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23

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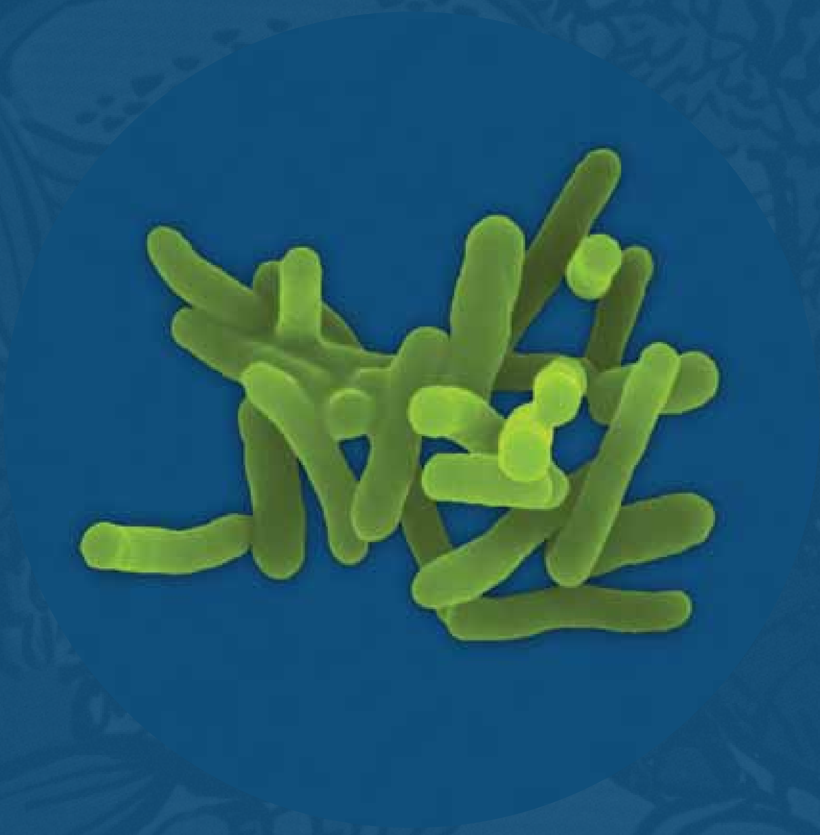

WHO

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Multicriteria-based ranking for risk management of food-borne parasites

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3–7 September 2012, FAO Headquarters, Rome, Italy

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Acknowledgments

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DECLARATIONS OF INTEREST

All participants completed a Declaration of Interests form in advance of the meeting. None were considered to present any potential conflict of interest.

Abbreviations used in the report

CAC	Codex Alimentarius Commission
CCFH	Codex Committee on Food Hygiene
FAO	Food and Agriculture Organization of the United Nations
FERG	WHO Food-borne Disease Epidemiology Reference Group
GAP	Good Agricultural Practice
GHP	Good Hygiene Practice
HACCP	Hazard Analysis and Critical Control Points
OIE	World Organisation for Animal Health
WHO	World Health Organization

Executive Summary

At the 42nd Session (December 2010) of the Codex Committee on Food Hygiene (CCFH), the Committee requested that FAO and WHO

> "review the current status of knowledge on parasites in food and their public health and trade impact in order to provide CCFH with advice and guidance on the parasite-commodity combinations of particular concern, issues that need to be addressed by risk managers, and the options available to them."

On the basis of this information, CCFH would determine the feasibility of developing general guidance as a framework for annexes that would address specific parasite-commodity combinations.

To address this request FAO and WHO initiated a series of activities that culminated in an expert meeting on 3–7 September 2012. Preceding the meeting, relevant data were identified and collated through a formal "call-for-data" and by written reports from experts representing the African, Asian, Australian, European, Near Eastern, North American and South American Regions. Some 93 potential parasites were initially identified for consideration. Preliminary work was also undertaken on the development of a ranking tool and experts provided inputs to this through an on-line questionnaire. This preliminary ranking work combined with additional discussions during the meeting, resulted in a list of 24 parasites for ranking. Experts further identified specific vehicles of transmission for each of the 24 parasites.

It is important to note that food-borne parasitic diseases present some unique challenges, and are often referred to as neglected diseases. Notification to public health authorities is not compulsory for most parasitic diseases, and therefore official reports do not reflect the true prevalence or incidence of the disease occurrences (under-reporting). The parasites have complicated life cycles, which may include multiple hosts, some of which could become food, or the parasites themselves could contaminate food. The disease can present with prolonged incubation periods (up to several years), be sub-clinical or asymptomatic, and epidemiological studies associating illness with a specific food type may not be possible.

With technical guidance, the experts defined global criteria for evaluating the 24 food-borne parasites and rated each parasite along these criteria. The criteria can be summarized as: (1) number of global illnesses; (2) global distribution; (3) morbidity-acute; (4) morbidity-chronic; (5) percentage chronic; (6) mortality; (7) increasing illness potential; (8) trade relevance; and (9) socio-economic impact. Each criterion was then weighted by the experts in terms of their importance. The three criteria for disease severity (3, 4 and 5) were combined into one criterion, giving a total of 7 criteria weights, reflecting the relative importance of each criterion to the overall score. The overall score for each parasite was calculated by normalized parasite criteria scores multiplied by fractional weights, and summed.

The primary outputs of the expert meeting were the development of the ranking tool and the actual global ranking, based primarily on public health concerns, i.e. 85% of weighting. The global ranking of food-borne parasites by "importance" and their primary food vehicle in descending order was:

Taenia solium – Pork
Echinococcus granulosus – Fresh produce
Echinococcus multilocularis – Fresh produce
Toxoplasma gondii – Meat from small ruminants, pork, beef, game (red meat and organs)
Cryptosporidium spp. – Fresh produce, fruit juice, milk
Entamoeba histolytica – Fresh produce
Trichinella spiralis – Pork
Opisthorchiidae – Freshwater fish
Ascaris spp. – Fresh produce
Trypanosoma cruzi – Fruit juices
Giardia duodenalis – Fresh produce
Fasciola spp. – Fresh produce (aquatic plants)
Cyclospora cayetanensis – Berries, fresh produce
Paragonimus spp. – Freshwater crustaceans
Trichuris trichiura – Fresh produce
Trichinella spp. – Game meat (wild boar, crocodile, bear, walrus, etc.)
Anisakidae – Salt water fish, crustaceans, and cephalopods
Balantidium coli – Fresh produce
Taenia saginata – Beef
Toxocara spp. – Fresh produce
Sarcocystis spp. – Beef and pork
Heterophyidae – Fresh and brackish water fish
Diphyllobothriidae – Fresh and salt water fish
Spirometra spp. – Fish, reptiles and amphibians

This ranking should be considered a "snapshot" and representative only of the information available at the time, the criteria used for ranking, and the weightings assigned to those criteria. Also, some of these parasites had very similar rankings, so it might be more relevant to consider the parasites in groups of concern, e.g. top 5, or top 10, rather than the individual ranking position. With more information or with changing human and animal behaviour, and with climate change effects, parasite scoring and subsequent ranking could also change. As with many phases of risk analysis, it may be important to repeat and update the process on a regular basis. In fact, with heavily weighted public health criteria, the ranking results in part reflect risk defined as a function of the probability of an adverse health effect, and the severity of that effect consequential to a hazard in food. If the parasites are ranked only on trade criteria scores, the order of importance changes: *Trichinella spiralis*, *Taenia solium*, *Taenia saginata*, Anisakidae and *Cyclospora cayetanensis* are the top five. In this way, individual criteria can be considered, e.g. by CCFH, outside of the total scoring and weighting processes to assure that specific concerns can be addressed transparently and separately if needed.

Since criteria weights were calculated separately from the individual parasite scoring, alternative weighting schemes reflecting the judgments of risk managers could be used to generate alternative ranking, using the scoring of the parasites undertaken by the expert meeting. Thus, the ranking process that was developed was considered to be as important an output of the meeting as the ranking result, since it allows the global ranking to be updated through changes in scoring and to reflect the priorities of different groups of risk managers or stakeholders through different weighting. The process can be completely re-run at national or regional level using data more specific to that particular country or region.

Finally, the meeting also highlighted some considerations for risk management including possible approaches for the control of some of these food-borne parasites. Reference is also made to existing risk management texts as appropriate. This information, together with the global ranking of the parasites, the identification of the primary food vehicles and information on food attribution, is aimed to assist Codex in terms of establishing their priorities and determining the next steps in terms of managing these hazards. However, it should be noted that management of specific parasites may then require further scientific input, which it was not feasible to provide as part of this present process.

1

Background

Infectious diseases caused by food-borne parasites, generally defined as

> "Any organism that lives in or on another organism without benefiting the host organism; commonly refers to pathogens, most commonly in reference to protozoans and helminths."
>
> (CDC, NO DATE)

are often referred to as neglected diseases, and from the food safety perspective parasites have not received the same level of attention as other food-borne biological and chemical hazards. Nevertheless, they cause a high burden of disease in humans. The infections may have prolonged, severe, and sometimes, fatal outcomes, and result in considerable hardship in terms of food safety, security, quality of life, and negative impacts on livelihoods.

Food-borne parasites can be transmitted by ingesting fresh or processed foods that have been contaminated with the transmission stages (spores, cysts, oocysts, ova, larval and encysted stages) via the environment; by animals (often from their faeces); or by people (often due to inadequate hygiene). Food-borne parasites can also be transmitted through the consumption of raw and under-cooked or poorly processed meat and offal from domesticated animals, wild game and fish containing infective tissue stages (Slifko, Smith and Rose, 2000). Despite the fact that the parasite does not replicate outside a live host, food processing techniques in common use can artificially amplify the quantity of contaminated food that reaches the consumer, increasing the number of human cases (e.g. sausage made from meats of different origin).

Notification to public health authorities is not compulsory for most parasitic diseases, and therefore official reports do not reflect the true prevalence or incidence of the disease (under-reporting) that occurs. Although the global impact of food-borne diseases on public health is largely unknown due to limited data, the burden of disease caused by some parasites has been estimated by the WHO Food-borne Disease Epidemiology Reference Group (FERG). FERG (Fürst, Keiser and Utzinger, 2012) assessed the global burden of human food-borne trematodiasis with data for the year 2005, and estimated that 56.2 million people were infected by food-borne trematodes, of which 7.8 million suffered from severe sequelae and 7158 died worldwide. This and other FERG papers include individual parasites and country data, as well as disability calculations, but reports do not routinely provide food attribution data.

The complexities of the epidemiology and life cycle of each parasite play a central role in the identification, prevention and control of the risks associated with food-borne parasitic diseases. Surveillance for parasitic diseases is complicated by the often prolonged incubation periods, sub-clinical nature and unrecognized, chronic sequelae. The spread of food-borne parasitic diseases is enhanced by changes in human behaviour, demographics, environment, climate, land use and trade, among other drivers. (Orlandi *et al.*, 2002; Macpherson, 2005; Broglia and Kapel, 2011). Some examples worth mentioning in the context of this report are the globalization of food trade, which offers new opportunities for dissemination; variations in food preferences and consumption patterns, such as the expected global increase in meat consumption in emerging countries over the next 20 years; the increasing tendency to eat meat, fish or seafood raw, under-cooked, smoked, pickled or dried; or the demand for exotic foods such as bush meat or wild game. The impact of climate change on parasite life cycles in the environment will depend on several factors, such as the number of hosts (one, two or more) involved in the transmission, the presence or absence of intermediate hosts or vectors, free living stages[1] and reservoir host species (Mas-Coma, Valero and Bargues, 2009; Polley and Thompson, 2009). The potential for climate change could affect parasite host(s) habitats, present a greater likelihood of contamination due to extreme weather events, and create increased pressure on some food sources (Davidson *et al.,* 2011).

Options for control of some parasites that can cause human and zoonotic diseases have been addressed collaboratively by FAO, WHO and the World Organisation for Animal Health (OIE). Extensive guidelines for the surveillance, management, prevention and control of taeniosis/cysticercosis and trichinellosis have been published in 2005 and 2007, respectively, and OIE is currently revising the chapter in the *Terrestrial Animal Health Code* for *Trichinella* spp., *Echinococcus granulosus*

[1] For the purposes of food-borne animal parasite discussions, a free-living stage is a stage of a parasite that lives outside of its host or hosts (Rohr *et al.*, 2011).

and *Echinococcus multilocularis*. Aquaculture product standards are addressed by the Codex Alimentarius Commission (CAC) and the FAO Fisheries and Aquaculture Department. EU directives for food-borne parasites already exist. However, increased multidisciplinary collaboration is needed for risk-based prevention and control of parasites at all stages of the production-to-consumption continuum. Such control is necessary to safeguard public health and minimize production problems and economic losses caused by parasites.

One of the CAC committees, the Codex Committee on Food Hygiene (CCFH), is currently developing "Guidelines for the Control of Specific Zoonotic Parasites in Meat: *Trichinella spiralis* and *Cysticercus bovis*[2]", working in close cooperation with OIE. In undertaking this work the Committee recognized the need to address food-borne parasites more broadly, based on their risk to human health as well as their socio-economic and trade impacts, and, if needed, to provide more general guidance for their control. Therefore, at its 42nd Session (December 2010) the Committee requested that FAO and WHO

> "review the current status of knowledge on parasites in food and their public health and trade impact in order to provide the CCFH with advice and guidance on the parasite-commodity combinations of particular concern, the issues that need to be addressed by risk managers, and the options available to them."

On the basis of this information, CCFH would evaluate the feasibility of developing a general guidance document that would provide a framework where annexes could address specific parasite×commodity combinations. FAO and WHO convened an Expert Meeting on Food-borne Parasites on 3–7 September 2012 at FAO Headquarters, Rome, Italy, to respond to the request of the CCFH.

[2] Clarification note to the CCFH: During the expert meeting, the more precise taxonomic term *Taenia saginata* was used instead of the older and less formal designation, *Cysticercus bovis*. The human disease is taeniasis due to the tapeworm form, while the cattle disease is cysticercosis due to the metacestode (cysticercus) form (Flisser, Craig and Ito, 2011).

2

Objectives and approach

The objectives of the meeting were as follows:

- To develop a ranked list of food-borne parasites of global importance.
- To identify the foods of greatest concern for the most important food-borne parasites.
- To provide an overview of the risk management options and approaches available for the control of the most highly ranked food-borne parasites.

A systematic, evidence-based approach was taken to prioritize the food-borne parasites of global importance. An expert-based, multicriteria ranking tool was designed, and implemented during the meeting. It built on data gathered in advance of the meeting by means of an FAO/WHO formal "call for data" and through electronic working procedures facilitated by the FAO/WHO Secretariat. Additional data came from detailed presentations at the meeting itself. Results of this ranking exercise achieved the first objective and informed systematic discussions to address the second and third objectives.

The meeting was attended by 21 internationally recognized experts in food-borne parasites from 20 countries covering all global regions, together with 9 resource people and the FAO/WHO secretariat, as well as additional resource people from FAO and WHO (see list of Contributors in the front matter). The expert meeting was chaired by Dr Joke van der Giessen, Dr Brent Dixon served as Vice-Chair and Dr Rebecca Traub served as Rapporteur.

The process used to rank food-borne parasites and identify risk management strategies is shown in Figure 1. The process comprised 6 primary steps: (1) Identification of parasites for ranking; (2) Identification of key foods of concern for each parasite; (3) Identification and definition of criteria by which each parasite would be evaluated; (4) Expert scoring of each parasite based on the criteria; (5) Weight importance of each criterion in overall parasite scoring; and (6) Calculation of parasite scores and subsequent ranking. As shown in the figure, some steps can be further broken down into stages, many of which began prior to the meeting. The figure also shows which activities in the process were primarily conducted by the FAO/WHO secretariat and which were done entirely by experts or by experts with FAO/WHO facilitation.

The expert-based parasite ranking exercise was developed following a multicriteria assessment (MCA) approach. It was specifically based on a number of similar assessments conducted for zoonotic and infectious diseases in the past few years (e.g. Anderson *et al.*, 2011; Cardoen *et al.*, 2009; Havelaar *et al.*, 2010; Humblet *et al.*, 2012; Krause *et al.*, 2008; Ng and Sargeant, 2012). Most of these ranking approaches follow a similar multicriteria approach in which a set of hazards are evaluated with a set of criteria, including but not limited to public health, and then overall scores are computed based on a weighting of those criteria. There is no standard methodology for conducting a multicriteria assessment, however, as such ranking exercises are designed for specific risk management contexts, they are inevitably constrained by resources, time and data availability.

The multicriteria-based ranking process included a number of efforts to collect, collate and share data and acquired knowledge. Published information was collected from the peer reviewed literature. This included the publications from the FERG Parasitic Diseases Task Force, FAO/WHO/OIE guidelines and others.

In the 2011 call for data, FAO and WHO requested information on (1) impact of food-borne parasitic diseases; (1A) impact on public health and (1B) socio-economic impact; (2) monitoring and inspection systems; (3) control and management; (4) risk assessment and risk profiles; and (5) risk ranking. Twenty-two member countries and one regional body (EU) responded. Results showed that most had adopted surveillance systems for food-borne parasitic diseases (n=20); monitoring and inspection systems for food-borne parasites (n=15); and appropriate control and management measures (n=15). However, data or information, or both, on socio-economic impact, were very limited, as were risk assessments, profiles and ranking. Most of the respondents recognized that T*richinella, Cryptosporidium, Echinococcus, Giardia, Toxoplasma* and *Taenia* were important as food-borne pathogens.

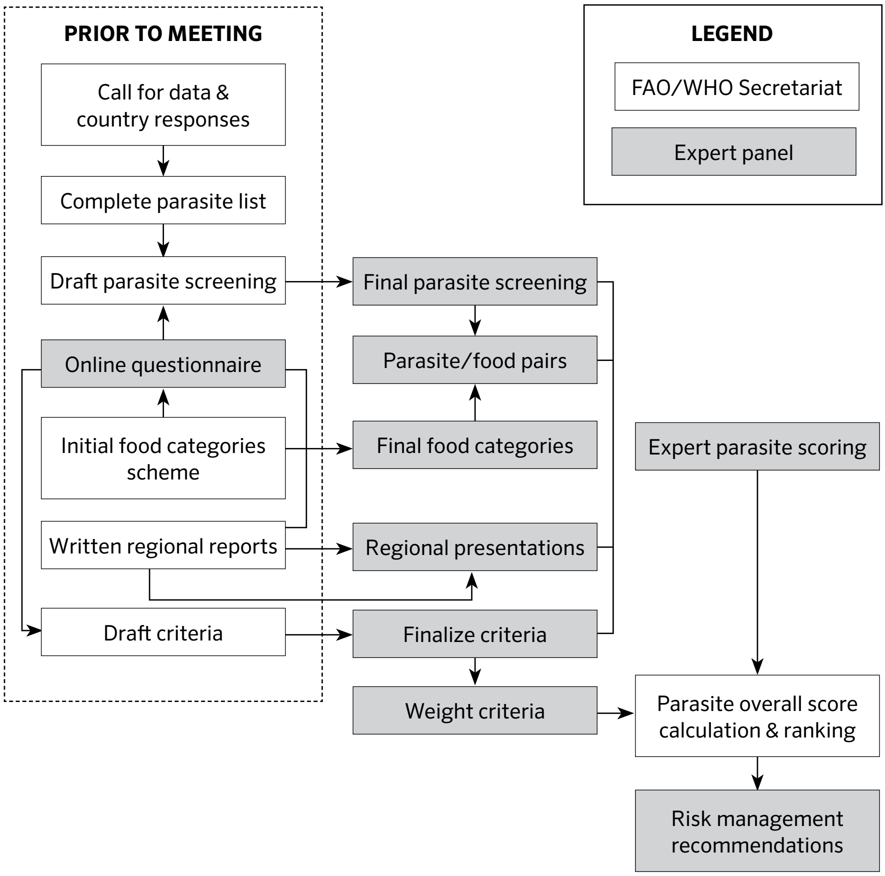

FIGURE 1. Flow chart of the multicriteria ranking exercise

Written reports were produced in advance of the meeting for each of seven geographic regions: Africa, Asia, Pacific (only included Australia), Europe, Near East, North America and South America. Presentations based on these reports were made by the experts at the meeting. The regional reports considered the current overall quantity and quality of data at the regional and global levels; burden of disease and food attribution; data on parasite prevalence, incidence and concentration in the main food categories; agri-food trade; consumer perception; social sensitivity; and risk management options. These reports were used by the experts in their deliberations during the meeting (see Annex 8 of this report).

An online questionnaire was sent to the 21 experts to examine the importance of criteria by which parasites might be evaluated and to elicit experts' initial judgments on the global and regional importance of each of 93 parasites. The questionnaire also captured information about the background and expertise of each expert.

2.1 IDENTIFICATION OF PARASITES

Following a "call for data" (July 2011) and input from experts, a comprehensive list of 93 parasites was created. This list was intended to capture the global set of human parasites for which consumption of food may be a relevant pathway.

An online questionnaire (July 2012) was sent to experts and each expert was asked to score the global and regional importance of each parasite from "not important" to "very important." It was decided that scoring 93 parasites was beyond the scope of the meeting, so results from these scores were used to create a three-tiered initial prioritization of parasites (Table A1 in Annex 1).

This initial prioritization was then used by experts in a screening exercise conducted at the meeting. Led by the Chair and Vice-Chair, experts reduced the parasite list by using inclusion and exclusion criteria. First, parasites were grouped by species or genera (Table A1.2 in Annex 1); then, where applicable, based on common transmission routes, clinical manifestations and attributable food-borne sources. Parasites were excluded when the proportion of food-borne illnesses was negligible or when parasites were only relevant in a limited geographic area (Table A1.3 in Annex 1). The result was a final list of 24 parasites to be ranked.

2.2 DEFINITION OF PRIMARY AND SECONDARY PARASITE AND FOOD PATHWAYS

In order to characterize primary food-borne pathways for key parasites, an eight-category food scheme was developed and incorporated into regional written reports generated by experts prior to the meeting. In their reports, experts identified specific foods within these categories and provided references to support food associations. These categories were created to capture both food animal reservoirs and hosts, as well as foods contaminated within the food chain (such as produce contaminated by water).

Following discussion at the meeting, consensus was reached among the experts on a food scheme comprising five broad categories (land animals; aquatic animals; dairy products; plants; and other) and seventeen sub-categories. This scheme is shown in Table 1.

This scheme was then applied to each of the 24 parasites, and used to identify the primary food vehicles associated with each parasite. For some parasites, secondary food vehicles were also defined, as shown in Table 2.

TABLE 1. Food category scheme

Food category	Food subcategory
Land animals	Beef
	Pork
	Poultry
	Small ruminants
	Other meat
	Game and wild animals
Aquatic animals	Marine fish
	Freshwater fish
	Shellfish
	Aquatic mammals
Dairy products	Dairy products
Plants	Berries
	Fruit juices
	Other fruit
	Leafy greens
	Other vegetables
	Fresh produce (refers to 2 or more of the above)
Other	Other foods

2.3 DEFINITION OF CRITERIA FOR PARASITE SCORING

Based on previous prioritization studies and risk management needs, five categories were considered for the analysis: public health, microbial ecology, animal health, agribusiness and trade, and socio-economic impact. A number of potential criteria in these categories were included in the online questionnaire to appraise the applicability of these criteria and to elicit experts' judgment on which criteria were more important. This information was used to generate an expansive list of 41 potential criteria in these five categories.

