestion of a living worm, it causes an acute and transient infection, lead to abdominal pain, nausea, vomition, slight irritation of bowel and diarrhoea. Some patients may exhibiting clinical manifestations of allergy and infection after eating living parasites simultaneously (Audicana and Kennedy, 2008). The Anisakis simplex allergens are highly resistant to heat and freezing while, cooking is expected to kill the parasites it may not result in loss of their allergenicity and sensitisation (Audicana et al., 2002). Anisakis simplex may be the cause of chronic and relapsing acute urticaria (Falcao et al., 2008). Different methods for preparation of fish such as salting, curing, pickling and smoking, which are generally sterilize to other food-borne but not sufficient for Anisakids (Audicana and Kennedy, 2008). Preventive measure include the evisceration of fish as soon as possible after catching, freezing (-20°C for 60 hrs), public health education and proper cooking, Gnathostoma spinigerum has been reported from Thailand, India, Japan and other Far East countries. Human get infected from contact with meat of infected intermediate host such as fish, amphibians and birds. The larvae in human do not reach maturity and frequently migrate under the skin, mucous membrane, eyes and brain where they cause eosinophilic meningitis (Bhatia et al., 2006).

TREMATODES
The liver flukes such as Clonorchis sinensis and Opisthorchis spp. are considered as emerging public health problem (Keiser and Utzinger, 2005) and according to an estimate about 600 million and 80 million people are at risk for infection with Clonorchis sinensis and Opisthorchis spp, respectively. The Oriental or Chinese liver fluke is of major socioeconomic importance in Far-East countries particularly China, Japan, Korea and Taiwan. The parasite is transmitted via snails that act as first intermediate host.
REFERENCES