The FAO/WHO Secretariat narrowed the list of potential criteria to 11 and presented these to the experts at the meeting. Following extensive discussions on the list of criteria, consensus was reached on a final list of 9 criteria. Of these criteria, 5 relate to the quantity and severity of global disease, while two others relate to the global distribution of these illnesses and the potential for short-term emergence of increased disease. The remaining two criteria relate to the potential for the parasite (in its primary and secondary foods, defined previously) to affect trade, and the impact of the parasite on economically vulnerable communities.

TABLE 2. Parasites and main food vehicles

Parasites	Primary food category	Primary food vehicles	Secondary food vehicles	Global food attribution [1]
Anisakidae	Aquatic animals	Marine fish, crustaceans and cephalopods		All food-borne (fish).
Ascaris spp.	Plants	Fresh produce		Food-borne association but proportion unknown Mainly soilborne (geophagic). Multiple exposure routes in endemic areas. [2]
Balantidium coli	Plants	Fresh produce		Food-borne association but proportion unknown.
Cryptosporidium spp.	Plants	Fresh produce, fruit juice, milk		Food-borne association but proportion unknown (Estimated to be 8% in USA (Scallan *et al*,, 2011). Food-borne outbreaks documented. Water may be most important route.
Cyclospora cayetanensis	Plants	Berries, fresh produce		Mostly food-borne, e.g. basil, berries, lettuce, etc.
Diphyllobothriidae	Aquatic animals	Fish (freshwater and marine)		All food-borne.
Echinococcus granulosus	Plants	Fresh produce		Food-borne association but proportion unknown.[3]
Echinococcus multi-locularis	Plants	Fresh produce		Food-borne association but proportion unknown. Epidemiological risk surveys suggest food is not major transmission route.[4]
Entamoeba histolytica (Older studies did not distinguish Entamoeba *histolytica* from *E. dispar.*)	Plants	Fresh produce		Food-borne association but proportion unknown. Waterborne route important. Hygiene and food handlers often implicated.
Fasciola spp.	Plants	Fresh produce (aquatic plants)		Mainly food-borne through aquatic plants. Outbreaks reported.
Giardia duodenalis (syn. G. *intestinalis*, *G. lamblia*)	Plants	Fresh produce	Molluscan shellfish	Food-borne association but proportion unknown. Food-borne outbreaks documented. Handlers and multiple food types implicated (Christmas pudding, etc.). Water-borne outbreaks reported.
Heterophyidae	Aquatic animals	Fresh- and brackish-water fish		All food-borne (fish).
Opisthorchiidae	Aquatic animals	Freshwater fish		All food-borne (fish).

Parasites	Primary food category	Primary food vehicles	Secondary food vehicles	Global food attribution [(1)]
Paragonimus spp.	Aquatic animals	Freshwater crustacea		All food-borne.
Sarcocystis spp.	Land animals	Beef	Pork	All food-borne for S. suihominis and S. bovihominis
Sparganosis – *Spirometra* spp.	Other	Frog, snake meat		All food-borne
Taenia saginata	Land animals	Beef		All food-borne. Taeniosis exclusively meatborne.
Taenia solium	Land animals	Pork		Taeniosis exclusively meatborne.
	Plants (cysticercosis)	Fresh produce		Food-borne association but proportion unknown. Cysticercosis mainly soilborne; contaminated plants may be significant in some regions.
Toxocara spp.	Plants	Fresh produce		Food-borne association but proportion unknown. Mainly soilborne (geophagy).
Toxoplasma gondii	Land animals	Meat from small ruminants, pork, beef, game meat (red meat and organs)	Fresh produce, seafood, dairy products	Food-borne association (fresh produce) but proportion unknown. Multiple routes of infection, but transmission through meat is important. (Meatborne *Toxoplasma* infections estimated to be 22% in USA, Boyer *et al.*, 2011; 53% in Chile, Muñoz *et al.*, 2010; 26% in Colombia, López *et al.*, 2005) Waterborne outbreaks documented.
Trichinella spiralis	Land animals	Pork	Horse, Game meat	Exclusively meatborne. Making sausage or similar food products increases the risk to the consumer from a single animal.
Trichinella spp. (other than *Trichinella spiralis*)	Land animals	Game meat [(5)]	Pork	Exclusively meatborne.
Trichuris trichiura	Plants	Fresh produce		Food-borne association but proportion unknown. Mainly soilborne.
Trypanosoma cruzi	Plants	Fruit juices		Food-borne outbreaks documented. Fruit juice in limited geographic area. Mainly transmitted by insects

Notes: (1) The information in this column is based on peer reviewed publications in the scientific literature, unpublished reports and expert opinion, which may be the only approach to estimate food attribution for some of the parasitic diseases on a global basis. (2) Ascaris spp. eggs can become ubiquitous in an endemic area, making attribution difficult if not impossible. (3) The incubation period for *Echinococcus granulosus* can be as long as 5 to 15 years; it is not possible to precisely identify an exposure occurring many years previously. However, there are many articles indicating that E. granulosus eggs contaminate plants, and evidence that people in the endemic, developing countries consume vegetables, including raw. It is almost impossible to pinpoint the food source because the transmission routes are varied (e.g. contact with dog, other canids (fox, wolf), soil, etc.). (4) The incubation period for Echinococcus multilocularis can be 5–15 years, and the disease, alveolar echinococcus, is diagnosed at an advanced stage; it is not possible to precisely identify an exposure occurring many years previously. (5) Wild boar, crocodile, bear, walrus, etc.

The final criteria selected for scoring were: (1) Number of global food-borne illnesses (manifesting disease); (2) Global distribution (number of regions); (3) Acute morbidity severity (disability weight); (4) Chronic morbidity severity (disability weight); (5) Fraction of illness that is chronic (%); (6) Case-fatality ratio (%); (7) Likelihood of increased human burden (%); (8) How relevant is this parasite-food pathway for international trade?; and (9) What is the scope of the impact on economically vulnerable communities?

For each of these 9 criteria, between three and five scoring levels were defined. For 7 criteria, these scoring levels were defined quantitatively, while the remaining two were qualitative. Scoring levels were intended to allow for appropriate differentiation among the 24 parasites. These criteria, along with a question pertaining to data quality, are shown in Annex 2. Note that question 8, on international trade concerns, relates specifically to the pathogen in its primary food vehicle, whereas all other questions refer to the parasite in general.

2.4 SCORING PARASITES ACCORDING TO CRITERIA

Experts were divided into five groups of 4 to 5 people, organized so that each group had, to the extent possible, coverage across regions and expertise. Each group was given three documents: a summary card form for each parasite (see Annex 2), a document explaining each criterion and how to score it (Annex 3), and a list of parasites. The lists of parasites provided to each group were staggered in order to maintain equal numbers of scores across parasites, because all groups were unlikely to complete summary cards for all 24 parasites.

Each group used available material, such as regional written reports, published literature and WHO material on disability weights, coupled with online searches, to facilitate a discussion of each criterion for each parasite. Each group scored a summary card for each parasite on their list. Preliminary criteria scores were tabulated into spreadsheets for each group, and preliminary scores were presented back to the group. Discussions around large disparities in preliminary scores allowed the group to identify some differences in interpreting criteria. Once the expert panel reached consensus and greater clarity and agreement on criteria definitions, groups re-convened to review their scores. Following a second tabulation of preliminary results and similar discussion on criteria definitions, a third round of scoring was conducted to obtain final group parasite criteria scores.

Ultimately, two groups scored all 24 parasites and the remaining groups scored 21, 18 and 14 parasites respectively. Thus, 11 parasites had 5 sets of criteria scores, 7 parasites had 4 sets of scores, and 6 parasites had 3 sets of scores.

2.5 DEFINITION OF CRITERIA WEIGHTS

In multicriteria assessment, individual criterion scores are combined into an overall score for each parasite. In this instance, each criterion score was first normalized to a 0–1 scale, with equal divisions among levels. To combine these criteria scores, each criterion was weighted as a fraction of the total score, with all weights summing to 100%.

TABLE 3. Mean of elicited criteria weights used in the multi-criteria ranking.

Scoring criterion		Criterion weight
W1.	Number of global food-borne illnesses	0.22
W2.	Global distribution	0.14
W345.	Morbidity severity	0.22
W6.	Case-fatality ratio	0.15
W7.	Increasing illness potential	0.07
W8.	Trade relevance	0.10
W9.	Impacts on economically vulnerable communities	0.10

In this approach, each criterion is assigned its own weight, though in this case, three criteria relating to the severity of disease morbidity were combined (3, severity weight for acute disease; 4, severity weight for chronic disease; and 5, fraction of disease that is chronic) into a single adjusted criterion. Details are explained in the next section, but this combination resulted in requiring a single weight for morbidity severity, shown in Table 3 as W345. Thus, although there are 9 criteria used to compute the overall score for each parasite, there are only 7 criteria weights.

A worksheet (Annex 4) was given to each group and to six from the FAO/WHO Secretariat. Table 3 presents the mean criteria weights across all participants.

Criteria weights reflect the relative importance of the individual criterion in the overall score. Table 3 shows that public health criteria had most influence on the outcome of the ranking, accounting for 80% of the total weights agreed by experts. In particular, disease severity (morbidity severity and case-fatality ratio) accounted for 39% of the total score. These average expert criteria weights were incorporated into the ranking model.

Because criteria weights are calculated separately from individual parasite scoring, alternative weighting schemes reflecting the judgments of risk managers or stakeholders could be used to generate alternative rankings that nevertheless are based on expert parasite criteria scores.

2.6 CALCULATION OF PARASITE SCORES

The overall score for each parasite is given by the following equation:

$$Score = C1*W1+C2*W2+\{C3*(1-C5)+C4*C5\}*W345+C6*W6+C7*W7+C8*W8+C9*W9$$

where C are parasite-specific normalized criteria scores and W are constant criteria weights that are the same for all parasites. Criteria 3, 4 and 5 are combined to produce a single morbidity criteria; it is essentially the weighted average of acute and chronic disease severity. Thus, criteria 3, 4 and 5 have one associated weight, denoted in the equation as W345. Otherwise the calculation is straightforward: normalized parasite criteria scores are multiplied by fractional weights, and summed. Overall scores therefore range from 0 to 1.

A spreadsheet model was developed to calculate overall scores for each parasite based on all group summary cards and averaged criteria weights. The resulting scores were then ranked to produce the current list of global food-borne parasites.

3

Results

3.1 THE GLOBAL RANKING OF FOOD-BORNE PARASITES

The results of the ranking exercise, where the top ranking parasites are arranged on the x-axis from left to right in decreasing rank order and the average weights (in percentage) on the y-axis, are presented in Figure 2. This figure was obtained from the average of all elicited weights for the criteria. Among the top ranked parasites are those that have already been singled out by WHO as neglected tropical diseases (NTD), and identified by FERG as priorities for further burden of illness studies.

As noted in Chapter 2, this ranking is a combination of scoring the parasites based on predefined criteria and weighting the criteria based on the importance assigned to them by the expert meeting participants. Since many of the criteria were public health related, there were not big differences between the final ranking and the outcome of the scoring exercise alone, where all criteria are considered to have equal weight. Sensitivity analysis was carried out using alternative criteria weighting schemes (see Annex 5). Figure A5.3 in Annex 5 compares the ranks for global foodborne parasites scored across alternative criteria weighting schemes. Figure A5.5 in Annex 5 presents the scores for the public health criteria only, weighted equally, compared with baseline ranking based on all criteria and elicited weights. These figures are included for reference and indicate that the top 4 parasites remain the same based on expert scoring. It is also interesting to note that the gradually declining trend along the x-axis from left to right remains generally the same. Therefore the weighting of criteria did not radically change the ranks,

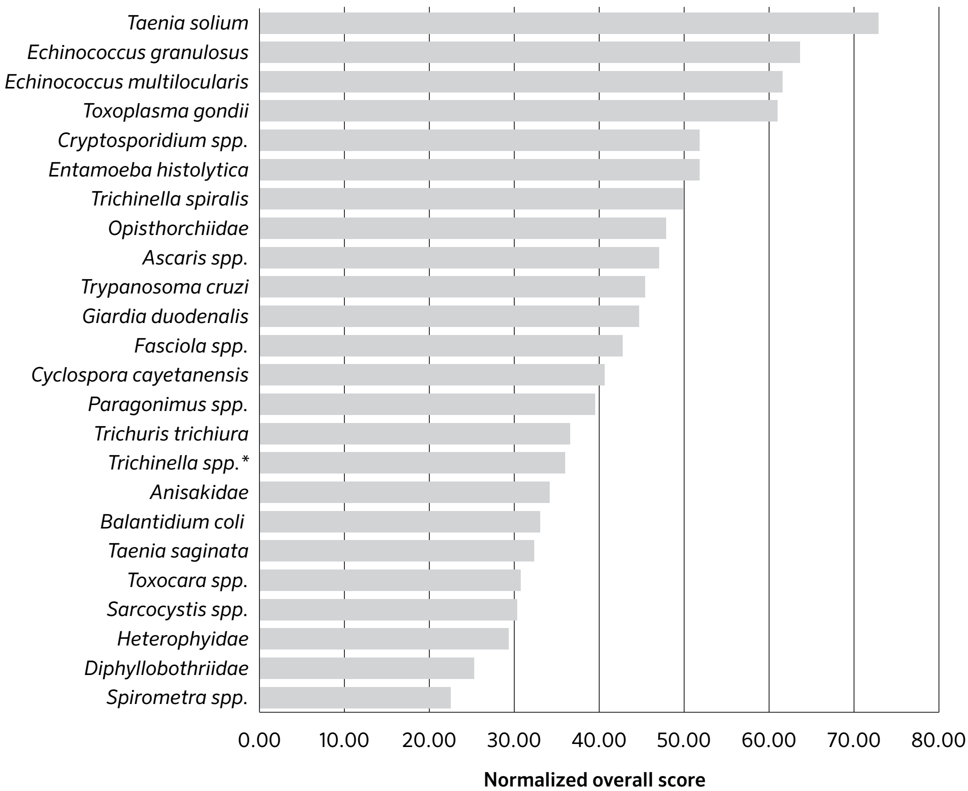

FIGURE 2. Global ranking of food-borne parasites using a multicriteria ranking tool for scoring parasites, with weighting of scoring criteria based on criteria scores and weights elicited from expert meeting participants (Note: *Trichinella* spp.* includes *Trichinella* species except T. *spiralis*).

and the public health criteria alone were not so different from the expert ranking. This also reflects the dominance of public health-related criteria in the ranking tool.

A short overview of the top 8 parasites in the above ranking is provided below. Further information relevant to the management of these parasites is provided in Chapter 4. As risk managers consider individual parasites, there will be a need to go into more depth for each. Specific information on the 24 ranked parasites was generated after the meeting and can be found in Annex 7.

Taenia solium

Taenia solium (ranked 1st in Figure 2) is estimated to infect millions of persons worldwide. It is unique in that the larval or cysticercus stage can infect humans as well as pigs, and can cause a wide range of debilitating neurological problems, including epilepsy. Human cysticercosis often occurs in areas where traditional pig husbandry is practiced, and is endemic in the Andean area of South America, Brazil, Central America and Mexico, China, India, Southeast Asia, and sub-Saharan Africa. The disease can be spread by poor sanitation and hygiene and improper slaughterhouse services. Human neurocysticercosis is increasingly being reported in developed countries, possibly due to increases in globalization and immigration (Carabin *et al.*, 2011).

Echinococcus granulosus and *E. multilocularis*

In a recent report on neglected tropical diseases, scientists stated for *Echinococcus granulosus* and *E. multilocularis* (ranked 2nd and 3rd in Figure 2):

> "The diseases caused by these parasites represent a substantial burden on the human population. Present estimates suggest that cystic hydatid disease, caused by *Echinococcus granulosus*, results in the loss of 1 to 3 million disability-adjusted life years per annum. The annual cost of treating cases and economic losses to the livestock industry probably amount to US$ 2 billion. Alveolar echinococcosis, caused by *E. multilocularis,* results in the loss of about 650 000 disability-adjusted life years per year. These diseases are perhaps some of the more important global parasitic diseases, with more than 1 million people affected at any one time, many showing severe clinical syndromes."
>
> (WHO, 2011)

Toxoplasma gondii

Toxoplasma gondii is capable of infecting virtually all warm blooded animals, including humans. It has been estimated that close to 30% of the world population may be infected by *Toxoplasma gondii*. Pregnant women and immunocompromised individuals are the main risk groups, although immune-competent persons may develop ocular disease as a result of an infection later on in life. Furthermore, *T. gondii* infection has been associated with behavioural changes and development of psychiatric disorders. The parasite may be transmitted trans-placentally to the foetus when T. *gondii* infections occur during pregnancy. This can result in foetal death, central nervous system abnormalities or eye disease, affecting the child throughout its lifetime. The two routes of food-borne infection—via tissue cysts in various types of meat or organs, or via oocysts contaminating a wide range of food vehicles—makes transmission control a challenge.

Cryptosporidium spp.

The importance of *Cryptosporidium* spp. as a food-borne parasite has emerged in part through outbreak investigations that have linked fresh produce, fruit juice and dairy products with disease. In the USA, it is estimated that 8% of the annual food-borne disease burden may be attributed to this parasite. For most people, symptomatic cryptosporidiosis is characterized by acute watery diarrhoea, often accompanied by abdominal pain, nausea or vomiting, low grade fever, headache and general malaise. Most patients recover within 2–3 weeks, but highly immunocompromised patients may suffer chronic illness, also leading to severe disease and sometimes death. For most parasitic infections there is some treatment available, but for *Cryptosporidium* spp. infections in the immunocompromised, there is none. There is also increasing evidence that cryptosporidiosis may have long-term effects, such as chronic gastrointestinal conditions. In addition, it is noted that cryptosporidium oocysts are very resistant to chlorine commonly used to treat water.

Entamoeba histolytica

Entamoeba histolytica, as with *Cryptosporidium* spp., is probably primarily transmitted through food handlers and contaminated water, which can enter the food chain causing illnesses attributed to fresh produce; it should be noted that, unlike some *Cryptosporidium* spp., *E. histolytica* is not zoonotic. Amoebiasis is traditionally limited to dysenteric-like symptoms, with abdominal pain, bloody or mucoid diarrhoea, and tenesmus, but has the ability to invade extra-intestinal tissues also, e.g. inducing liver abscesses, and extra-hepatic spread of E. histolytica is associated with relatively high mortality (20–75%). One of the problems with its detection is that microscopy methods used for E. histolytica do not differentiate it from non-pathogenic species. This parasitic disease is of importance globally, but occurs predominately in developing countries and may be transmitted with immigrant populations to developed areas. Unlike *Cryptosporidium* spp., *E. histolytica* is susceptible to chlorine.

Trichinella spiralis

Trichinella spiralis, like all *Trichinella* species, has a unique lifecycle in that there is no environmental transmission stage – thus all cases are due to ingestion of meat containing the encysted larvae; meat types typically associated with *T. spiralis* include pork, horse meat, and game. Globally, there were 65 818 human infections reported between 1986 and 2009, with most of these reported for hospitalized patients in Romania, where 42 patient deaths were reported. However, there may be increased exposure through human behavioural trends, e.g. consumption of raw horse meat, dog meat, wild boar, and other sylvatic animal meats, as well as practices of free-range animal husbandry (infected animals are asymptomatic).

Opisthorchiidae

The Opisthorchiidae family includes various digenean parasites, of which the most medically important are *Clonorchis sinensis, Opisthorchis viverrini* and *Opisthorchis* *felineus.* All are transmitted to humans via ingestion of the encysted metacercaria in the flesh or skin of freshwater fish. Opisthorchiasis/clonorchiasis occurs autochthonously in southeast Asia, eastern Europe, and central Asia. FERG reported over 8 million infections globally in 2005, almost all of which occurred in southeast Asia, where over 300 000 people were heavily infected and 1323 died. Disability-adjusted life years was 74 367. The FERG report further states that awareness of this food-borne problem is limited; only Japan and South Korea have established successful control programmes for fish-borne trematodiases. Opisthorchiasis is particularly worrisome in its potential to be carcinogenic; case-control studies have suggested that a substantial proportion of cholangiocarcinoma in some Asian countries can be due to infection with *O. viverrini*.

Summary

The fact that this is a global ranking may mean that some diseases that are severe and often fatal, but limited to a particular region, are not highly ranked. One example is Chagas disease, transmission of which is at present largely restricted to parts of Central and South America, with FERG reporting over 11 000 deaths due to T*rypanosoma cruzi* worldwide in 2004. However, survival of the trypomastigotes in fruits and juices might present an unknown risk for global dissemination in the world market.

The parasites currently being considered by the CCFH were ranked seventh (*T. spiralis*) and nineteenth (*T. saginata/C. bovis*) for overall importance by the experts.

3.2 TRADE SCORES FOR THE RANKED PARASITES

The data used to rank parasites and generate Figure 2 are used to produce Figure 3, in which only the average trade criteria scores for each parasite are displayed. This figure suggests that there may be additional or separate trade issues that could be considered by risk managers such as Codex and national food authorities.

The parasites currently contemplated by the CCFH, *T. spiralis* and *T saginata/C. bovis,* were considered among the most important for trade, based on criteria scores. In the regional reports, *Trichinella spiralis, Taenia saginata, Taenia solium* and/or *Echinococcus granulosus* were mentioned as current or potential trade concerns in the African, Australian, European, Near Eastern and South American Regions. The North American and Asian Regions did not address this issue directly.

It may be of interest to risk managers that the Anisakidae that ranked lower (17th) in overall importance, scored higher for the trade criteria, and were mentioned in

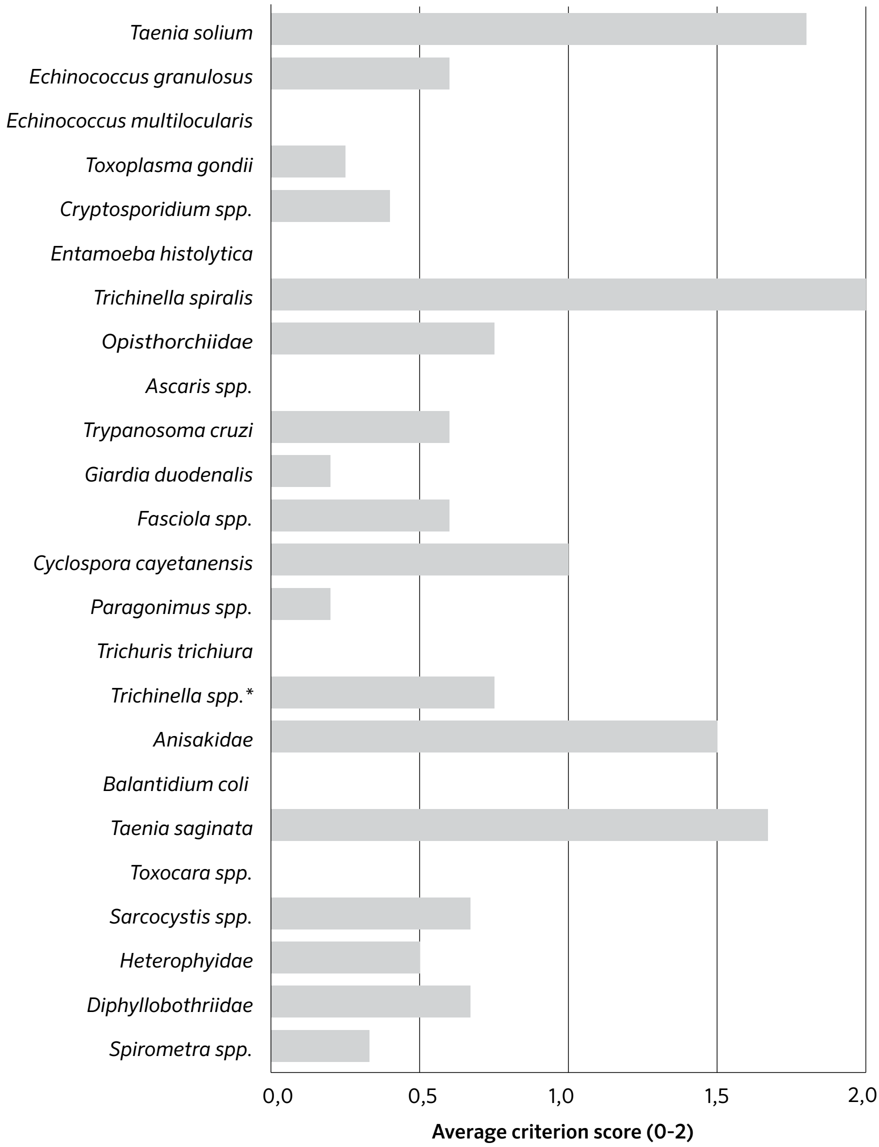

FIGURE 3. Relative ranking of international trade importance of parasites in primary food vehicles: average expert scores for Criterion 8 (based on Table 2; *Trichinella* spp.* includes all *Trichinella* species except *T. spiralis*)

several country reports as a class of organisms important to the country. These are probably countries that trade or consume fish extensively.

Conversely, parasites of concern in the overall ranking may not rank high as a trade concern. An example is *Toxoplasma gondii,* which might be prevalent in meat products but is microscopic and does not affect the appearance of the products, and there is no rapid, inexpensive, accurate test available. Therefore, for trade purposes, it would be ranked lower than the easily visible and detectable parasites.

3.3 SOCIO-ECONOMIC IMPACTS FOR THE RANKED PARASITES

The data analysed to rank parasites and generate Figure 2 are also used to produce Figure 4, which presents average scores for the socio-economic impact criterion. The figure indicates that there may be additional or separate socio-economic concerns not addressed in the overall ranking or in trade issues. An example of this is *Cyclospora cayetanensis*, which may require further investigation. It is probable that this reflects the known and on-going, socio-economic impacts on Guatemalan berry farmers, following the relatively extensive outbreaks of cyclosporiasis in North America during the 1990s. Outbreaks were primarily associated with berries imported from Guatemala.

Diseases caused by *Taenia solium* (ranked 1st) and *Echinococcus granulosus* and *E. multilocularis* (ranked 3rd and 4th, respectively) contribute to economic losses in human and animal populations in many parts of the world. They are considered preventable diseases that can be controlled or eliminated and should be prioritized (Carabin *et al*., 2005). Stigmatization and social isolation, attached to the occurrence of epilepsy caused by neurocysticercosis (*T. solium* infection), are examples of societal impact presented in the African Regional report, that are difficult to quantify but add to the socio-economic burden of this disease.

The parasites currently contemplated by the CCFH, T. *spiralis* and *T. saginata/C. bovis* were not considered important in terms of the socio-economic criterion.

3.4 CONCLUSIONS

The ranking exercise has provided a picture of the food-borne parasites of global importance today and has created a seemingly useful tool that is transparent and reproducible. The tool can be used with emphasis on different criteria and with or without weight factors. It is imperative that future use of this ranking tool and

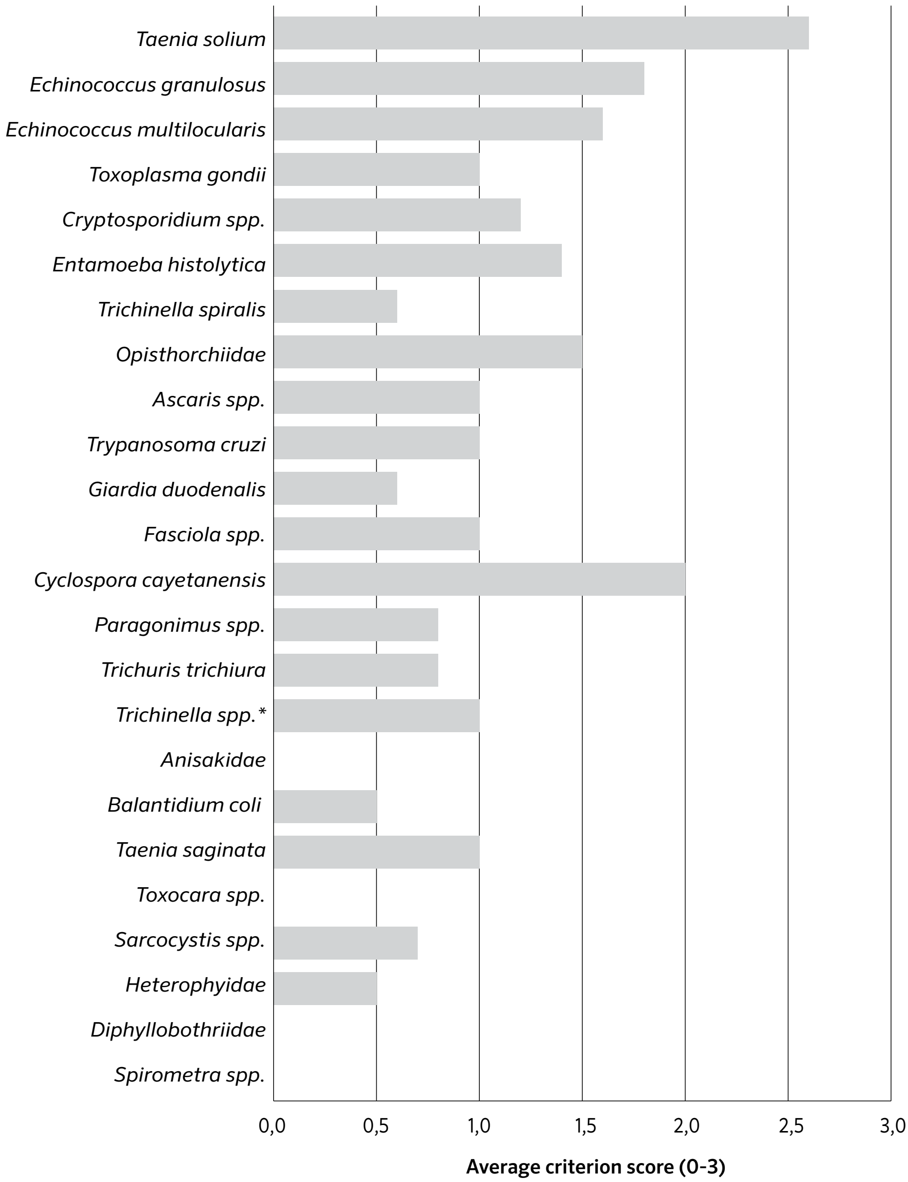

FIGURE 4. Relative ranking of socio-economic impacts of parasites to vulnerable communities: average expert scores for Criterion 9 (based on Table 2; *Trichinella* spp.* includes all *Trichinella* species except *T. spiralis*)

strategy be undertaken in a transparent manner. By using this approach, the results can be compared when the procedure is repeated.

The experts ranked the most important parasites by using multicriteria analysis during the meeting. The results shown in Figure 2 indicate that the method clearly defines those parasites that are highly ranked and those considered of lower rank. While *Taenia solium* clearly came out on top, there were less marked differences between the parasites that ranked second, third and fourth. Similarly those that ranked fifth, sixth and seventh are very close together, suggesting that the individual ranking is less important than the overall picture that the ranking provides in terms of food-borne parasites. As noted in the explanation of the weighting of the criteria, public health importance was the primary driver of ranking, with almost equal importance being given to illness and severity. This importance given to severity will have contributed to the high ranking of *Echinococcus granulosus*, ranked second, followed by *E. multilocularis*.

Toxoplasma gondii ranked fourth. The predominant disease burden of this parasite is confined mainly to substantial risks in pregnancy to the unborn, and in immunocompromised people (e.g. HIV/AIDS, transplantation patients). However, acquired toxoplasmosis also may contribute also an additional, substantial disease burden; many uncertainties still exist. The ranking order is affected by data availability; in the absence of data, or when data is limited, it is more difficult to categorize a parasite×food commodity. New data may influence ranking order. For example, the increasing number of papers linking toxoplasmosis with chronic illness (Havelaar *et al*., 2012), including mental illness (Henriquez *et al*., 2009) may push this parasite further up the ranking in the near future. Therefore, the parasite ranking list developed here should not be considered to be absolute or static; in order to remain current and fit for purpose, it must be updated periodically. The tool can be used also for prioritizing regional and national agendas for policy or research activities. There may be more specific data at national or regional level, as well as differing judgments on the importance of the various criteria, which could lead to a different ranking at a local level.

4

Risk management options for the higher ranked parasites

The identification of ranked parasites in Figure 2 is based not only on scientific evidence where available (including both published and unpublished data), but also on expert experience and opinion, and is weighted primarily by the public health concerns of the experts. The ranking of parasites by overall importance is the primary input to the risk managers in CCFH, who will then consider other issues relevant to management priorities and actions.

The ranking approach used in the expert meeting can be applied at the national level, where scoring may change, based on data availability and where weights may be placed on different criteria, based on the national situation or risk management issue.

Risk managers need to ensure that aspects other than the initial ranking by the experts that need to be considered in the decision-making process should also be evidence-based where possible, and done in a transparent manner. This section outlines some of these other considerations.

4.1 GENERAL RISK MANAGEMENT CONSIDERATIONS

It is important to recognize at all levels—global, regional and local—that there is a significant lack of information regarding food attribution for many parasitic diseases (Table 2). This is especially true for parasitic infections in which there may be a prolonged period (possibly many years) before symptoms appear (e.g. *Echinococcus* spp.) or those producing a chronic progression of disease (*Ascaris* spp., *Trypanosoma cruzi* and *Trichuris trichiura*). Food may be an important vehicle of transmission, but these parasites are not considered to be exclusively food-borne. For example, food may not be the primary transmission vehicle for *Echinococcus* spp.; however, the experts still considered these parasites as potential food-borne risks and advocate that further evidence be gathered to close this knowledge gap. *Echinococcus granulosus* and *E. multilocularis* ranked 2nd and 3rd, respectively, based largely on the potential severity of their associated diseases.

4.2 GENERIC RISK MANAGEMENT OPTIONS

As with other food-borne biological hazards, there are some generic good practices that are relevant for the control of food-borne parasites but are not necessarily unique to parasites. The importance of such practices may therefore already be captured in various existing risk-management documents. However, the recognition of parasites as being somewhat neglected warrants mention of any relevant control measures and management options.

4.2.1 Primary production and pre-harvest

While many of the parasites of concern are meat or fish-borne, for many others the entry into the food chain is via water or soil, or both. For example, *Ascaris, Cryptosporidium, Cyclospora, Echinococcus* and *Giardia* are essentially transmitted through the faecal-oral route, but may be transmitted by contaminated water during primary production of foods such as fresh produce. Thus, the primary production and pre-harvest stage of the food chain are critical in terms of control of numerous parasites, and it was considered that parasites may not be adequately considered in Good Agriculture Practices (GAPs). Some important considerations are highlighted here.

Parasites transmitted by the faecal-oral route

Given the importance of the faecal-oral route of transmission for some parasites, areas for cultivation of fresh produce, particularly for raw consumption, need to be assessed in terms of their susceptibility to faecal contamination, whether from run-off from wild animals, farm animals, domestic animals or and humans, and the necessary measures taken to manage the identified risk.

The importance of on-farm sanitation and hygiene in interrupting the life cycle of parasites and minimizing the opportunity for the faecal-oral route of transmission needs to be recognized, with appropriate installation and use of the relevant facilities promoted, e.g. functional on-farm latrines, and adequate hand-washing facilities.

The use of organic fertilizer, particularly on produce, should be monitored closely in order to ensure that it is composted adequately to destroy parasite transmission stages prior to use. However, it should be noted that the effectiveness of composting in destroying or inactivating parasites is uncertain, and should be considered a knowledge gap.

Zoonotic parasites

For those parasites with an indirect life cycle, special consideration must be given to breaking the cycle at the level of the intermediate host, such as snail (intermediate host) control in the case of trematode parasites in aquaculture.

The role of dogs and cats (domestic or feral) in transmission of certain parasites needs to be highlighted and farmers and other relevant stakeholders educated on good practices, e.g. no feeding of raw or untreated carcasses or offal of livestock and fish to domestic dogs and cats, or allowing wild canids and felids access to dead livestock, aborted foetuses, etc., and fish products; population control of semi-domesticated, stray or feral dogs and cats in close vicinity to the farm or aquaculture ponds.

Mass treatment of reservoir hosts, such as livestock, at frequent intervals in a sustainable fashion should ensure reduction in environmental contamination of infective stages. This applies to dogs in the case of echinococcosis by *Echinococcus granulosus*.

Water is an important vehicle for transmission for a number of food-borne parasites. Thus attention to water quality throughout the food-chain, from primary production through processing to consumption is very important.

Although not specific to primary production, monitoring and surveillance were considered to be important tools in the control of parasites, and for complete effectiveness may need to begin at the pre-harvest stage. For example, the ability to trace back infected animals at the abattoir level will allow identification of 'high risk' animals or fish populations or regions, and help allocation and targeting of resources for control. Furthermore, the ability to trace back fresh produce to the country, and even farm, of origin will allow identification of 'high risk' regions for subsequent risk management decisions. Monitoring and surveillance programmes can identify potentially emerging trends and risks for regional incursion (displaced forest animals or hosts in expanding urban environments).

4.2.2 Post-harvest

While post-harvest opportunities for control will be very dependent on the commodity of concern, it was considered that current Good Hygiene Practice (GHP), and HACCP plans for processing, etc., might not address parasitic hazards adequately.

In terms of processing, many parasite stages in meat and fish are susceptible to freezing as a process step and to controlled cooking at the process and consumer levels. However, the time×temperature combinations can be important, and in the cases of some parasites, such as *E. multilocularis* eggs, lower temperature domestic freezing may not be adequate. Irradiation can be an effective control measure and guidelines are available for its use in the control of *Toxoplasma* and *Trichinella*. Other control measures such as curing, salting, drying and high pressure processing need evaluation for specific parasites and food commodity contexts. Vacuum packing and chilling do not alter the viability of parasites in meat (e.g. *Toxoplasma* tissue cysts in meat).

4.2.3 Education

Education and awareness raising was identified as an important component of food-borne parasite control, and in some cases may be the only feasible option available. Education should be directed to actors throughout the food chain from farm and abattoir workers to food handlers (consumers and food retail outlets), and should address the gamut from good animal husbandry practices to hygiene and sanitation measures. In terms of consumer education there may also be a need to address specific high risk population groups. For consumers, especially those who are pregnant or immunocompromised (e.g. individuals with HIV/AIDS), advice on the preparation and consumption of high risk foods such as fresh produce and tubers, carrots etc., adequate cooking of meat and fish prior to consumption and the importance of hygiene, e.g. hand-washing, is critical.

4.3 SOME SPECIFIC CONSIDERATIONS FOR RISK MANAGEMENT

During the meeting specific consideration was given to the management of the eight top ranked parasites, and some of the important aspects for consideration by risk managers in deciding how to address these parasites. These considerations for *Taenia solium*, *Echinococcus granulosus*, *E. multilocularis, Toxoplasma gondii, Cryptosporidium* spp., *Entamoeba histolytica, Trichinella spiralis* and the Opisthorchiidae family are summarized in Table 4. Where they were identified, details of existing risk management texts or guidelines are provided. It should be noted that providing more specific input on the top eight ranked parasites was a function of the time available at the expert meeting rather than any technical consideration.

In addition, Table 5 provides some information on the global trade in those commodities identified as primary vehicles for the ranked parasites, thus providing an overview of their importance.

TABLE 4. Some specific risk management considerations relating to the top eight ranked parasites

Parasite	Hosts and main transmission routes – Food chains of concern	Severity of illness	Overarching factors for consideration in risk management	Examples of management options and challenges along the food chain			Examples of risk management texts and guidance
				On-farm	Post-harvest or processing	Retail and consumer	
Taenia solium	Two transmission routes: Undercooked pork – adult tapeworm infection (taeniosis) *T. solium* eggs – environment (e.g. via fresh produce) – larval stage infection (cysticercosis)	Taeniosis – a relatively benign disease. Cysticercosis a severe, potentially fatal, infection	Classified as eradicable but expensive and challenging to control. Human host means behaviour important in transmission Control strategies linked to whether a geographic area is categorized high or low risk	Vaccine use and chemo-therapeutic control in pigs. Good pig husbandry practices critical for sustainable control. Safe application of manure to control environmental contamination. Maintain high water quality.	Safe slaughter practices and an effective inspection system. Food handler education to target personal hygiene.	Consumer education on the role of humans in transmission. Consumption of raw produce in endemic areas is high risk. Cooking is effective.	FAO/WHO/OIE 2005.
Echinococcus granulosus	Fresh produce Sheep, cattle, goats and pigs are intermediate hosts	Severe clinical syndrome, cystic hydatid disease	Not complicated to control but requires coordination among relevant authorities. Effective treatment of dogs needs confinement and incineration of faeces for 2 days post treatment, then repeat in 45 days.	Elimination of the parasite in dogs. Education of farmers to minimize on-farm contamination and infection of animals. Control of water used, including fruit and vegetable production. Sheep and/ or dog vaccination may be a future option.	Effective inspection system to ensure GHP and GAP. Ability to trace back to farm. Keeping dogs away from potentially infected offal and from near abattoirs. *Echinococcus* eggs are not susceptible to freezing (except when core temperature of food is minus 80°C for 48 hrs or minus 70°C for 4 days).	Education of food handlers and consumers regarding food preparation and personal hygiene. *Echinococcus* eggs are not susceptible to freezing (except when core temperature of food is minus 80°C for 48 hrs or minus 70°C for 4 days).	WHO/OIE, 2001. OIE, 2005a. WHO, 2011.

Parasite	Hosts and main transmission routes – Food chains of concern	Severity of illness	Overarching factors for consideration in risk management	Examples of management options and challenges along the food chain			Examples of risk management texts and guidance
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Echinococcus multilocularis	Fresh produce. New trend may be migration of the parasites with sylvatic incursion into residential areas.	Severe clinical syndrome, alveolar echinococcosis	Far more challenging to control than *E. granulosus* given the predominance of a sylvatic cycle involving foxes and rodents.	Difficult to control in wildlife. Anthelminthic impregnated bait for foxes in peri-urban areas or around farms – may be difficult to sustain and also expensive.	*Echinococcus* eggs are not susceptible to freezing	Education of food handlers and consumers may be the most feasible form of control in endemic areas. Washing produce not be sufficient to remove parasites. *Echinococcus* eggs not susceptible to freezing (see above).	WHO/OIE, 2001. OIE, 2005a. WHO, 2011.
Toxoplasma gondii	Meat and offal from a range of animals (pigs, cattle, sheep, goats, game) may contain infectious tachyzoites. Oocysts can contaminate fresh produce and molluscan shellfish. Oocysts can be a source of on-farm infection for domestic animals.	Mild to moderate to severe, can cause abortions and congenital defects. May be linked to chronic mental and neurologic sequelae in adults.	Challenging to control because there are multiple possible vehicles. Non-food-borne infections complicated by the domestic "house" cat as a known parasite reservoir and source of infection.	Control feasible in housed or feedlot pigs and cattle (can be confirmed by serological testing - *Toxoplasma*-free designation) Not feasible in free range farmed animals. Vaccine available for sheep, but tissue cysts still present in meat.	Commercial freezers can kill tissue cysts in meat; domestic freezers or cooling under gas or vacuum may not be effective. Susceptible to pasteurization and cooking. Testing of meat & organ products not a viable option as cysts are small and randomly distributed. Lack of standardized methods means that fresh produce is not routinely tested for *T. gondii* oocysts.	Education of high-risk consumer groups is imperative; this includes pregnant women and immuno-compromised individuals.	Jones and Dubey, 2012. Kijlstra and Jongert, 2008.

Parasite	Hosts and main transmission routes – Food chains of concern	Severity of illness	Overarching factors for consideration in risk management	Examples of management options and challenges along the food chain			Examples of risk management texts and guidance
				On-farm	Post-harvest or processing	Retail and consumer	
Cryptosporidium spp.	Fresh produce, fruit juice, and milk. Likely entry into the food chain is by water and/or contamination by food handlers. The entire water system must be addressed, e.g. reservoir, piping, etc.	Mild to moderate to severe and chronic (immuno compromised)	Control measures for water quality throughout the water supply and food chain. Oocysts: (a) very resistant to chlorine, (b) detection methods do not assess viability, (c) can survive within, and be protected by, the stoma of fresh fruits and leafy vegetables.	Composting may be insufficient to inactivate oocysts. No housing of calves (and other livestock) in areas where produce is grown. Thorough washing of farm equipment, e.g. collection baskets. Dedicated use of equipment may help control.	Commercial tanks for washing produce can become contaminated. Transport vehicles, storage equipment & rooms important sources of cross-contamination. Susceptible to pasteurization and freezing. ISO developing a standard for detection in food. but expensive, efficiency may be low, small sample size may not account for heterogeneous distribution.	Consumer education is critical for HIV+ and other immunocompro-mised individuals, at risk for severe and chronic infections. Fresh produce may be high risk. Washing of fresh fruits and vegetables recommended but will not remove all oocysts.	ISO Standards. US-EPA Standards. UK-DWI Standards. Robertson and Fayer, 2012.
Entamoeba histolytica	Fresh produce. Largely water-borne and associated with food handlers. The cysts are sensitive to chlorine washes.	Mild to moderately severe. Diarrhoeal illness, liver abscess.	Diagnosis of *E. histolytica* requires specific tools to differentiate it from non-pathogenic *E. dispar* and *E. moshkovskii*.			Illnesses in the past have been linked to lack of hygiene during food preparation and consumption.	Theel and Pritt, 2012

Parasite	Hosts and main transmission routes – Food chains of concern	Severity of illness	Overarching factors for consideration in risk management	Examples of management options and challenges along the food chain			Examples of risk management texts and guidance
				On-farm	Post-harvest or processing	Retail and consumer	
Trichinella spiralis	Pork, horse and game meat.	Acute illness, low fatality rate	Trichinellosis occurs worldwide.	There are specific recommendations for *Trichinella*-free pig farming and national herd certification programmes.	Processing such as sausage making can spread one infected animal among many products, increasing the risk from a single contaminated animal.	Controlled in many countries, where present, by consumer education to cook pork thoroughly. Controlled by some religious and ethnic dietary restrictions.	FAO/WHO/OIE 2007. OIE, 2005b
Opisthorchiidae	Freshwater fish. The parasite occurs in fish in the wild and very rarely in those grown under commercial aquaculture. Multiple hosts, e.g. farm animals.	Severe infections, chronic sequelae, carcinogenic potential	It may be impossible to control the infection in wild-caught fish. Currently, of regional importance for Asia.	Discourage the feeding of unsterilized night soil (i.e. human faeces) to commercially farmed fish. Architecture and location of commercial ponds important to avoid contamination by faecal run-off.		During food preparation and consumption, Opisthorchiidae can be controlled by freezing and by thorough cooking.	FAO, 2012

TABLE 5. Commodity-trade volumes and monetary values of the primary food vehicles of transmission of the higher ranked parasites

Food Category	Trade volume (tonne) 2010 or 2009 (1)	Trade value (1000 US$) 2010 or 2009 (1)
Beef and veal	5 208 618	23 893 619
Pork	3 728 741	10 061 812
Goat meat	53 431	239 167
Sheep meat	962 169	5 110 599
Game/wild animal meat	55 198	477 096
Marine fish (edible product)	22 431 962	49 163 711
Freshwater fish (edible product)	3 627 385	17 797 345
Freshwater crustaceans (edible product)	31 818	226 837
Marine crustaceans (edible product)	2 947 344	19 591 627
Molluscan shellfish (bivalves) (edible product)	466 790	2 148 135
Berries	123 417	571 570
Fruit juice	2 707 796	3 527 824
Other fruits	1 955 370	1 660970
Vegetables, fresh	2 444 437	3 251 556

Sources: The information is based on that available for the year 2010 in the FAO Statistical database (FAOSTAT) as of 19 October 2012. (1) Information for fish, crustaceans and bivalves are for the year 2009, based on the latest available data from FAO Fisheries and Aquaculture Statistics Service, 2012.

5

Conclusions and recommendations

Providing risk managers with the information they need for decision-making is a critical element of food safety management. This meeting of technical experts was convened with the objective of providing information for globally important food-borne parasites. Given the breadth of the area of food-borne parasites, FAO and WHO concluded that addressing the task required a structured and transparent approach that made optimal use of existing information and was able to build on existing and relevant initiatives underway in both organizations. This led to the development of a multicriteria-based ranking tool, and challenged all the participants to use the available information and their expertise and apply it to the ranking exercise. While this initiative took substantial effort, the meeting concluded that the output, a transparent, reproducible and qualitative (with quantitative inputs) approach to ranking food-borne parasitic hazards of global importance and the application of that tool to produce a global ranking of food-borne hazards of concern was significant, and should provide CCFH with the requested overview of the parasite-commodity combinations of concern.

It is important to acknowledge that the present ranking is global and based on the state of knowledge and experience in 2012. Taking a global perspective, it is not expected that this would necessarily reflect parasite ranking at national level, where more precise information may be available and specific local conditions can be taken into consideration. For the current ranking, it is fully recognized that this could change as more research, data and information on food-borne parasites become available for further analysis and ranking refinement. Like many phases of risk analysis, this process is potentially most useful if it is replicated and updated on a continuous basis.

Furthermore, it is well recognized that initiatives such as the FERG initiative to assess the global burden of food-borne disease will in the medium term provide much more extensive information in terms of the public health importance and burden of food-borne diseases and be critical to furthering our understanding and knowledge. However, like any in-depth study, they are also resource and time intensive. In the meantime, ranking approaches such as the one described here allow the use of whatever information is available at a particular point in time to identify those parasites (or other hazards) of greatest concern and also to take into account aspects other than the public health element. The systematic and transparent approach means that they can be updated as new information comes on board and can be considered as one means of translating existing knowledge on food-borne parasites into a format that focuses the risk manager's attention.

The meeting concluded that food-borne parasites had not always received the attention they deserved based on their public health, trade and socio-economic importance. It was hoped that exercises such as this would serve to increase the awareness of food-borne parasites at a global level. Although it was recognized that the current meeting was aimed at providing advice to the CCFH, managing food-borne parasites is clearly a multidisciplinary task with a critical role for partners, not only those working with different parts of the food chain, but also in diverse disciplines addressing water, wildlife, the environment and more.

The meeting recognized that the ranking alone is not adequate for decision-making, and that the establishment of priorities by risk managers also requires consideration of other factors. Therefore, the experts aimed to provide additional information which could facilitate the decision-making process, including the primary food vehicles of concern for each of the parasites, knowledge on food attribution, and some information in relation to control of these parasites. An example of how these different elements could then be used by risk managers is presented in Annex 6. However, this report does not profess to be fully comprehensive, but rather raises awareness of certain aspects to be considered in the preliminary risk management phase. The existing materials, particularly for management of zoonotic parasites at the primary production stage, were fully acknowledged, and the meeting highlighted the importance of updating such texts. For example, the meeting recommended that the FAO/WHO/OIE guidelines for the surveillance, prevention and control of trichinellosis (2007) be periodically reviewed and updated to reflect technological advances.

The meeting also recognized that there are numerous knowledge gaps that hamper our efforts to control food-borne parasites, including the difficulty of attributing food or other vehicles for the transmission of parasite infection and illness. The importance of ongoing research into food-borne transmission of parasites was emphasized. One example is where recent studies suggest that, for *Toxoplasma gondii,* oocyst infection attributed to produce might be much more important than previously thought. While it was not within the scope of this meeting to address such aspects in detail, the meeting did recommend that if Codex decides to move forward with development of risk management guidance for specific parasites, then it should request more specific scientific input on the individual parasites.

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Annexes

Annex 1

Identification of food-borne parasites for consideration

An online questionnaire was utilized to prioritize 93 listed parasites at a regional and global level with respect to their public health significance and trade implications. The questionnaire also provided a valuable resource for the experts in developing criteria to be used for the ranking process (Table A1.1). The results were grouped into four tiers related to the global relevance of the listed parasites. Tier 1 and Tier 2 parasites were classified as "important" ('very' or 'somewhat') from a global perspective by at least 50% (n=25) and 40% (n=12) of experts, respectively.

TABLE A1.1 Tiered list of parasites under consideration

Tier 1 parasites (identified by more than 50% of the experts as being globally important)		
Anisakis simplex	*Echinococcus granulosus*	*Toxocara canis*
Anisakis spp.	*Echinococcus multilocularis*	*Toxocara cati*
Ascaris lumbricoides	*Entamoeba histolytica*	*Toxoplasma gondii*
Clonorchis sinensis	*Fasciola gigantica*	*Trichinella britovi*
Cryptosporidium hominis.	*Fasciola hepatica*	*Trichinella pseudospiralis*
Cryptosporidium parvum	*Giardia lamblia*	*Trichinella spiralis*
Cryptosporidium spp.	*Taenia saginata*	*Trichuris trichiura*
Diphyllobothrium latum	*Taenia solium*	*Trypanosoma cruzi*
Diphyllobothrium spp.		
Tier 2 parasites (scored by more than 40% of experts as being globally important)		
Ancylostoma duodenale	*Gnathostoma spinigerum*	*Opisthorchis felineus*
Balantidium coli	*Hymenolepis nana*	*Sarcocystis* spp.
Cyclospora cayetanensis	*Metagonimus* spp.	*Taenia asiatica*
Enterobius vermicularis	*Necator americanus*	*Trichinella nativa*

Tier 3 parasites (those with the greatest number of "very important" global scores or regional scores and those with the highest cumulative importance scores, i.e. sum of number of experts indicating a parasite is global and regionally important)		
Angiostrongylus cantonensis	*Opisthorchis viverrini*	*Sarcocystis hominis*
Blastocystis spp.	*Paragonimus heterotremus*	*Strongyloides stercolaris*
Capillaria philippinensis	*Paragonimus* spp.	*Trichinella murelli*
Fasciolopsis buski	*Paragonimus westermani*	
Tier 4 – Remaining parasites		
Alaria alata	*Echinostoma revolutum*	*Nanophyetus salmincola*
Alaria americana	*Echinostoma* spp.	*Paragonimus kellicoti*
Alaria spp.	*Gastrodiscoides hominis*	*Pseudoterranova decipiens*
Ancylostoma ceylanicum	*Gnathostoma binucleatum*	*Sarcocystis fayeri*
Angiostrongylus costaricensis	*Gnathostoma hispidu*	*Sarcocystis suihominis*
Baylisascaris	*Haplorchis pumilo*	*Spirometra erinacei*
Blastocystis hominis	*Haplorchis* spp.	*Spirometra mansoni*
Capillaria hepatica	*Haplorchis taichui*	*Spirometra mansonoides*
Centrocestus spp.	*Heterophyes* spp.	*Spirometra ranarum*
Contracaecum/Phocascaris	*Hymenolepis diminuta*	*Spirometra* spp.
Cystoisospora belli	*Kudoa septempunctata*	*Taenia multiceps*
Dicrocoelium dendriticum	*Lecithodendriid flukes*	*Taenia serialis*
Dientamoeba fragilis	*Linguatula serrata*	*Trichinella papuae*
Dioctophyme renale	*Mesocestoides lineatus*	*Trichinella zimbabwensis*
Diplogonoporus grandis	*Mesocestoides variabilis*	*Trichostrongylus* spp.

The Tier 3 list comprised those with the greatest number of "very important" global scores or regional scores, and those with the highest cumulative importance scores (sum of number of experts indicating a parasite is global or regionally important), while Tier 4 contained the remaining parasites. The experts decided to further screen this 4-tiered list through grouping of parasites by genus or family (Table A1.2), and where applicable, based on common routes of transmission, clinical manifestations, and food-borne sources of infection. This resulted in a list of 24 parasites for the ranking exercise (Table 2 in Section 2.2 in the main report). Table A1.3 lists parasites that were considered important by the experts at the regional or national level but were excluded at the global level for the stated reasons.

TABLE A1.2. Parasite groupings

Parasites	Grouping	Parasite	Grouping
Anisakis simplex *Anisakis* spp. *Pseudoterranova decipiens*	Anisakidae	*Paragonimus heterotremus* *Paragonimus* spp. *Paragonimus westermani* *Paragonimus kellicoti*	*Paragonimus* spp.
Cryptosporidium hominis *Cryptosporidium parvum* *Cryptosporidium* spp.	*Cryptosporidium* spp.	*Sarcocystis* spp. *Sarcocystis hominis* *Sarcocystis fayeri* *Sarcocystis suihominis*	*Sarcocystis* spp.
Diphyllobothrium latum *Diphyllobothrium* spp. *Diplogonoporus grandis*	Diphyllobothriidae	*Spirometra erinacei* *Spirometra mansoni* *Spirometra mansonoides* *Spirometra ranarum* *Spirometra* spp.	*Spirometra* spp.
Fasciola gigantica *Fasciola hepatica*	*Fasciola* spp.	*Toxocara canis*	*Toxocara* spp.
Metagonimus spp. *Centrocestus* spp. *Heterophyes* spp. *Haplorchis pumilo* *Haplorchis* spp. *Haplorchis taichui*	Heterophyidae	*Trichinella britovi* *Trichinella pseudospiralis* *Trichinella native* *Trichinella murelli* *Trichinella papuae* *Trichinella zimbabwensis*	*Trichinella* spp.
Opisthorchis felineus *Opisthorchis viverrini*	Opisthorchiidae		

TABLE A1.3. Parasites excluded from original list

Broad Category	Parasites EXCLUDED	Criteria for exclusion
Meat-borne	*Taenia asiatica*	Regional
	Taenia serialis	Unlikely / rare zoonosis
Fish- and shellfish-borne	*Capillaria philippinensis*	Regional – Philippines
	Contracaecum/ Phocascaris	Proportion of cases attributable to food-borne infection negligible
	Echinostoma spp.	Regional – SE Asia
	Gnathostoma spp.	Regional – SE Asia
	Kudoa septempunctata	Regional – SE Asia
	Lecithodendrid flukes	Regional – SE Asia
Plant (fruit- and vegetable-borne, including berries, fruit juice)	*Blastocystis* spp.	Proportion of cases attributable to food-borne infection negligible
	Strongyloides stercoralis	Proportion of cases attributable to food-borne infection negligible
	Ancylostoma spp.	Proportion of cases attributable to food-borne infection negligible
	Necator americanus	Proportion of cases attributable to food-borne infection negligible
"Other"	*Angiostrongylus cantonensis*	Regional – Asia Pacific
	Hymenolepis spp.	Proportion of cases attributable to food-borne infection negligible

Annex 2

Food-borne parasite ranking exercise: summary card

Group:		Parasite/food:				
Criterion	**Bin 0**	**Bin 1**	**Bin 2**	**Bin 3**	**Bin 4**	**Score**
Number of global food-borne illnesses (manifesting disease)	<10 000	10 000 – 100 000	100 000 – 1 000 000	1 000 000 – 10 000 000	>10^7	
Global distribution (number of regions)	N/A	1	2	3-4	>4	
Acute morbidity severity (disability weight)	0 (none)	<0.03 (very mild)	0.03–0.1 (mild)	0.1–0.30 (moderate)	>0.30 (severe)	
Chronic morbidity severity (disability weight)	0 (none)	<0.03 (very mild)	0.03-0.1 (mild)	0.1–0.30 (moderate)	>0.30 (severe)	
Fraction of illness that is chronic (%)	0%chronic	<25% chronic	25–50% chronic	50–75% chronic	>75% chronic	
Case-fatality ratio (%)	0%	0–0.1%	0.1–1%	1–10%	>10%	
Likelihood of increased human burden (%)	None	0–25% (low)	25–50% (moderate)	75–100% (high)	100% (still increasing)	
How relevant is this parasite-food pathway for international trade?	Not at all	Some relevance	High relevance			
Scope of impact to economically vulnerable communities?	None	Low	Moderate	High		
What is the quality of available evidence for this parasite?	Very Poor	Poor	Adequate	Good	Very Good	

Further comments relevant for the discussion on risk management

Annex 3

Food-borne parasite ranking exercise form: explanation of criteria

The summary card used to conduct this exercise should be considered an expert elicitation. We are asking for your expert judgment on 9 scored parameters, each of which is intended to capture some aspect of the global importance of each parasite. We realize that data may not be available to support your scores, but we ask you to use your knowledge of the literature and your considered opinion to answer these questions.

Please indicate group and parasite/food pathway on the sheet.

We ask that for each parasite you estimate each criterion, using the levels marked in the bins to indicate your group score. You may circle multiple bins as marked in the example below to indicate a broader range of values, but it is CRITICAL that you come to a SINGLE CONSENSUS BEST GUESS SCORE for the criterion and mark it numerically in the rightmost column.

Please take notes on a separate piece of paper to indicate important assumptions or data sources that you would like to record. Please mark on that paper the group and parasite/food pathway so we can associate it with your scores.

Please remark additional comments relevant to risk management below and on the back.

Example:

	Bin 0	Bin 1	Bin 2	Bin 3	Bin 4	Score
Mortality rate (case-fatality ratio) (%)	0%	0–0.1%	0.1–1%	1–10%	>10%	**2**

Criterion No. 1. Number of global food-borne illnesses

Criterion: Number of individuals worldwide that <u>manifest clinical illness</u>

Explanation: This criterion measures the magnitude of global food-borne disease as the number of people worldwide <u>who have clinical</u>

symptoms of illness and who were infected by food. If you do not feel that you can estimate this number directly, you can calculate it based on numbers you may feel more comfortable with. Namely, it can be considered a function of the global prevalence of infection multiplied by the percent of infections that are result from food consumption multiplied by the percent of infections that are symptomatic multiplied by the global population of (7 billion people). For parasites that are generally regarded as acute infections (e.g. *Trichinella*), it is incidence times percent symptomatic times percent food-borne times global population.

For example: Your best estimate is that Parasite A has a global prevalence of about 20%, of which about 50% you believe to be food-borne. Of these infections, the literature suggests that 10% of infections are symptomatic. This equates to a global illness rate of 1% (20% × 50% × 10%). Thus, you would estimate about 70 000 000 cases (1% of 7×109).

Ranges:

Bin 0	Bin 1	Bin 2	Bin 3	Bin 4
<10 000 illnesses	10 000 – 100 000 illnesses	100 000 – 1 000 000 illnesses	1 000 000 – 10 000 000 illnesses	>10 000 000 illnesses

Criterion No. 2. Geographical distribution (endemic regions)

Criterion: Number of regions in which this parasite is geographically distributed (in which it shows a natural cycle)

Explanation: This criterion reflects the global distribution of the parasite across world regions as a simple count of the number of major regions (Africa, Asia, Europe, Near East, North America, Latin America and the Carribbean, Pacific) in which the disease is regularly found.

Ranges:

Bin 0	Bin 1	Bin 2	Bin 3	Bin 4
Not applicable	1 region	2 regions	3-4 regions	> 4 regions

Criterion No. 3. Acute Morbidity Severity

Criterion: Loss of health-related quality of life due to acute infection

Explanation: This criterion reflects the degree to which an acute manifestation of illness reduces health-related quality of life. The value of the criterion is anchored between 0 (full health, asymptomatic, no illness) to 1 (worst possible health state or death). It depends on both the severity and duration of illness. For a large number of health conditions, including many infectious diseases and some parasitic diseases, disability weights have already been published.

Ranges:

Bin 0	Bin 1	Bin 2	Bin 3	Bin 4
0 (none)	< 0.03 (very mild)	0.03 –0.01 (mild)	0.01–0.30 (moderate)	>0.30 (severe)

Decision rules: If a pathogen causes more than one acute disease, a population weighted average is applied. Calculate your best guess point estimates for identified acute conditions and weight by likelihood. Then assign a bin using the ranges above.

Refer to the table of disability weights below (from Havelaar *et al.*, 2010; Annex 1) or see WHO publications. The *Global Burden of Disease 2004 Update* includes a summary table on page 33 (WHO, 2008).

This annex to the 2004 report includes more detailed disability weights (WHO, 2004; see http://www.who.int/healthinfo/global_burden_disease/GBD2004_DisabilityWeights.pdf)

Table of disability weights for acute and chronic conditions

Very mild (disability weight <0.03)	Duration (in days)	Moderate (0.1<disability weight <0.3)	Duration (in days)
Otitis media	14	Inflammatory bowel disorder	183
Hepatitis	30	Reactive arthritis	183
Folliculitis	7	Tuberculosis	365
Cystitis	14	Chronic pulmonary disease (bronchitis, asthma, emphysema)	365
Gastroenteritis, severe	10–15		

Conjunctivitis	7	Diabetes mellitus	365
Tonsillitis	7		
Bronchitis	14		
Mild (0.03<disability weight <0.1)		**High (disability weight >0.3)**	
Allergic rhinitis	119	Renal failure	365
Reactive arthritis	42	Guillain-Barré syndrome	365
Tinea pedis	183	Visual disorder, severe	365
Eczema	35	Paraplegia	365
Otitis externa	35	AIDS	365
Gastroenteritis, hospitalized	7–14	Meningitis	
Laryngitis	7	Dementia	365
Sinusitis	183		
Irritable bowel syndrome	183		
Haemolytic uremic syndrome	30		
Visual disorder, mild	365		
Hepatitis	92		
Gastroenteritis, chronic	183		
Influenza	14		

Criterion No. 4. Chronic Morbidity Severity

Criterion: Loss of health-related quality of life associated with chronic illness.

Explanation: This criterion reflects the degree to which a chronic manifestation of illness reduces health-related quality of life. The value of the criterion is anchored between 0 (full health, asymptomatic, no illness) to 1 (worst possible health state or death). It depends on both the severity and duration of illness. For a large number of health conditions, including many infectious diseases and some parasitic diseases, disability weights have already been published.

Ranges:

Bin 0	Bin 1	Bin 2	Bin 3	Bin 4
0 (none)	<0.03 (very mild)	0.03–0.01 (mild)	0.01–0.30 (moderate)	>0.30 (severe)

Decision rules: If a pathogen causes more than one chronic disease, a population weighted average is applied. Calculate your best guess point estimates for identified chronic conditions and weight by likelihood. Then assign a bin using the ranges above.

Refer to Criterion 3 for additional guidance on disability weights.

Criterion No. 5. Fraction chronic

Criterion: Percent of global food-borne illnesses (estimated in Criterion 1) that are considered chronic (see note below; this is a weighting criterion only)

Explanation: This criterion is used to partition the illnesses estimated in Criterion 1 into those with acute manifestations and those with chronic manifestations (scored in Criteria 3 & 4). It is assumed that 100% of illnesses estimated in Criterion 1 manifest in either acute or chronic illness. Note that this fraction will not be directly scored as a criterion in the scoring model; rather, it will be used to weight acute and chronic disease severities (Criteria 3 & 4). Therefore, the bin numbers do not go from "less important" to "more important" as do categories for other parasites.

Ranges:

Bin 0	Bin 1	Bin 2	Bin 3	Bin 4
0%	<25% chronic	25–50% chronic	50–75% chronic	>75% chronic

Decision rule: We recognize that some portion of chronic illness may be preceded by acute infection and therefore the actual percentages may not add up to 100%. However, for this exercise, we ask you to ignore this overlap and simply focus on providing a best estimate for the fraction that is chronic.

Criterion No. 6. Mortality rate

Criterion: Case-fatality ratio

Explanation: This criterion estimates the likelihood that a given cases of illness will result in death. Mortality rate is dependent on disease symptoms and severity, as well as underlying health of the infected person.

Ranges:

Bin 0	Bin 1	Bin 2	Bin 3	Bin 4
0%	0 –0.1%	0.1–1%	1–10%	>10%

Criterion No. 7. Increasing trend in disease

Criterion: Likelihood of a significant increase in human illness.

Explanation: This criterion reflects the potential for the human health burden associated with this particular parasite to increase in the near term, for example through changes in food production, processing and consumption.

Ranges:

Bin 0	Bin 1	Bin 2	Bin 3	Bin 4
None	0–25% (low)	25–50% (moderate, or unsure)	75–100% (high)	100% (still increasing)

Criterion No. 8. International trade

Criterion: Relevance of the parasite and its PRIMARY food sources or vehicles to affect international trade.

Explanation: This qualitative criterion estimates the degree to which this particular parasite and its main food sources or vehicles may affect international trade. While the characteristics of the parasite or disease severity relate to trade, it is largely a function of the food source or vehicle; if the primary food-borne pathway is not widely traded, or not currently traded from a region in which the parasite is currently endemic, it may not be likely to have an impact on trade. At the same time, if the parasite is in a food product that is widely traded or if there are current issues associated with the parasite-food pathway, it is of greater relevance.

Ranges:

Bin 0	Bin 1	Bin 2
No relevance	Some relevance	High relevance

Criterion No. 9. Distributional impacts (socio-economic impact)

Criterion: Scope of impact to economically vulnerable populations

Explanation: This criterion reflects the degree to which this disease affects economically vulnerable communities, namely the extent to which this parasite causes reductions in household or community productivity, or the ability of a household or community to have access food (i.e. can produce and/or purchase food). Vulnerable communities include pastoral communities, small fishing communities, small rural communities in developing countries, migrant populations in developed countries, minority indigenous populations (Inuit in Canada, aboriginals in Australia), or other similar communities.

Ranges:

Bin 0	Bin 1	Bin 2	Bin 3
None	Low Primarily affects individual households; affected households have reduced productive capacity or have reduced access to food	Moderate Primarily impacts individual households but also affects communities; households have reduced productive capacity or access to food; communities also have some reduced productive capacity or access to food	High Affects entire communities; communities bear major losses to productive capacity and/or have seriously diminished access to food.

Criterion No. 10. Quality of evidence

Criterion: Quality of available evidence to support judgments (Not a scored criterion)

Explanation: This question reflects the extent to which you feel you were able to assess criterion-based data or information for a specific parasite.

Ranges:

Bin 0	Bin 1	Bin 2	Bin 3	Bin 4
Very Poor	Poor	Adequate	Good	Very Good

Comments

Lastly, please indicate comments, if any, that should be considered in the discussion of risk management for this parasite food pathway

References

Havelaar, A.H., van Rosse, F., Bucura, C., Toetenel, M.A., Haagsma, J.A., Kurowicka, D., Heesterbeek, J.H., Speybroeck, N., Langelaar, M.F., van der Giessen, J.W., Cooke, R.M. & Braks, M.A. 2010. Prioritizing emerging zoonoses in the Netherlands. PLoS One, 5(11): e13965. [Online doi: 10.1371/journal.pone.0013965.]

WHO. 2004. Global burden of disease 2004 update: Disability weights for diseases and conditions. Available at http://www.who.int/healthinfo/global_burden_disease/GBD2004_DisabilityWeights.pdf Accessed 2013-07-05.

WHO. 2008. Global Burden of Disease 2004 Update. See http://www.who.int/healthinfo/global_burden_disease/GBD_report_2004update_part3.pdf Accessed 2013-07-05.

Annex 4

Criteria weights worksheet

The overall parasite score is given by two equations:

$$C1*W1 + C2*W2 + C345*W345 + C6*W6 + C7*W7 + C8*W8 + C9*W9 \quad \textit{Eq. 1}$$

$$C345=\{C3*(1\text{-}C5) + C4*C5\} \quad \textit{Eq. 2}$$

where C are criteria scores normalized to a 0–1 scale and W are the criteria weights, which sum to 100%. Eq. 2 calculates the average severity weight for the parasite, an average of chronic disability weight and acute disability weight using the fraction of illnesses that are chronic. Thus, criteria 3, 4 and 5 have one associated weight, denoted as W345. Otherwise the calculation is straightforward: normalized parasite criteria scores are multiplied by fractional weights.

Criteria weights are simply the fraction of the total score reflected by the criteria in question. Therefore, if you think 25% of the overall score should be driven by C1, W1 should be marked with a 25. For comparison purposes, equal weighting of all criteria would result in a value of 14.285%.

Make sure that all numbers sum to 100%, and that no criterion weight is less than 5%. Please use integers only (no decimal points).

Criterion	Weighting Code	Criterion Weight (Fraction of Total Score)
C1. Number of global food-borne illnesses	W1	
C2. Global distribution	W2	
C3. Acute morbidity severity C4. Chronic morbidity severity C5. Chronic illness fraction	W345	
C6. Case fatality rate	W6	
C7. Increasing illness potential	W7	
C8. Trade relevance	W8	
C9. Impacts to economically vulnerable communities	W9	
SUM		100%

Annex 5

Sensitivity analysis

In addition to the results presented in the main text, a number of analyses were conducted to examine elicited scores and the sensitivity of the ranking results to different model inputs.

First, variability was examined across groups in elicited scores. Figure A5.1 shows group scores for all nine criteria, averaged over all parasites scored by each group. Because each group scored a slightly different set of parasites, the average scores are not directly comparable, but they do show some interesting patterns. Criterion 2, on the global distribution of disease of each parasite, shows consis-

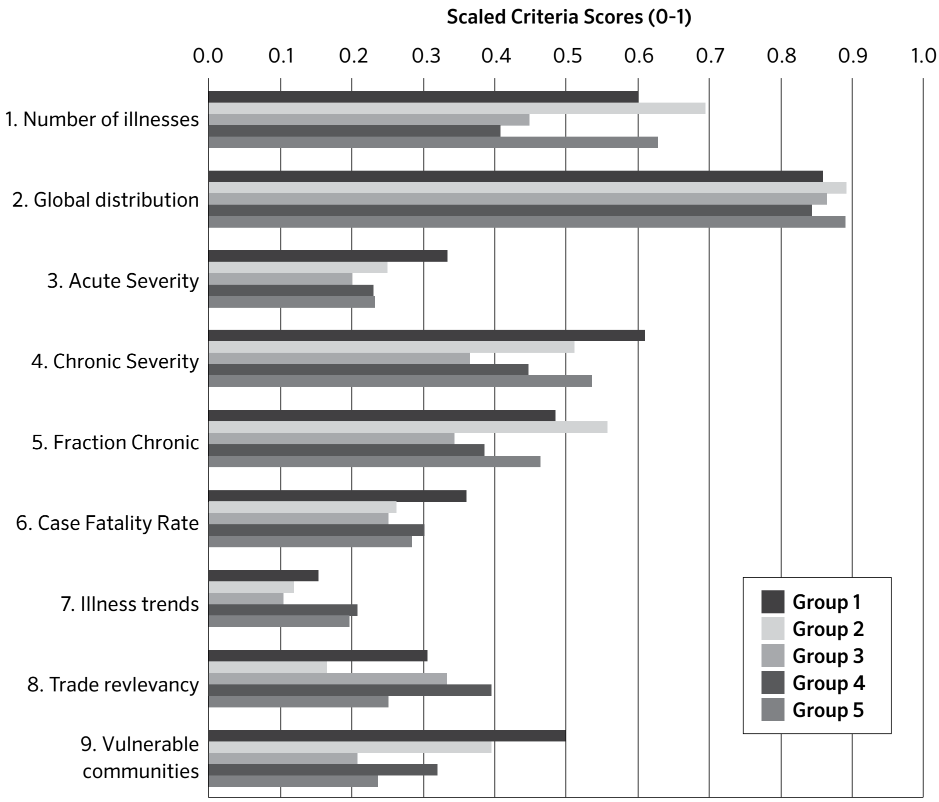


FIGURE A5.1. Group scores by criteria, averaged across parasites tently high average scores, which suggests that experts generally agreed that the set of screened pathogens reflects parasites of global relevancy. The severity of chronic disease consistently scored higher than the severity of acute disease for this set of parasites. Overall, scores for illness trends were low, suggesting that current, endemic disease may be more of a concern than disease movement or emergence.

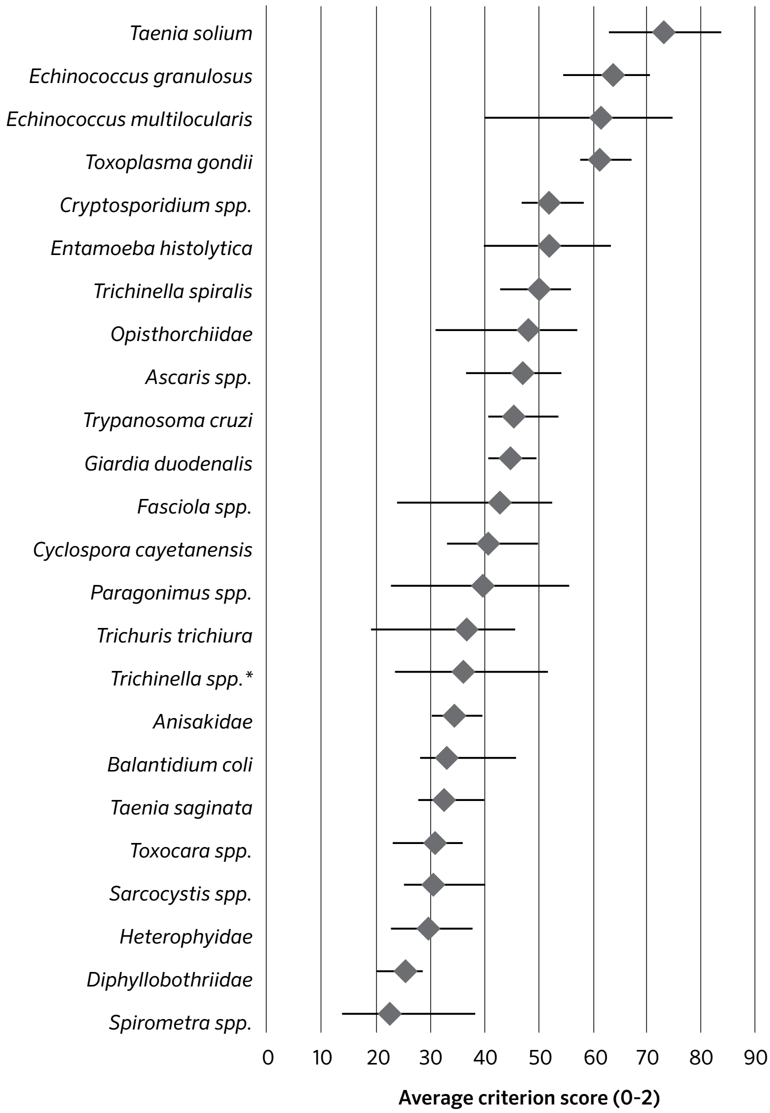


FIGURE A5.2. Means and ranges of normalized risk scores across expert groups under baseline model conditions

Just as there is variability across expert groups in average criteria scores across parasites, there is variability across groups for specific parasites. This is shown in Figure A5.2, which shows the mean normalized risk scores presented in the main text of the report, as well as the ranges of estimates across groups. Some parasites, such as *Toxoplasma gondii*, have relatively little variability across experts, while parasites such as *Echinococcus multilocularis* and *Paragonimus*, have notably larger variability. This variance can be interpreted as a signal of the strength of scientific knowledge about a given parasite: the greater the variance, the greater the uncertainty in information available to experts.

In examining sensitivity of the model itself, alternative weighting schemes were of particular interest.

In some multi-criteria decision analyses, different groups of experts are used to score the individual criteria and to develop the weights that define how criteria scores will be combined into a final risk score. That is, subject matter experts are elicited for criteria scores, while risk managers are elicited for criteria weights. In part due to time and resource constraints, weights were elicited from expert groups, as well as from the FAO/WHO Secretariat, acting as risk managers. The mean of elicited weights across all participants was used for the baseline model and ranking.

Criterion weights were roughly similar across experts and risk managers, as shown in the rounded values presented in Table A5.1. Risk managers tended to put greater weight on potential for increased illness, trade relevance and impacts to economically vulnerable communities than did experts, but all participants tended to put greater weight on public health criteria. These are compared with an equal weighting scheme, in which each criterion is treated as of equal importance in the overall risk score.

Sensitivity analyses of rankings were conducted around three alternative weighting schemes: mean of expert weights, mean of risk manager weights, and equal criteria weighting. Table A5.2 and Figure A5.3 show multicriteria risk scores (normalized to 0–100) for global foodborne parasites for the baseline and the three alternative schemes mentioned above. Although different schemes result in slightly different scores, the ranking is fairly robust among the alternative schemes.

Sensitivity analyses of rankings were conducted around three alternative weighting schemes: mean of expert weights, mean of risk manager weights, and equal criteria weighting. Table A5.2 and Figure A5.3 show multicriteria risk scores (normalized to 0–100) for global foodborne parasites for the baseline and the three alternative schemes mentioned above. Although different schemes result in slightly different scores, the ranking is fairly robust among the alternative schemes.

TABLE A5.1. Mean of elicited criteria weights used in multicriteria ranking

Scoring criterion		Weighting			
		Baseline	Expert	Secretariat	Equal
W1.	Number of global foodborne illnesses	0.22	0.24	0.20	0.14
W2.	Global distribution	0.14	0.15	0.12	0.14
W345.	Morbidity severity	0.22	0.23	0.21	0.14
W6.	Case-fatality ratio	0.15	0.16	0.15	0.14
W7.	Increasing illness potential	0.07	0.06	0.09	0.14
W8.	Trade relevance	0.10	0.06	0.13	0.14
W9.	Impacts on economically vulnerable communities	0.10	0.09	0.11	0.14

Given the similarities in expert and Secretariat scores, the biggest differences can be seen in the equal weighting scheme, though even under that scheme the ranks of the first four parasites are identical. Figure A5.4 shows how these alternativee schemes affect the rank order of parasites in the overall ranking. The dots show the baseline rank, while the vertical lines display the range of ranks across the three alternative scenarios. This figure shows that ranks are quite stable, with some parasite-specific deviation. Those with the greatest deviation in scores are *Taenia saginata* and *Cyclospora cayetanensis*, followed by *Trichinella spiralis*, *Ascaris* spp., *Paragonimus* spp., *Anisakidae* and *Toxocara* spp. Most of these are parasites with higher scores in trade relevancy or impacts on socio-economically vulnerable populations, as the equal weighting scheme increases the importance of these criteria.

TABLE A5.2. Normalized multicriteria risk scores for global foodborne parasites under alternative criteria weighting schemes

	Weighting scheme			
	Baseline	Expert	Secretariat	Equal
Taenia solium	72.9	73.1	72.7	70.7
Echinococcus granulosus	63.6	65.9	61.8	60.5
Echinococcus multilocularis	61.6	65.0	58.8	56.8
Toxoplasma gondii	61.0	64.9	57.7	53.0

Cryptosporidium spp.	51.8	54.7	49.4	46.9
Entamoeba histolytica	51.8	55.5	48.7	46.0
Trichinella spiralis	49.9	48.8	50.8	50.1
Opisthorchiidae	47.9	49.3	46.7	43.8
Ascaris spp.	47.1	50.9	43.9	40.1
Trypanosoma cruzi	45.4	46.6	44.4	40.1
Giardia duodenalis	44.7	48.0	41.9	38.5
Fasciola spp.	42.7	44.5	41.3	39.8
Cyclospora cayetanensis	40.6	40.4	40.8	41.6
Paragonimus spp.	39.5	41.9	37.5	34.2
Trichuris trichiura	36.6	39.6	34.0	32.1
Trichinella spp.*	36.0	36.6	35.5	36.4
Anisakidae	34.1	33.1	35.0	36.1
Balantidium coli	33.0	35.6	30.8	29.7
Taenia saginata	32.3	30.7	33.7	35.6
Toxocara spp.	30.8	33.7	28.4	26.2
Sarcocystis spp.	30.3	31.1	29.7	29.4
Heterophyidae	29.3	30.2	28.5	27.8
Diphyllobothriidae	25.2	25.9	24.7	24.3
Spirometra spp.	22.5	23.5	21.6	19.8

In addition to examining alternative criterion weights, alternative sets of criteria were explored. In particular, rankings were generated based on public health criteria alone. Figure A5.3 shows the result of an alternative ranking model utilizing only criteria 1–6, with equal criteria weighting (W1=W2=W345=W6=0.25). These results show greater differences than with prior exploration of weighting schemes alone, though the order is largely preserved. The removal of the other criteria resulted in a notable downward shift in rankings of parasites with trade importance, such as *Taenia solium*, *Trichinella spiralis*, *Taenia saginata*, *Cyclospora* spp. and Anisakidae. This sensitivity analysis suggests that while trade relevancy is not the primary driver underlying overall risk scores in the baseline scenario, it did exert an important influence on the final rankings.

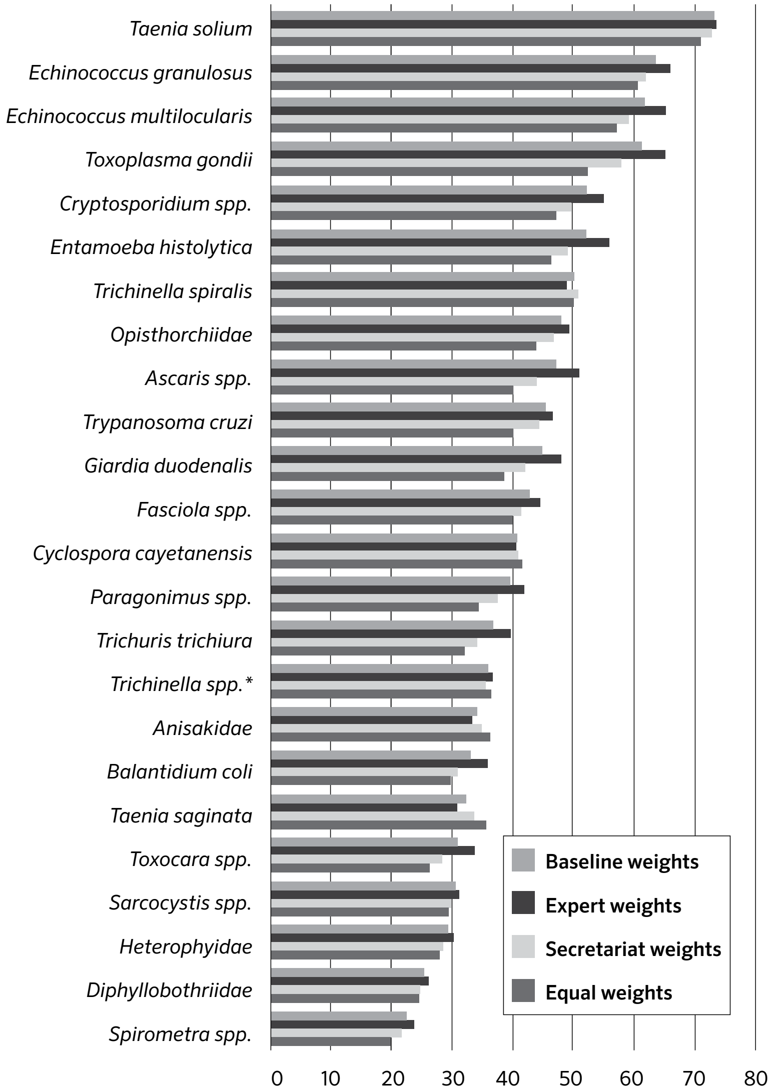


FIGURE A5.3. Comparison of multicriteria risk scores of global foodborne parasites across alternative criterion weighting schemes

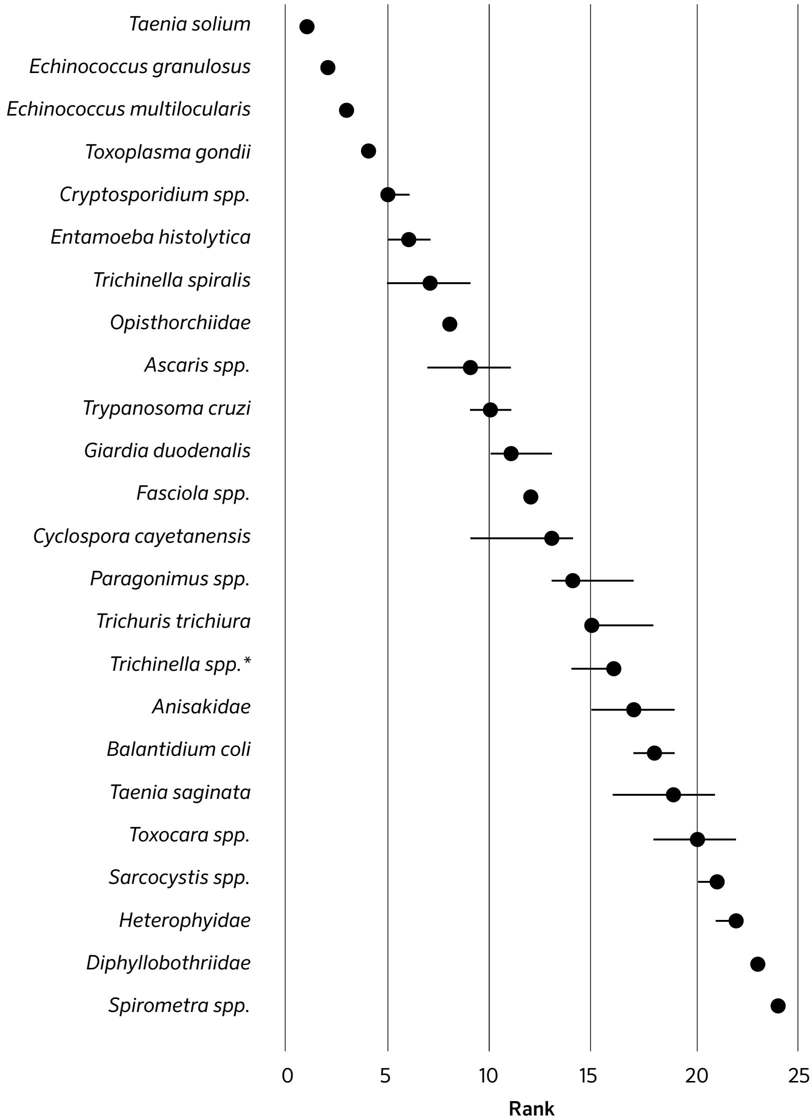


FIGURE A5.4. Rank scores of global foodborne parasites across alternative criterion weighting schemes, presented as ranges around baseline ranks

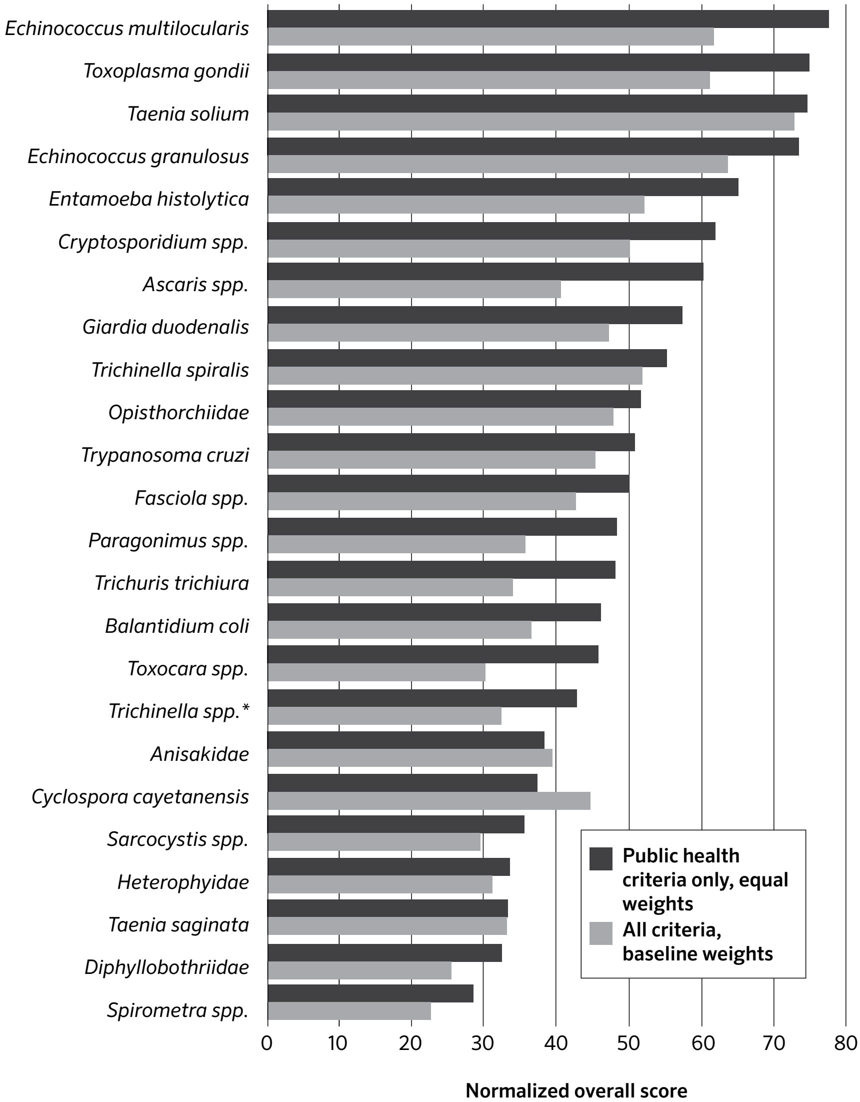


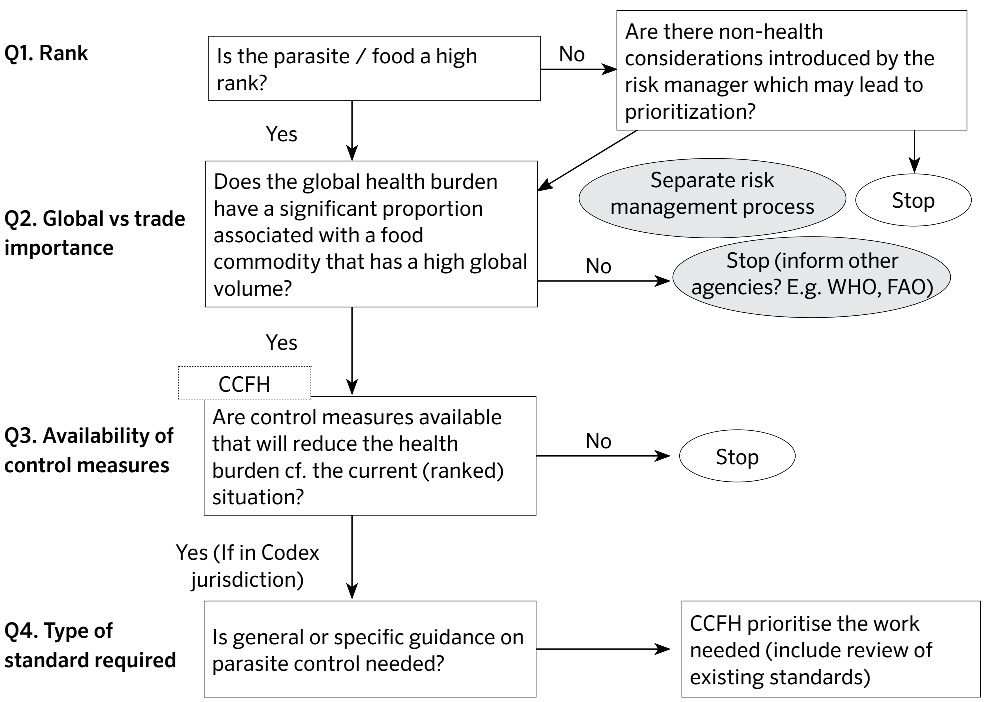
FIGURE A5.5. Multicriteria ranking of global foodborne parasites based on public health criteria only, weighted equally, compared with baseline ranking based on all criteria and elicited weightingsc

Annex 6

Risk management actions

The Codex Alimentarius Commission recognizes the requirement for a multidisciplinary inter-sectoral approach for the control of food-borne parasites, given their unique life-cycles and epidemiology as demonstrated by their efforts to work closely with OIE as well as FAO and WHO in the development of risk management guidance related to specific parasites. However, as Codex is aiming to address food-borne parasites in a more generic manner, as well as to develop specific guidance for priority hazards, following the trend towards risk-based standards and adopting a food-chain approach, Codex requested additional information from FAO and WHO to assist it in that endeavour. This report aims to provide at least some of the information required by CCFH in prioritizing its work on food-borne parasites. An example of a decision-tree approach that CCFH or other risk managers could use in the prioritization of ranked parasites and their primary vehicle of concern is presented below.

FIGURE A6.1. Decision tree for the risk management process



Annex 7

Specific information for the ranked parasites

For a Glossary of Parasitological Terms, see Annex section A7.25

After the meeting, the experts developed informative summaries for the resulting 24 ranked parasites, for use by risk managers or any interested stakeholder. A glossary was also provided by the expert group to help the reader with the terminology.

A7.1 ANISAKIDAE AND ANISAKIASIS

General information

Anisakiasis refers to infection of people with nematode larvae belonging to the nematode Family Anisakidae, and it is a serious zoonotic disease. Although there are several zoonotic species in this family, the two species most often associated with anisakiasis are *Anisakis simplex* the 'herring worm' and *Pseudoterranova decipiens*, the 'cod worm' (Chai, Murrell and Lymbery, 2005). The complex life history of *A. simplex* involves a marine intermediate host (euphasid crustacean), a paratenic host (marine fish or squid) and a definitive host (marine mammal).

Anisakiasis occurs when people ingest third-stage larvae that occur in the viscera or muscle of a wide range of marine fish and squids. Humans are accidental intermediate hosts in which the parasites rarely develop further; this invasion can cause gastrointestinal abscesses.

Geographical distribution

Anisakiasis occurs throughout the world, but is reported most frequently from Asia (especially Japan) and Western Europe, where risky food behaviour customs (i.e., eating raw, lightly cooked, or marinated fish in dishes such as sushi, salted or smoked herring, gravlax, and ceviche) are common (Lymbery and Cheah, 2007). Recent molecular genetic studies have shown that these species, *A. simplex* and *P. decipiens*, actually comprise a number of sibling species, often with distinct geographical and host ranges, or both (Mattiucci *et al.*, 2005). Within the Anisakis simplex complex are: *A. simplex* (*sensu stricto*), found in the northern Atlantic; *A. simplex* C, found in the northern Pacific and southern waters below 30°N; and

A. pegreffi, found in the Mediterranean Sea. Three species have also been described for the *Pseudoterranova decipiens* complex: *P. decipiens* A in the northeast Atlantic and Norwegian Sea, *P. decipiens* C in the northwest Atlantic and Barents Sea, and *P. decipiens* B throughout northern waters. Where the ranges of these species overlap, they appear to preferentially utilize different definitive host species.

Historically, most authors estimate there have been 15 000 to 20 000 total human cases. There has been an increase in reported prevalence throughout the world in the last two decades, probably due to better diagnostic tools, increased demand for seafood, and a growing demand for raw or lightly cooked food, although none of these factors has been rigorously evaluated. The areas of highest prevalence are Japan (after eating sushi and sashimi), and along the Pacific coast of South America (from eating ceviche, seviche or cebiche).

Disease

When humans eat infected fish harbouring live third-stage larvae, the larvae migrate to the gastrointestinal mucosa, where they die, but induce the formation of abscesses. Presumptive diagnosis in humans may be made on the basis of the patient's recent food habits (Gutierrez, 2011). Definitive diagnosis requires demonstration of worms by gastroscopy or surgery. No treatment is recommended for transient infection. In the gastrointestinal form (embedded larvae), surgery or gastroscopic procedure is also curative.

There is little information on chronic morbidity. However, the development of allergy to the parasite's allergens (even when the fish is thoroughly cooked) is now recognized. Gastroallergic anisakiasis is an acute IgE-mediated generalized reaction, manifested by urticaria and anaphylaxis, with or without accompanying gastrointestinal symptoms (Audicana and Kennedy, 2008). Occupational allergy, including asthma, conjunctivitis and contact dermatitis, has also been observed in fish-processing workers.

There is little information available on illness fraction or case fatality rates, probably because most cases are acute and treated.

Trade relevance

Anisakid infections are a trade issue because of regulations imposed by countries on imports. Many countries have regulations requiring inspection of fish for zoonotic parasites, and for inactivating any nematode larvae, etc., that may be present. Regulations and inactivation methods may differ in specifics between countries. (See EU, no date; and Chapter 5 in FDA, no date).

Impact on economically vulnerable populations

Developing countries can be affected by the necessity of taking steps to ensure fish exports are free of live anisakids. The inactivation methods described above can be expensive, and when not completely successful lead to rejection of exports by importing countries, especially fresh fish products.

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A7.2 *ASCARIS* SPP.

General information

Ascaris lumbricoides is the large intestinal roundworm (nematode) of humans, and the infection is termed 'ascariasis' or 'ascariosis', and rarely 'ascarosis'. 'Ascariasis' is the most widely used, and will be used here. The adult worms are large (females up to 35 cm, males up to 31 cm in length), and individual worms can weigh as much as 7 or 8 g (Elkins and Haswellelkins, 1989). The adults occupy the small intestine and the female lays large numbers of eggs (estimated to be in the hundreds of thousands of eggs per day per female) (Brown and Cort, 1927; O'Lorcain and Holland, 2000). The eggs are voided in the faeces and are sticky, thick shelled and highly persistent in the environment such that they can survive for several years in soil. They contaminate water supplies following rain or flooding, vegetables either directly from soil or by irrigation, and probably the hands and clothing of agricultural workers or other people in contact with contaminated soil. The practice of using human faeces as fertilizer in subsistence farming presents a significant risk of continued transmission.

Ascaris suum is the large roundworm of pigs and is considered to be a separate species from *A. lumbricoides*. The two species are virtually indistinguishable morphologically, immunologically and biochemically, although there are some distinguishing immunological and biochemical features (e.g. Kennedy *et al.,* 1987). DNA-based surveys have indicated that *A. suum* is mostly confined to pigs, and *A. lumbricoides* to humans, but that there is evidence of cross-infections such that *A. suum* may present a significant risk to humans Peng and Criscione, 2012; Zhou *et al.,* 2012; Nejsum *et al.,* 2005). In regions endemic for both parasites it appears mostly, but not exclusively, to be the case that adult worms of *A. lumbricoides* have a host preference for humans, and adult worms of *A. suum* have a host preference for pigs (Peng and Criscione, 2012). In regions where *A. lumbricoides* does not occur in humans, there have been cases of infection with *A. suum* that have been attributed to contamination from pig farms (Nejsum *et al.,* 2005; Anderson, 1995).

In both species, infection occurs by ingestion of viable eggs, which hatch in the small intestine, releasing the infective-stage larvae of the parasite, which is in its third developmental stage (L3). The larvae then undergo a tissue migration involving the liver then the lungs. In the lungs the larvae break through to the air spaces, migrate up the trachea, are then swallowed and thereby re-introduced to the gastrointestinal tract, where they mature to adult worms in the small intestine.

The global prevalence of human ascariasis in the 1990s was estimated to be approximately 1.5 billion with 100–200 million people affected clinically, a large proportion of whom were children (reviewed in O'Lorcain and Holland (2000) and

Peng and Criscione (2012). More recent estimates are slightly lower at 1.2 billion people infected, which is largely due to China's large-scale treatment programmes (reviewed in O'Lorcain and Holland (2000) and Peng and Criscione (2012)), but some estimates remain as high as 2 billion people currently infected.

Geographical distribution

The distribution of both species of *Ascaris* is essentially global, but with low prevalences in countries with well-developed sanitation systems, and very high prevalences in regions with poor sanitation. The greater association with tropical and subtropical countries may merely be because many of these have poorer overall sanitation systems and parasite control programmes, and the viability and development to infectivity of eggs is favoured under warm, moist conditions. Exposure of humans to eggs of *A. suum* will be less likely in regions where pigs are not farmed.

Disease

Ascariasis in humans presents mainly in the gut (small intestine and ileum) and the lungs, though larval migration through the liver and peritoneum likely also cause damage (O'Lorcain and Holland, 2000). In the gut, the worms can occur in such numbers that blockage and rupture or perforation can occur in extreme cases. The parasites have also been known to cause death by migrating into and blocking the pancreatic or bile ducts. The worms in the gut can cause malabsorption and anorexia, which will contribute to malnutrition (O'Lorcain and Holland, 2000). The malabsorption may be due to a loss of brush border enzymes, erosion and flattening of the villi, and inflammation of the lamina propria, and premature cessation of lactase production has also been intimated (O'Lorcain and Holland, 2000). Migration of larvae through the lungs can cause severe immune hypersensitivity responses (Loeffler's Syndrome) that may be life-threatening. This appears to be more common in arid areas when periodic rains mobilise dormant *Ascaris* eggs from soil and other sources such as latrines, resulting in a high level of contamination of water and food supplies. It is highly likely that severe pulmonary reactions can be caused by exposure to the eggs of either *A. lumbricoides* or *A. suum* (as is known in sheep and cattle from exposure to *A. suum* eggs, and in experimentally infected animals such as rats, mice and rabbits, the larvae of either species reach the lungs). Infection with adult *Ascaris* can be detected by observation of eggs in faeces, although this requires the presence of a reproductive female. *A. suum* infections of humans in developed countries is often with single or low numbers of worms. Loeffler's Syndrome can be detected by X-ray appearance of shadows on the lungs (Loeffler, 1956), and detection of larvae and eosinophils in sputum or throat swabs. A characteristic feature of infection with parasitic worms is high levels of IgE antibody and eosinophils in blood, and eosinophils and mast cells in infected tissues; there is evidence that allergic-type immune responses may be part of the protective response to Ascaris (McSharry *et al.,* 1999). Important allergens have been described from *Ascaris*. See O'Lorcain and Holland (2000) for further detail on ascariasis disease symptoms and other effects.

Trade relevance

Contamination of fresh produce with Ascaris eggs has not been an issue in trade up to now. The main risk here is through fresh vegetables that have been contaminated with eggs directly from the soil in which they were grown, or the water with which they were irrigated or treated and prepared post-harvest. Trade in pigs can clearly also be a source of infection to new areas. The robustness of Ascaris eggs means that they can survive for long periods during transport, and they can survive low temperatures, including freezing to some degree, desiccation and chemical attack, though not cooking. Once soil is contaminated with viable eggs, it can remain so for up to a decade.

Impact on economically vulnerable populations

The potential impact of ascariasis is chronic and insidious for communities, and can be severe and even life-threatening for individuals. In addition to the overt disease symptoms due to A. lumbricoides infection detailed above, there is evidence that chronic infection can affect the growth rate and final height, of children, and their cognitive development (reviewed in O'Lorcain and Holland, 2000, and Bundy, Walson and Watkins, 2013), which is likely to be particularly so in double or multiple infections with other species of worm parasites. In regions where pigs are kept, the risks of intestinal infection with adult A. suum may be low, but migratory larvae will still cause damage to liver and lungs, and it is likely that the risk of Loeffler's Syndrome will be similar with either species of Ascaris. Lamentably little research has been carried out on the prevalence, morbidity and mortality due to Loeffler's Syndrome or less acute but chronic, repetitive damage to the lungs, in humans infected with either parasite. This paucity of information on the pulmonary stage of infection is particularly unfortunate given the possibility that lung damage could exacerbate lung infections and consequent mortality in children (O'Lorcain and Holland, 2000).

Other relevant information

Drugs for the treatment for the intestinal stage of ascariasis are cheap, readily available and relatively free of side-effects. Treatments for the tissue migratory phases would be rare, partly because of the difficulty of diagnosis, and possibly also the risk of causing deleterious reactions to dead larvae in liver, lungs or elsewhere (O'Lorcain and Holland, 2000). There are no vaccines available against ascariasis. There continues to be a debate about whether infection with Ascaris or other helminth parasites increases or decreases the risk of allergic reactions to environmental allergens (Pinelli *et al.*, 2009).

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A7.3 *BALANTIDIUM COLI*

General information

Balantidium coli is a protozoan parasitic species that causes the disease balantidiasis (CDC, no date; Anon., 2003). It is the only member of the ciliate phylum known to be pathogenic to humans (CDC, no date; Anon., 2003a). Infection occurs when the cysts are ingested, usually through contaminated food or water. This parasite lives in the caecum and colon of humans. *B. coli* has two developmental stages, a trophozoite stage and a cyst stage. Trophozoites multiply and encyst due to the dehydration of faeces. It can thrive in the gastrointestinal tract as long as there is a balance between the protozoan and the host without causing dysenteric symptoms. Infection most likely occurs in people with malnutrition due to the low stomach acidity or people with immune compromised systems (Anon., 2003b; Schuster and Ramirez-Avila, 2008).

Geographical distribution

The disease is considered to be rare and occurs in less than 1% of the human population. Most infections occur in developing countries where faeces are more likely to get in contact with food and drinking water. In addition to humans, pigs and other animals carry the disease. People who raise pigs have a greater risk of getting infected with balantidiasis. Co-infections with other parasites are likely to aggravate the damage wrought by each individual parasite, and they probably share common sources of infection (i.e. contaminated water) (Roberts and Janovy, 2009).

Balantidiasis in humans is common in the Philippines, but it can be found anywhere in the world, especially among those that are in close contact with swine. It has been noted in Latin America, Bolivia, Southeast Asia and New Guinea.

Disease

Common symptoms of balantidiasis include chronic diarrhoea, occasional dysentery (diarrhoea with passage of blood or mucus), nausea, foul breath, colitis (inflammation of the colon), abdominal pain, weight loss, deep intestinal ulcerations, and possibly perforation of the intestine. Fulminating acute balantidiasis is when the disease comes very suddenly and with great intensity. Haemorrhaging can occur, which can lead to shock and death. Untreated fulminating acute balantidiasis is reported to have a fatality rate of 30%. In acute disease, explosive diarrhoea may occur as often as every twenty minutes. Perforation of the colon may also occur in acute infections which can lead to life-threatening situations. If balantidiasis is not treated the persistent diarrhoea leads to high fluid loss and dehydration. If abdominal bleeding occurs, it can lead to death (Schuster and Ramirez-Avila, 2008).

Trade relevance

There have not yet been significant trade issues with respect to findings of *B. coli* in foods, but with the increasing number of surveillance studies reporting positive results worldwide, and the growing number of produce-associated illness outbreaks, more trade issues resulting in import restrictions and recalls may occur in the future. *B. coli* causes reduced production performance in the animals affected, which has an impact on the economy, both locally for farmers and nationally for the country (Roberts and Janovy, 2009).

Impact on economically vulnerable populations

The disease is a problem primarily in developing countries, where water sources may be contaminated with swine or human faeces. Balantidiasis infections can be prevented by following appropriate hygiene practices (such as not using human faeces as fertilizer in agriculture; washing hands after going to the toilet and before meals; washing vegetables; and cooking meat properly). Infective *B. coli* cysts are killed by heat (Schuster and Ramirez-Avila, 2008).

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A7.4 *CRYPTOSPORIDIUM* SPP.

General information

Cryptosporidium spp. are protozoan parasites reported worldwide in a large number of different hosts, including humans. The infectious stages of *Cryptosporidium* spp., known as oocysts, are shed with the faeces of the host and can survive for long periods under cool and moist conditions.

Routes of transmission include waterborne, person-to-person, zoonotic and food-borne. The waterborne route is numerically the most important means of transmission of cryptosporidiosis. Numerous waterborne outbreaks of cryptosporidiosis have occurred worldwide as a result of oocyst contamination of drinking water sources and recreational water. The largest waterborne illness outbreak of any kind in the United States of America occurred in the spring of 1993, when an estimated 403 000 people became ill with cryptosporidiosis in Milwaukee, Wisconsin. Food-borne transmission of cryptosporidiosis is thought to be much less common than waterborne or person-to-person transmission; about 8% of domestically acquired cases in the United States of America are food-borne (Scallan *et al.,* 2011). It is, however, emerging as an important public health issue.

Food-borne outbreaks of cryptosporidiosis associated with the consumption of fresh produce have been reported mainly in the United States of America and in northern Europe (Dixon *et al.,* 2011; Robertson and Chalmers, 2013). The foods implicated in these outbreaks have included green onions, sandwich-bar ingredients, parsley, carrots, red peppers, and lettuce. In some cases these outbreaks were attributed to infected food-handlers. A large outbreak affecting approximately 300 people occurred in the UK in 2012 and was associated with the consumption of pre-cut bagged salad products (HPA, 2013). There have also been four cryptosporidiosis outbreaks associated with drinking unpasteurized apple cider, all in the United States of America. Unpasteurized milk has been associated with outbreaks of cryptosporidiosis in Australia and the UK. Chicken salad was implicated in an outbreak in the United States of America and may have been contaminated by a food worker who also operated a daycare facility.

Numerous surveys performed worldwide have reported the presence of *Cryptosporidium* oocysts on a wide variety of fresh produce items (Dixon *et al.,* 2013). *Cryptosporidium* oocysts have also been reported worldwide in the gills and tissues of oysters and other molluscan shellfish, including clams, cockles and mussels (Fayer, Dubey and Lindsay, 2004).

Control measures to reduce the likelihood of contamination of produce at the pre-harvest stage with *Cryptosporidium* include the use of good quality water for irrigation, mixing of pesticides, or washing and processing; restricting access of livestock and other animals to crop lands and surface waters; monitoring the health of farm workers and encouraging good hygiene; and using only composted manure as fertilizer. Post-harvest control measures include the use of good quality water for washing and processing produce; monitoring and enforcing good personal hygiene in food handlers; prevention of cross-contamination; and the incorporation of HACCP plans. At the consumer level, good hygiene and avoidance of cross-contamination are again important control measures. Thorough washing of fresh produce is recommended, but probably will not be fully effective in removing all contaminating oocysts. Although oocysts are somewhat resistant to freezing, they can be inactivated by storing produce at -20°C for >24 hours, or at -15°C for at least a week. Alternatively, oocysts will be readily destroyed in foods that are subsequently cooked.

Geographical distribution

In recent years, human infection with *Cryptosporidium* spp. has emerged as a global public health problem. Prevalence, however, is very difficult to determine as data is not available from many countries. In one estimate, the prevalence of *Cryptosporidium* in patients with gastroenteritis was 1–4% in Europe and North America, and 3–20% in Africa, Asia, Australia, and South and Central America (Current and Garcia, 1991). Laberge and Griffiths (1996) estimated that the prevalence rates based on oocyst excretion were 1–3% in industrialized countries, and up to 10% in developing countries. Cryptosporidiosis has been reported in 106 countries worldwide (Fayer, 2008).

Approximately twelve species of *Cryptosporidium*, and several genotypes, have been reported in humans. However, 90% of reported human infections involve *C. hominis*, which is found primarily in humans, and *C. parvum*, which is an important zoonotic species. *C. hominis* is thought to account for more human cases than *C. parvum* in North America, Australia, Asia, sub-Saharan Africa and some parts of Europe. Generally speaking, *C. parvum* is more prevalent in rural or agricultural regions, probably as a result of zoonotic transmission. In recent years, *C. meleagridis* has been reported more commonly in humans. For example, Cama *et al.* (2008) reported a relatively high prevalence of infection with *C. meleagridis* in children in Peru. Similarly, *C. cuniculus* was found to be the third most commonly identified species, after *C. parvum* and *C. hominis,* in sporadic cases of cryptosporidiosis in the UK (Chalmers *et al.,* 2011). Several other *Cryptosporidium* species and genotypes are only occasionally found in humans (Xiao, 2010).

Disease

Cryptosporidiosis is an enteric disease which is self-limiting in immunocompetent individuals. The disease is characterized by watery diarrhoea and a variety of other symptoms, including, abdominal pain, weight loss, nausea, vomiting, fever and malaise (Chalmers and Davies, 2010). Symptoms in some immunocompromised patients become chronic, debilitating and potentially life-threatening. Cryptosporidiosis accounts for up to 6% of all reported diarrhoeal illnesses in immunocompetent persons (Chen *et al.,* 2002). Twenty-four percent of AIDS patients with diarrhoea are infected with *Cryptosporidium* spp. (Guerrant, 1997). In the United States of America, Scallan *et al.* (2011) reported a hospitalization rate of 25%, and a death rate of 0.3%, in laboratory-confirmed cases of cryptosporidiosis. In addition to the patients' immune status, there is some evidence that clinical manifestations of cryptosporidiosis may also be partially dependent upon the species of *Cryptosporidium* involved in the infection. With the exception of Nitazoxanide, which is approved in the United States of America for treating diarrhoea caused by *Cryptosporidium* in immunocompetent patients, drug development has been largely unsuccessful against cryptosporidiosis.

Trade relevance

There have not yet been significant trade issues with respect to the finding of *Cryptosporidium* oocysts in foods, but with the increasing number of surveillance studies reporting positive results in a wide variety of foods worldwide, and the growing number of produce-associated illness outbreaks, more trade issues resulting in import restrictions and recalls may occur in the future. As has already been seen with respect to *Cyclospora cayetanensis* in fresh berries, these actions could have significant impacts on the agricultural industry and the economy of developing countries that produce and export fresh produce. An ISO international standard for the detection and enumeration of *Cryptosporidium* and *Giardia* in fresh leafy green vegetables and berry fruits is currently being drafted and may have implications for trade in future as more standardized food testing is done.

Impact on economically vulnerable populations

Along with giardiasis, cryptosporidiosis was included in the WHO Neglected Diseases Initiative in 2004. Diseases included in this initiative "occur mainly in developing countries where climate, poverty and lack of access to services influence outcomes", and where they "impair the ability of those infected to achieve their full potential, both developmentally and socio-economically" (Savioli, Smith and Thompson, 2006). As such, cryptosporidiosis in particular may have considerable negative impacts on economically vulnerable populations.

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A7.5 *CYCLOSPORA CAYETANENSIS*

General information

Cyclospora cayetanensis is a coccidian parasite that can be acquired by ingestion of contaminated raw produce (vegetables, herbs and fruits) and possibly drinking water. Sporulated oocysts excyst in the gastrointestinal tract and invade the epithelial cells of the small intestine, where asexual and sexual multiplication occurs. Unsporulated oocysts are formed and excreted in the faeces of the infected individual. It takes 7–15 days under ideal environmental conditions for these oocysts to sporulate and become infectious. Oocysts measure 8–10 µm in diameter and autofluoresce when exposed to UV light. Sporulated oocysts consist of two sporocysts, each containing two sporozoites. *C. cayetanensis* seems to be specifically anthroponotic. A few reports described *Cyclospora* oocysts in the faeces of dogs, ducks and chickens, but unsuccessful experimental infections and lack of histopathological evidence of infection do not support the availability of an intermediate or definitive host other than human (Ortega and Sanchez, 2010) and these undoubtedly represented spurious passage of oocysts. In the past decade, other *Cyclospora* species have been described in non-human primates, but molecular information has confirmed that these species are not *C. cayetanensis* (Eberhard *et al.*, 1999).

In the United States of America, it is estimated that annually the mean number of episodes of gastroenteritis caused by *Cyclospora* is 11 407 (CI: 137–37 673) with a 6.5% hospitalization rate (Scallan *et al.,* 2011). To date, no deaths have been reported due to *Cyclospora* infections and there is no evidence that *Cyclospora* is endemic in the United States of America.

Waterborne transmission can occur (Rabold *et al.*, 1994). Oocysts have been identified in water used for human consumption in various studies; however, foodborne transmission has been reported more frequently and has been linked to lettuce, basil, snow peas and berries (blackberries and raspberries) (Shields and Olson, 2003) that were consumed raw, and frequently associated with social events. In 1996, 1465 cases of cyclosporiasis, associated with consumption of Guatemalan raspberries, were reported in the United States of America and Canada. In 1997, 1012 more cases were reported associated with the consumption of Guatemalan raspberries, and 342 cases implicated contaminated basil. In 1998, raspberry importations were not permitted into the United States of America whereas importation into Canada continued. That year, 315 cases of cyclosporiasis were reported in Canada, again implicating raspberries imported from Guatemala (Herwaldt, 2000). Since then, Cyclospora cases have been reported in the United States of America every year, and in most instances no specific food commodity has been associated with those outbreaks. Outbreaks of *Cyclospora* have also been reported in

Europe (Doller *et al.*, 2002). In most instances, reports from Europe describe cases associated with travel to endemic areas (Cann *et al.*, 2000; Clarke and McIntyre, 1996; Green *et al.*, 2000). In December 2000, 34 persons acquired cyclosporiasis in Germany. The food items implicated as a result of the epidemiological investigation (butterhead lettuce (from Southern France), mixed lettuce (from Bari, Italy), and chives (from Germany)) were not available for microbiological examination (Doller *et al.*, 2002).

Geographical distribution

Cyclospora has been reported to be endemic in China, Cuba, Guatemala, Haiti, India, Mexico, Nepal, Peru and Turkey. Other reports from travellers suggest that *Cyclospora* could also be endemic in other tropical regions, including Bali, Dominican Republic, Honduras, Indonesia, Papua New Guinea and Thailand (Ortega and Sanchez, 2010). The prevalence of *Cyclospora* in these regions has changed as the socio-economic conditions of the populations have changed. There are reports of infection in parts of Africa, but the absence of infection has been noted in many studies that looked specifically for it, and further study and confirmation of the distribution of the organisms in this part of the world is required.

Disease

Cyclosporiasis is characterized by watery diarrhoea, nausea, abdominal pain and anorexia. Low-grade fever, flatulence, fatigue and weight loss have also been reported. Biliary disease, Guillain-Barrè Syndrome and Reiter's Syndrome have been reported to follow *Cyclospora* infections (Ortega and Sanchez, 2010).

The severity of illness is higher in children, the elderly, and immunocompromised individuals. Symptomatic cyclosporiasis is common in naïve (non-endemic) populations. Illness usually lasts 7–15 days, but in immunocompromised and a few immunocompetent individuals it can last up to 3 months (Bern *et al.,* 2002). Recurrence has been reported in HIV patients. The drug of choice to control infection is trimethoprim sulfamethoxazole, but in patients who are allergic to sulfa, ciprofloxacin has been used as an alternative treatment. If not treated, the host's immune response should eventually control the infection (Pape *et al.,* 1994).

In endemic areas, children under 10 years frequently acquire the infection, and as they grow and have repeated exposures, infections can be less symptomatic and of shorter duration (Bern *et al.,* 2000, 2002; Hoge *et al.,* 1995; Ortega *et al.,* 1993). The environmental conditions that favour *Cyclospora* endemicity are not fully elucidated, nor are the conditions that allow for a marked seasonality characteristic in locations where *Cyclospora* is endemic (Lopez *et al.,* 2003; Madico *et al.,* 1997; Schlim *et al.,* 1999).

Trade relevance and impact on economically vulnerable populations

Cyclospora has affected international trade and susceptible populations. This was very evident during the 1995–1997 outbreaks in the United States of America. Importation of berries (Herwaldt, 2000), particularly raspberries, was affected, causing significant financial losses to the producers, exporters and importers. In 1996, United States of America strawberry growers were affected as it was assumed that cases of cyclosporiasis were linked with California strawberries. The California Strawberry Commission estimated that this false assumption led to US$ 16 million in lost revenue to the growers in California during the month of June in that year. Later it was determined that these outbreaks were associated with the consumption of imported Guatemalan raspberries (Herwaldt *et al.,* 1997). In 1996, before the *Cyclospora* outbreaks occurred, the number of raspberry growers in Guatemala was estimated to be 85. By 2002, only 3 remained. For many growers the decision to leave the industry was based on losses due to the lack of foreign demand of their berries and export markets closures (Calvin, Flores and Foster, 2003). The losses resulting from these outbreaks were significant not only financially but also for the reputation of the Guatemalan berry industry and the communities involved.

The global burden and prevalence of this parasite worldwide need to be considered. Its effect in global trade has been notorious in commodities imported from endemic areas. However, effects on the economy and health of the population in endemic countries, where exports are not an element of consideration in terms of outbreaks in developed countries, need to be further studied.

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A7.6 *DIPHYLLOBOTHRIUM* SPP.

General information

Human diphyllobothriasis is a fish-borne zoonosis distributed worldwide and it is transmitted by cestodes belonging to the genus *Diphyllobothrium*. The life cycle of these tapeworms involves two intermediate hosts (zooplankton and some marine and freshwater fish species, especially those anadromous species that migrate from salt to fresh water to spawn), and piscivorous mammals and birds as definitive hosts. Fourteen of the 50 known species of *Diphyllobothrium* so far described are known to infect humans (Scholz *et al.,* 2009). The occurrence of the disease is closely linked to the consumption of raw or undercooked freshwater or marine fishes.

Diphyllobothriasis is considered a mild illness and is not reportable, therefore the estimates of global illnesses attributed to this fish-borne zoonosis are based on limited human surveys and clinical case reports. Chai, Murrell and Lymbery (2005) estimated global infection at 20 million. Dorny and co-workers (2009) estimated that in about 20% of the infections, clinical manifestations occur.

Geographical distribution

Americas

Until 1982, diphyllobothriasis was a reportable disease in the United States of America, with 125–200 cases reported during the period 1977–1981 (Ruttenber *et al.,* 1984). In North America, most cases occur in the Great Lakes region and Alaska, although cases have been reported elsewhere (Cushing and Bacal, 1934; Margolis, Rausch and Robertson, 1973; Turgeon, 1974). The following species of *Diphyllobothrium* were documented as infecting humans in North America: *D latum, D dendriticum, D. dalliae, D. lanceolatum, D. ursi, D. alascense* and, just recently, *D. nihonkaiense* (reviewed by Scholz *et al.,* 2009).

Human infections are commonly reported within the Southern Cone of South America, most commonly with *D. latum* and *D. pacificum* (Mercado *et al*., 2010), which includes Chile (Mercado *et al*., 2010; Torres *et al*., 1993), Argentina (Semenas, Kreiter and Urbanski, 2001) and Peru (Lumbreras *et al*., 1982) on the Pacific coast. In Chile, 0.4–1.4% of the population shed *Diphyllobothrium* eggs in high-risk zones (Torres *et al*., 1993; Navarrete and Torres, 1994).

Asia

In Japan, it is estimated that, on average, about 100 cases per year of diphyllobothriasis occur (Oshima and Kliks, 1987), and in the Republic of Korea, at least 47 cases have been reported since 1971 (Lee *et al.,* 2007; Jeon *et al.,* 2009), most commonly with *D. nihonkaiense*. In China, 12 cases (Guo *et al.,* 2012) of infection with *D. latum* were reported in 2009–2011; however, these figures are likely to be a gross underestimate of true incidence. Sporadic reports of clinical illness have also been reported in Malaysia (Rohela *et al.,* 2002, 2006), India (Devi *et al.,* 2007; Duggal *et al.,* 2011; Ramana *et al.,* 2011) and Taiwan (Chou *et al.,* 2006; Lou *et al.,* 2007). In easternmost Russia, where *D. klebanovskii* is considered the important zoonotic species, human prevalence usually ranges from 1.0 to 3.3%. Since the completion of the Krasnoyaek Reservoir on the Enisel River the prevalence of *D. klebanovskii* has risen as high as 7.7% in people living along the reservoir shore (Scholz *et al.,* 2009; Chai, Murrell and Lymbery, 2005).

Europe

D. latum has been considered to be the principal species infecting humans in Europe, with *D. dendriticum* present in northern Europe. The incidence appears to be on the decline overall. In Scandinavian countries it persists in several regions. Currently Switzerland, Sweden, Finland and Estonia report more than 10 cases per year (440 in Estonia in 1997), while Lithuania, Poland, Hungary, Italy and France average 2–10 cases annually. Only sporadic cases occur in Norway, Austria and Spain. Over 30 cases have been identified on the Swiss shores of Lake Maggiore since 1990, and 70 cases on the Swiss and French shores of Lake Leman between 1993 and 2002 (Dupouy-Camet and Peduzzi, 2004).

Disease

Severity of acute morbidity

Acutely, patients may experience vomiting, abdominal discomfort, cramps, diarrhoea and shed ribbon-like proglottids in their faeces (Lumbreras *et al.,* 1982; Ramana *et al.,* 2011; Wicht *et al.,* 2008).

Severity of chronic morbidity

This was reviewed by Scholtz *et al.* (2009). In addition to chronic relapsing diarrhoea and abdominal discomfort (Wicht *et al.,* 2008; Choi, Lee and Yang, 2012), prolonged or heavy infection may cause megaloblastic anaemia due to a parasite-mediated dissociation of the vitamin B12-intrinsic factor complex within the gut lumen, making B12 unavailable to the host. Approximately 80% of the B12 intake is absorbed by the worm, with a differential absorption rate of 100:1 in relation to absorption by the host (Scholz *et al.,* 2009).

Chronic illness fraction

About 40% of infected individuals may show low B12 levels, but only 2% or less develop clinical anaemia, which is hyperchromic and macrocytic and may be associated with low platelets or low white blood cell counts (Scholz *et al.,* 2009). This deficiency may produce damage to the nervous system, including peripheral neuropathy or central nervous system degenerative lesions (Scholz *et al.,* 2009).

Case fatality rates

No reports.

Increase in human illness potential

Increased human illness is unlikely with regards to severity, but is potentially an emerging zoonosis due to increased globalization associated with travel and trade, as well as increases in global popularity of eating dishes such as sushi and sashimi. Risks are mostly associated with wild-caught fish given the primarily sylvatic nature of the parasite's life cycle.

Trade relevance

As the demands for 'premium' quality fish and fishery products increase, harvesting and export of wild-caught fish from diphyllobothriid-endemic areas that are transported chilled (not frozen) pose the greatest risk to trade (Chetrick, 2007). Inactivation of larvae (plerocercoids) requires cooking fish at 55°C for at least 5 minutes, or freezing it at -18°C for at least 24 h before consumption. An increasing number of human cases of diphyllobothriasis due to 'exotically' located *Diphyllobothrium* species are being reported (de Marval *et al.*, 2013). To date, *D. nihonkaiense* infection has been reported in three Swiss (Wicht, de Marval and Peduzzi, 2007; Shimizu *et al.,* 2008) and two French locals (Paugam *et al.,* 2009; Yera *et al.,* 2006) and a case of *D. dendriticum* (de Marval *et al.,* 2013) in a Swiss local that had most likely consumed salmon imported from Finland (Wicht *et al.,* 2008).

Impact on economically vulnerable populations

True incidence and contribution to morbidity remain unascertained. The zoonosis is likely to have impacts, especially within developing communities, due to the neglected nature of parasitism.

Other relevant information

In those areas where mass drug administration programmes are carried out and known to be endemic for diphyllobothriasis, it may be important to consider the inclusion of praziquantel and educational measures aimed at discouraging the practice of eating insufficiently cooked fish.

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A7.7 *ECHINOCOCCUS GRANULOSUS*

General information

Echinococcus granulosus is a small (3–7 mm) cestode (tapeworm) belonging to the Taeniidae family. It belongs to the *Echinococcus* genus, which includes six species. The most important species of the genus in terms of public health importance and geographical distribution are *E. granulosus*, which causes cystic echinococcosis (CE) and *E. multilocularis*, which causes alveolar echinococcosis (AE).

Echinococcus species require two mammalian hosts for completion of their life-cycles (end and intermediate hosts). Tapeworm segments containing eggs (gravid proglottids) or free eggs are passed in the faeces of the definitive host, a carnivore. The eggs are ingested by intermediate hosts (many mammalian species), in which the larval stage (metacestodes) and infectious elements (protoscoleces) develop and cause CE. The cycle is completed if an infected intermediate host is eaten by a suitable carnivore. A common source of infection for carnivores is offal from infected livestock.

Infection of humans is due to accidental ingestion of *E. granulosus* eggs passed into the environment with faeces from definitive hosts (dogs are the main sources). *E. granulosus* is maintained in domestic and wildlife reservoirs, and its transmission is influenced by human activities, behaviour, hygiene, environmental factors and the lack of cooperation among public health, agriculture and local authorities. Eggs of *E. granulosus* are highly resistant to environmental conditions and can remain infective for many months (up to about 1 year in a moist environment at lower ranges of temperatures of about +4°C to +15°C). Eggs are sensitive to desiccation, and are killed within 4 days at a relative humidity of 25%, and within 1 day at 0%. Heating to 60–80°C will kill these eggs in less than 5 minutes. Most importantly, *E. granulosus* eggs can survive freezing temperatures (Eckert *et al.,* 1992; Gemmell and Lawson, 1986)

There are at least ten genetic variants (G1 to G10) of *E. granulosus,* of which seven (sheep strain G1, Tasmanian sheep strain G2, buffalo strain G3, cattle strain G5 (*E. ortleppi*), camel strain G6, pig strain G7/G9 and cervid strain G8) have been shown to be infectious for humans. The strain most often associated with human CE appears to be the common sheep strain (G1).

CE is not considered to be 'strictly' a food-borne disease because the infection occurs by ingestion of the *Echinococcus* eggs via contact with contaminated soil, infected dogs, or by consumption of food (mainly vegetables) or water contaminated with infected dog faeces. Food may be an important vehicle of transmission, but it may not be the primary vehicle for transmission for these parasites.

However, given the wide distribution and relatively high incidence and severity of CE, and since CE is one of the major contributors to the global burden of parasitic zoonoses (Torgerson and Macpherson, 2011), it is necessary to consider its food-borne route.

There are continuing challenges in diagnosing CE in different host species, including humans (Barnes *et al.,* 2012). In addition, no global estimates exist to date of CE burden in humans, and the incidence data is gathered from published literature that is generally based on surgical cases. Consequently, human cases of CE are systematically underreported by healthcare systems. Serra *et al.* (1999) and Nazirov, Ilkhamov and Ambekov (2002) reported that up to 75% of clinic- or hospital-diagnosed cases are never recorded in local or national databases or published reports.

One of the major factors influencing the prevalence of CE is close contact with untreated dogs, the habit and popular tradition of eating raw or inadequately cooked foods, and drinking water contaminated with *Echinococcus* eggs.

Geographical distribution

E. granulosus has a worldwide geographical distribution, with endemic foci present in every continent. Its distribution and prevalence depends on the presence of large numbers of sheep, cattle, goat and camel flocks that are the intermediate hosts of the parasite, and their close contact with dogs, the main final host, which transmit the infection to humans. At the same time, the highest prevalence of CE in human and animal hosts is found in countries of the temperate zones, including several parts of Eurasia (the Mediterranean regions, southern and central parts of Russia, central Asia, China), Australia, some parts of America (especially South America) and north and east Africa (Dakkak, 2010; Eckert *et al.,* 2001; Grosso *et al.,* 2012; Thompson and McManus, 2002). Due to the wide geographical distribution and extent greater than previously believed, CE is currently considered an emerging or re-emerging disease (Grosso *et al.,* 2012; Thompson and MacManus, 2002; Torgerson *et al.,* 2003).

Human CE, which is the most common *Echinococcus* spp. infection, probably accounts for more than 95% of the estimated 3 million global cases, with human AE causing only 0.3–0.5 million cases (Zhang, Ross and McManus, 2008). The annual incidence of CE can range from less than 1 to >200 per 100 000 inhabitants in various endemic areas (Pawlowski, Eckert and Vuitton, 2001; Dakkak, 2010).

Disease

The oncospheres released from ingested *E. granulosus* eggs enter the blood stream after penetration of the intestinal mucosa, and are distributed to the liver and other sites, where development of cysts begins. The liver is the most common site of the echinococcal cyst (>65%), followed by the lungs (25%); the cyst is seen less frequently in the spleen, kidneys, heart, bone or central nervous system (Moro and Schantz, 2009). The cysts vary greatly in size and shape, and may be present in large numbers in one organ. The location of cysts and cyst morphology depends on host factors and on the *E. granulosus* strain.

The incubation period ranges between 2 and 15 years in general, and clinical manifestations of CE are variable and determined by the site, size and condition of the cysts. It has been shown that rates of growth of cysts are variable, ranging from 1 to 5 cm in diameter per year (Moro and Schantz, 2009), and that the cysts of *E. granulosus* can grow to more than 20 cm in diameter in humans, but the clinical manifestations are generally mild and the disease remains asymptomatic for a considerable period. Thus, CE is a chronic cyst-forming disease characterized by long-term growth of the cysts in internal organs for several years (Spruance, 1974). The slowly growing hydatid cysts can attain a volume of several litres and contain many thousands of infectious elements (protoscoleces). Due to the slow-growing nature of the cyst, even if the infection is frequently acquired in childhood, most cases with localization of cysts in the liver and lung become symptomatic and are diagnosed in adult patients. At the same time, cysts located in the brain or eye can cause severe clinical symptoms even when small; thus, most cases of intracerebral echinococcosis are diagnosed in children (Moro and Schantz, 2009).

The signs and symptoms of hepatic echinococcosis can include hepatic enlargement (with or without a palpable mass in the right upper quadrant), right epigastric pain, nausea, biliary duct obstruction and vomiting. Pulmonary involvement can produce chest pain, cough and haemoptysis. CE is rarely fatal, but occasionally death occurs because of anaphylactic shock, or cardiac tamponade (Bouraoui, Trimeche and Mahdhaoui, 2005). Rupture of the cysts and sudden release of the contents can precipitate allergic reactions and produce fever, urticaria, eosinophilia and mild to fatal anaphylactic shock, as well as cyst dissemination that results in multiple secondary echinococcosis disease. Larval growth in bones is atypical; when it occurs, invasion of marrow cavities and spongiosa is common and causes extensive erosion of the bone.

The mortality rate, among surgical cases, is about 2 to 4%, and it increases considerably if surgical and medical treatment and care are inadequate (Zhang, Ross and McManus, 2008; Dakkak, 2010).

Trade relevance of cystic echinococcosis

A number of scientific publications have reported that *E. granulosus* might be imported either with intermediate or definitive hosts (Boubaker *et al.*, 2013).

This could represent a threat for those countries currently free from the parasite. Therefore, consideration may need to be given to the development of tools for pre-mortem diagnosis of hydatidosis in farm animals, which could be used to minimize the risk of importation of infected livestock. There must also be increased awareness of the possible occurrence of biological strains of the parasite that might be of greater or lower infectivity for humans.

At present no data are available on the actual prevalence of *E. granulosus* eggs in food or in drinking water in general. Even less is known about that which is traded internationally. Greater consideration of the possible occurrence of parasite strains that might be of greater or lower infectivity for humans may be important. However, the development of specific DNA detection techniques would provide an important diagnostic tool.

Action in definitive hosts is an effective means to strengthen the prevention of the introduction of the disease due to importation of dogs, cats and wild carnivores. Indeed, the World Organisation for Animal Health (OIE) has issued important recommendations in this regard:

> "Veterinary Authorities of importing countries should require the presentation of an international veterinary certificate attesting that the animals were treated against echinococcosis/hydatidosis prior to shipment, and that the treatment used is recognized as being effective" (OIE, 2012).

Impact of CE on economically vulnerable populations

As a cosmopolitan disease, CE represents an increasing public health and socio-economic concern in many areas of the world ((Eckert, Conraths and Tackmann, 2000; Garippa, Varcasia and Scala, 2004), and already results in a high disease burden in underdeveloped regions of the world, including areas of North Africa, the Near East, South America, Central Asia, and China (Wang, Wang and Liu, 2008). It affects both human and animal health and has important socio-economic consequences. However, the socio-economic impact of the disease is not fully understood in most endemic countries because it is necessary to consider not only human and animal health, but also agriculture, trade and market factors. Evaluation of the costs to national economies has been reviewed by Budke, Deplazes and Torgerson (2006). However, the true impact of CE may still be substantially under-represented.

In humans, costs associated with CE have been shown to have a great impact on affected individuals, their families, and the community as a whole (Budke, Deplazes and Torgerson, 2006; Torgerson, 2003). CE represents a substantial burden on the human population, and current estimates suggest that the disease results in the loss of 1 to 3 million disability-adjusted life years (DALYs) per annum (Torgerson and Craig, 2011). The World Health Organization (WHO) considered CE as: "… not only one of the most widespread parasitic diseases, but also one of the most costly to treat and prevent in terms of public health." (Eckert *et al.,* 2001). Furthermore, in most reports, between 1 and 4% of CE cases are fatal (Budke, Deplazes and Torgerson, 2006; Dakkak, 2010; Torgerson, 2003).

In livestock, there is a direct cost (mainly the loss of revenue through offal condemnation) and indirect costs (reductions in the growth, fecundity and milk production of infected animals) that are included in the estimate of the total costs associated with CE. According to Benner *et al.* (2010), indirect losses account for almost 99% of the total cost associated with CE. Torgerson and Craig (2011) estimated that the annual cost of treating cases and economic losses to the livestock industry probably amounts to US$ 2 billion.

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A7.8 *ECHINOCOCCUS MULTILOCULARIS*

General information

The fox tapeworm, *Echinococcus multilocularis* (Cestoda: Cyclophyllidea: Taeniidae) is mostly associated with a sylvatic life cycle, with foxes of the genera *Vulpes* and *Alopex* usually serving as definitive hosts, although other wild canids (e.g. raccoon dogs, wolves, coyotes) may also act as definitive hosts. A synanthropic cycle also occurs, in which domestic dogs usually act as definitive hosts; although domestic cats (and possibly wild felids) may serve as definitive hosts, experimental infections suggest that cats would appear to have only a minor role in the maintenance of *E. multilocularis* in endemic areas, and infections in cats may be of minimal public health significance (Thompson *et al.,* 2006).

For both sylvatic and synanthropic cycles, various different genera of rodents and lagomorphs may act as intermediate hosts, being infected by ingestion of the eggs released from the tapeworms in the faeces of the definitive hosts. The most common potential intermediate hosts include rodents in the genera *Microtus*, *Arvicola* and *Ondatra*, and lagomorphs in the genera *Ochotona*, depending on location. A number of other mammals, including humans and pigs, may also be infected with the eggs of the parasite; in humans, this may result in the disease state known as alveolar echinococcosis (AE). However, as metacestode development in these non-rodent mammals seems to be incomplete or retarded, and also as these animals are less likely to be later consumed by the definitive hosts, they do not seem to play a role in the perpetuation of the life cycle, and they are usually referred to as aberrant or accidental intermediate hosts (Böttcher *et al.,* 2013).

Geographical distribution

Data on the prevalence of AE in humans is scattered and patchy, probably partly due to diagnostic challenges, particularly in early stages of infection. However, improved diagnostics, such as specific serological tests in combination with imaging techniques, have increased diagnostic possibilities.

In North America, only a couple of cases of human AE have been recorded, despite a high prevalence and intensity of infection in wild canids and despite some populations, such as fox and coyote trappers, being highly exposed. In 2008, the EU reported an annual incidence of 1 case per 10 million inhabitants (EFSA, 2010), whereas reports from the United States of America indicate a much lower incidence (Bristow *et al.,* 2012). It has been suggested that this difference in incidence may represent genetic differences between strains of parasites, rather than differences in exposure risks or diagnostic capabilities between populations (Davidson *et al.,* 2012). Although *E. multilocularis* infections in wildlife in Europe appear to be increasing and expanding in prevalence, and the pattern of prevalence in humans is following the same trend (Schweiger *et al.,* 2007), human infection nevertheless continues to be considered as rare. For example, the mean annual incidence of human cases per 100 000 population, recorded with consistent methods, more than doubled in Switzerland, from 0.10 between 1993 and 2000, to 0.26 between 2001 and 2005 (Moro and Schantz, 2009), while in Latvia and Lithuania patient numbers seem to have been rising since 2002 (Bruzinskaite *et al.,* 2007; Keis *et al.,* 2007), indicating emergence of this infection in some parts of Europe. Expanding fox populations associated with rabies vaccination in some areas may contribute to the spread of this infection.

While *E. multilocularis* infection apparently does not occur in Australia, Africa, South or Central America, countries in Asia and Europe, as well as North America, remain important endemic areas. In particular, Russia and adjacent countries (Belarus, Ukraine, Moldova, Turkey, Armenia, Azerbaijan, Kazakhstan, Turkmenistan, Uzbekistan, Tajikistan, Kyrgyzstan and Mongolia), nine provinces or autonomous regions in China (Tibet, Sichuan, Inner Mongolia, Gansu, Ningxia, Qinghai, Xinjiang, Heilongjiang and Shaanxi) and the Japanese island of Hokkaido are important endemic foci (Davidson *et al.,* 2012). Indeed, by far the largest numbers of human cases are reported from three main foci in China, with prevalences ranging from 0.2% in northwestern Xinjiang to 4% in Gansu and Northwestern Sichuan (Craig, 2006). Specific individual villages report even higher prevalence, with 16% reported from the village of Ban Ban Wan, Gansu (Vuitton *et al.,* 2011).

Disease

Adult *E. multilocularis* tapeworms normally cause little harm to the definitive host and infection is asymptomatic. In intermediate hosts, including humans, ingested eggs develop to oncospheres, which penetrate the intestinal wall and are carried via blood to the liver in particular, but also to other organs, where they form multilocular cysts causing the disease, AE. From ingestion of eggs to onset of clinical symptoms (incubation time) in people may be from months to years, or even decades, depending on the location of the cysts and their speed of growth. In the vast majority of human AE cases, metacestodes of *E. multilocularis* initially develop in the liver (Kern, 2010), with cysts varying from a few millimetres up to 15–20 cm or more in diameter. These cysts can also reproduce aggressively by asexual lateral budding. This gradual invasion of adjacent tissue in a tumour-like manner is the basis for the severity of this disease. Metacestodes may also spread from the liver to other internal organs, such as the lungs, spleen, heart and kidney. Symptoms of severe hepatic dysfunction appear in the advanced clinical stage, in addition to symptoms from other affected organs.

The proportion of cases of AE that are actually food-borne is difficult to estimate, as diagnosis usually occurs long after infection and it may be difficult to associate an infection with a food-borne event many years previously. It should be noted that the tapeworm eggs excreted in the faeces of definitive hosts may contaminate various types of edible plants, including fruits and vegetables, as well as drinking water. The eggs are extremely tolerant of environmental conditions, as the oncosphere membrane surrounds and protects the infective part of the egg from the environment. *E. multilocularis* eggs are also extremely freeze-tolerant; freezing the eggs at -20°C does not affect their infectivity. However, the eggs are sensitive to desiccation and heat. Thus, although there is a large potential for food-borne infection via raw produce, it is difficult to obtain evidence for this, and consumption of raw outdoor produce did not emerge as an important risk factor for AE in a German study in which other factors had considerably higher odds ratios (Kern *et al.,* 2004). Other reports suggest that owning pet dogs with access to the outdoors may be the highest risk factor for AE (Stehr-Green *et al.,* 1988; Kreidl *et al.,* 1998). Nevertheless, the severity of the chronic morbidity associated with AE, and the potential for food-borne transmission without it necessarily being recognized, means that food-borne transmission should not be dismissed.

While there is negligible acute morbidity associated with AE, its chronic morbidity is severe and infection is potentially fatal. Most patients suffering from a chronic carrier status need continuous medical treatment and follow-up examinations. Surgery and various endoscopic or percutaneous interventions are required. In addition to anti-infective therapy with benzimidazoles, earlier diagnosis and long-term medical care has increased patients survival time during the last 35 years (Kern, 2010).

Trade relevance

Although globalization of trade suggests that *E. multilocularis* could also be introduced to countries via fresh produce, particularly with respect to the longevity of the infective eggs, a risk assessment from Norway concluded that import of *E. multilocularis* to mainland Norway (currently *E. multilocularis*-free) via fresh produce is unlikely (VKM, 2012). Import of this parasite to currently *E. multilocularis*-free regions seems to be more likely to occur via transport in either definitive or intermediate hosts, as has previously been documented (for example, introduction to Svalbard; Davidson *et al.,* 2012).

Different regions of the world have veterinary regulations for treatment of dogs, wild canids and cats to avoid the import of the infection. For example, within the EU there is a specific regulation regarding preventive health measures for the control of *E. multilocularis* infection in dogs (EU, 2003). From an international perspective, the OIE terrestrial code provides recommendations for the importation of dogs, wild canids and cats from an infected country.

Impact on economically vulnerable populations

It should be noted that in communities where access to either diagnosis or prolonged (life-long) treatment, or both, is limited, then the potential impact of infection is considerable. AE is a serious public health problem mainly in the more sparsely populated regions of China (including the Tibetan plateau and Inner Mongolia) and is often associated with pastoral minority communities. Failure to diagnose AE (or its misdiagnosis) leads to advanced disease, making treatment difficult and prognosis poor; cases studies in rural China have indicated that poor public health infrastructure may result in diagnostic and treatment challenges for AE (McManus *et al.,* 2011). Thus, although the prognosis for AE is reasonable when treatment is available, the prognosis is bleak in the absence of treatment or with failure for diagnosis (Torgerson *et al.,* 2010), and in economically vulnerable populations annual mortality may be similar to the incidence. The disease burden from AE has been compared to that of rabies (Torgerson *et al.,* 2010), with annual AE mortality estimated as being approximately one-third of that due to rabies, which has been estimated at approximately 55 000. The authors note that, unlike with rabies, there is no vaccine for AE, and therefore although AE is rare globally, in some highly endemic communities in China (and possibly other economically vulnerable populations) it imposes high burden, and is likely to be one of the leading causes of death.

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A7.9 *ENTAMOEBA HISTOLYTICA*

General information

Entamoeba histolytica is an intestinal protozoan and causes amoebic colitis, dysentery, and extraintestinal abscesses. Amoebiasis is the second leading cause of death from protozoan disease worldwide (Haque *et al.,* 2003; Stanley, 2003). *E. histolytica* has a life cycle consisting of the infectious cyst form and the trophozoite, the invasive and disease causing stage. The incidence of amoebiasis was previously overestimated as two or more morphologically indistinguishable species were thought to be responsible for disease. However, differentiation by molecular diagnosis such as PCR (rRNA, peroxiredoxin, tRNA-linked short tandem repeats) led to the consensus that only *E. histolytica* (and maybe *E. moshkovskii*) is invasive and causes disease, whereas *E. dispar* is commensal and non-invasive. The current estimation of the disease burden is approximately 50 million infections, resulting in an estimated 40 000 to 110 000 deaths annually (PAHO, 1998). Infection mostly occurs by ingestion of food or water contaminated with faeces containing *E. histolytica* cysts. However, direct ingestion of faeces by oral and anal sex, particularly among men who have sex with men, and also by faecal smearing among persons with intellectual disabilities, are considered to be the major route of infection in industrialized countries (Weinke *et al.,* 1990; Nozaki, 2000). Since waterborne routes are primarily important in developing countries, the exact proportion of food-borne association with amoebiasis is not known.

Geographical distribution

Amoebiasis is distributed throughout the world and is a potential health risk in all countries where water and food are not adequately separated from faecal contamination. In Mexico, serological studies showed that >8% of the population had amoebiasis (Caballero-Salcedo *et al.,* 1994). In Hue City, Viet Nam, the annual incidence of amoebic liver abscess was reported to be 21 cases per 100 000 inhabitants (Blessmann *et al.,* 2002). In the United States of America, about three thousand cases of amoebiasis were recorded in 1993, comprising mostly immigrants from Central and South America, Asia and the Pacific Islands (MMWR, 1994). Travellers to endemic countries and regions are also at risk of amoebiasis infections. For instance, 10% of about 500 individuals with diarrhoea after travelling to a developing country were diagnosed with amoebiasis (Jelinek *et al.,* 1996), and 3% of about 3000 German travellers returning from the tropical regions were infected with *E. histolytica* (Weinke *et al.,* 1990).

Disease

Less than 10% of individuals infected with *E. histolytica* develop symptoms (Haque *et al.,* 2003; Stanley, 2003; Ali and Nozaki, 2007). Clinical symptoms of amoebic colitis include bloody diarrhoea with multiple mucoid stools, abdominal pain and tenderness. Fulminant amoebic colitis is characterized by profuse bloody diarrhoea, fever, pronounced leucocytosis, and severe abdominal pain, and occasionally seen in individuals at risk, including pregnant women, immunocompromised individuals, including those with AIDS, diabetes or alcoholism. Amoebic liver abscess is the most common extraintestinal manifestation of an amoebic infection. Symptoms associated with amoebic liver abscess are fever, right upper quadrant pain and hepatic tenderness, and sometimes include cough, anorexia and weight loss. Pleuropulmonary amoebiasis, amoebic brain abscess and amoebic skin abscess also occasionally occur. In most cases, amoebic infection is cured by drug treatment or is self-limiting, and persistent and chronic infection does not usually occur. Protective acquired immunity against amoebiasis does not last long, particularly in children, which leads to repeated infections. The case fatality rate of amoebiasis is not well known. However, in Japan, 10 deaths were reported among the 2574 confirmed cases in 2003–2006 (IASR, 2007). The case fatality rate in developing countries may be significantly higher.

Trade relevance

As mentioned above, attribution of food-borne association with overall incidence of amoebiasis is not very clear. As transmission occurs through consumption of fresh produce, trade involving all endemic countries and regions may have an impact on transmission of the parasite. However, amoebiasis is considered to be mostly irrelevant to international trade. It is important to improve hygiene and awareness of potential food-borne transmission in food handlers.

Impact on economically vulnerable populations

Children, particularly malnourished children, are more susceptible than adults (Haque *et al.,* 2003). Trade-associated impact to these populations is not known.

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A7.10 *FASCIOLA* SPP.

General information

Over 80 different species of food-borne trematodes have been reported from human infections (Fürst, Keiser, and Utzinger. 2012; Chai, 2007). Worldwide, about 56.2 million people were infected with food-borne trematodes (including *Fasciola*) in 2005: 7.9 million presented severe sequelae and 7158 died (Fürst, Keiser, and Utzinger. 2012).

Fasciola (Fasciolidae) is a plant-borne trematode. Two species have been found to affect humans: *Fasciola hepatica* and *F. gigantica*. Fascioliasis is an important disease in sheep, cattle and humans and is chiefly confined to the liver, where the most important pathogenic sequelae are hepatic lesions and fibrosis, and chronic inflammation of the bile ducts (Mas-Coma, Esteban and Bargues, 1999; Mas-Coma, Bargues and Valero, 2005).

The emergence of fascioliasis appears to be partly related to climate change, where mainly anthropogenic modifications of the environment have increased the geographical range of intermediate hosts (aquatic snails) and livestock (WHO, 1995; Mas-Coma, Valero and Bargues, 2009). The World Health Organization includes human fascioliasis on its list of priorities among neglected tropical diseases (NTDs) (WHO, 2008)

Geographical distribution

Fascioliasis is widely distributed among herbivorous animals and humans, throughout most of the world. Human fascioliasis infection estimates increased from the 2000 reported in 1990 to 17 million people in 1992, and in 51 different countries in 1998 (Esteban, Bargues and Mas-Coma, 1998). Fascioliasis occurs worldwide in over 50 countries, especially where sheep or cattle are reared. In general, *F. hepatica* is present in Europe, Africa, Asia, the Americas and Oceania, and *F. gigantica* is mainly distributed in Africa and Asia (WHO, 2007). Fürst, Keiser, and Utzinger (2012) reported 2 646 515 fascioliasis patients globally, including North, Central and Latin America; North and Eastern Africa; Near East; Asia; and Europe. It has been reported, in Viet Nam, that fascioliasis is an emerging problem, increasing from 12 provinces with 500 cases in 2000, to 52 provinces with over 20 000 cases in 2012 (De *et al.,* 2003; De, Le and Waikagul, 2006; De, 2012).

Disease

People usually become infected from eating raw watercress or other water plants contaminated with immature *Fasciola* larvae (metacercariae). On ingestion, the larval flukes migrate through the intestinal wall, into the abdominal cavity, migrate to the liver and finally into the bile ducts, where they develop into mature, egg-laying adult flukes (Mas-Coma, Valero and Bargues, 2009; Esteban, Bargues and Mas-Coma, 1998).

Acute morbidity

In the liver the most important pathogenic sequelae are hepatic lesions such as liver tumours or abscesses, and in some cases, bleeding, and the occurrence of ectopic lesions when immature flukes deviate during migration and enter into other organs (Mas-Coma, Esteban and Bargues, 1999). The major clinical symptoms are abdominal pain, fever, dyspepsia, fatty food intolerance, weight loss, digestive disorders, jaundice, allergy, enlarged liver, lithiasis of the bile duct or the gall bladder, urticaria, and respiratory symptoms. The usual signs are hepatomegaly and splenomegaly, ascites, anaemia, chest signs, jaundice, vomiting and bleeding from the bile duct (De, 2011; Chen and Mott, 1990; Esteban, Bargues and Mas-Coma, 1998). The major sub-clinical symptoms are tumours or liver abscesses detected by ultrasound, CT scans or MRI; eosinophilia; and positive ELISA test by *Fasciola* antigen.

The pathology typically is most pronounced in the bile ducts and liver. However, fascioliasis is treatable, for example with Triclabendazole (Egaten) (WHO, 2007) (see also CDC, 2013).

Chronic morbidity

Chronic infection may cause expansion and thickening of the bile duct wall, and degenerative lesions in liver tissue resulting in liver cirrhosis. In some cases, parasites in the liver tissue may be calcified or become incorporated in a granuloma (Mas-Coma, Esteban and Bargues, 1999; Esteban, Bargues and Mas-Coma, 1998). Fascioliasis patients may experience weight loss, fever, and abdominal pain, which may result in a loss of strength and physical activity; high case fatality rates are reported (Mas-Coma, Esteban and Bargues, 1999).

Trade relevance

The import of domesticated livestock such as sheep, goats, oxen, zebu cattle, buffaloes, pigs, donkeys, horses, mules, yaks, camels, dromedaries, llamas and alpacas can lead to introduction of *Fasciola* into non-endemic areas (Mas-Coma, Esteban and Bargues, 1999;; Mas-Coma, Bargues and Valero, 2005). Because of this, export activity may be negatively affected, but there are no international restrictions known.

Impact on economically vulnerable populations

Fascioliasis may have a major impact on community human health due to the associated mortality, morbidity and disability. The costs for diagnosis, hospitalization and treatment are expensive, especially for rural populations in low income countries. Farm income can be affected because of direct effects on animal health and on economic value of livestock and their products. It is important to recognize that because of climate change the distribution of vector snails, reservoir hosts and suitable ecological habitats may increase, thereby leading to greater public health problems and economic impact on livestock producers and their communities. Increasing parasite resistance to the most effective drug, Triclabendazole, may also exacerbate these impacts.

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A7.11 *GIARDIA DUODENALIS*

General information

Giardia duodenalis, Giardia intestinalis, and *Giardia lamblia* are the names used to refer to the same flagellated, binucleated protozoan, but opinions differ regarding the name *G. intestinalis*. Recently, numerous biological and genetic analyses have shown that the same *Giardia* species present in humans are also found in a range of other mammalian species, so there is no taxonomic basis for the use of the name *G. lamblia*. For purposes of consistency we will use *G. duodenalis*.

The protozoan *G. duodenalis* is the most frequent intestinal parasite for humans in many countries [1]. Although *G. duodenalis* is the only species found in humans and many other mammals, including pets and livestock, it is now considered a multispecies complex whose members can be assigned to at least seven distinct assemblages or groups of strains (Feng and Xiao, 2011; Cacciò and Ryan, 2008). Only assemblages A and B have been detected in humans and in a wide range of other mammalian hosts, whereas the remaining assemblages, C to H, are likely to be host specific and have not yet been described infecting humans. One sub-assemblage of the A assemblage, the AII, has been described as infecting only humans (Feng and Xiao, 2011; Cacciò and Ryan, 2008).

Geographical distribution

G. duodenalis has a global distribution, causing an estimated 8×10^8 cases per year, and is the most common intestinal parasite of humans in many countries. In Asia, Africa and Latin America, about 200 million people have symptomatic giardiasis, with some 500 000 new cases reported each year (Lal *et al.*, 2013). Infection rates for giardiasis in humans are generally lower in developed countries. Food-borne transmission could occur through manure application to cropland; irrigation with contaminated water; and infected consumables such as meat and milk (Nash *et al.*, 1987). Most food-borne outbreaks of giardiasis has been related to direct contamination by a food handler, but a role for zoonotic transmission is also suggested (e.g. the consumption of a Christmas pudding contaminated with rodent faeces, and tripe soup made from the offal of an infected sheep) (Nash *et al.*, 1987). Unfortunately, no information is available on the proportion of food-borne sources for total *G. duodenalis* human infections (Nash *et al.*, 1987).

Disease

Severity of acute morbidity

Approximately 50% of exposed individuals clear the infection without clinical symptoms, and approximately 5% to 15% of individuals shed cysts asymptomatically (Caeiro *et al.*, 1999). The remaining 35% to 45% of individuals have symptomatic infection (Caeiro *et al.*, 1999). *Giardia* causes a generally self-limited clinical illness characterized by diarrhoea, abdominal cramps, bloating, weight loss and malabsorption. It is not fully understood why some individuals develop clinical giardiasis while others remain asymptomatic. Host factors and strain variation of the parasite are both likely to be involved.

Severity of chronic morbidity

Chronic giardiasis may follow the acute phase of illness or may develop in the absence of an antecedent acute illness. Symptoms of chronic giardiasis may include loose stools but usually not diarrhoea; steatorrhoea; profound weight loss; malabsorption; or malaise. The manifestations may wax and wane over many months. Even in cases of otherwise asymptomatic infection, malabsorption of fats, sugars, carbohydrates and vitamins may occur. This can lead to hypoalbuminaemia and deficiencies of vitamin A, B12 and folate. Acquired lactose intolerance occurs in up to 40% of patients; clinically, this manifests as exacerbation in intestinal symptoms following ingestion of dairy products (Cantey *et al.,* 2011). Recovery can take many weeks, even after clearance of the parasite (Cantey *et al.,* 2011). In some patients, persistence of infection is associated with development of malabsorption and weight loss (Ortega and Adam, 1997; Ish-Horowicz *et al.,* 1989). Children with chronic giardiasis may present growth retardation, protuberance of the abdomen, spindly extremities, oedema and pallor. Hypochromic microcytic anaemia is common. One study among Columbian children suggested that giardiasis was a strong predictor of stunted growth (Botero-Garcés *et al.,* 2009).

Chronic illness fraction

Chronic symptoms can develop in up to half of symptomatic individuals. In one study of experimentally infected individuals, 84% had a self-limited illness (mean duration 18 days); the remainder became chronically infected (Nash *et al*., 1987).

Case fatality rates

No mortality has been reported

Increase in human illness potential

Cultural practices and trends drive food selection and preparation, influencing the extent of exposure to parasitic protozoa through food. In Morocco, where untreated wastewater is traditionally used for irrigation, crops were contaminated with *Giardia* cysts (Amahmid, Asmama and Bouhoum, 1999). Giardiasis in resident children was linked to the use of raw wastewater in agriculture (Melloul *et al*., 2002). In some high-income countries, the popularity of raw salads, sushi and other seafood, and of drinks prepared from imported berries, has increased the risk of food-borne cryptosporidiosis and giardiasis (Graczyk, Graczyk and Naprawska, 2011).

Trade relevance

Currently *Giardia* is not considered relevant for trade. However, raising awareness of potential transmission through food, implementing appropriate food safety measures, and the development of cross-border transport protocols may need to be discussed in correspondence with new knowledge and information available about this parasite and its diversity. Consequently, it can be anticipated that food groups, such as fresh fruits and vegetables, may require new food safety controls for these parasites.

Impact on economically vulnerable populations

Children are more frequently infected than adults, particularly those from developing countries and those malnourished. *Giardia* infection in early childhood is associated with poor cognitive function and failure to thrive (Berkman *et al*., 2002).

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A7.12 HETEROPHYIDAE AND HETEROPHYIDIASIS

General information

Fish-borne intestinal trematodes (flukes), predominately the Heterophyidae, have many biological and epidemiological traits in common with the liver flukes and usually co-occur (Chai, Murrell and Lymbery, 2005). More than 35 species are reported to be zoonotic; species of *Metagonimus, Haplorchis, Heterophyes* and *Centrocestus* are the most prevalent. The number of species of fish (intermediate host) reported to be susceptible to infection with infective metacercariae is very large, more than 70, including both freshwater and marine species (Chai, 2007). An important epidemiological feature is the wide variety of reservoir hosts for these flukes, including fish-eating birds and wild and domestic mammals, especially cats, dogs and pigs. Human fondness for raw or lightly prepared fish foods is the primary human risk factor, and responsible for the wide geographical distribution of the human infections.

Geographical distribution

Heterophyid infections occur worldwide because of the wide distribution of reservoir and fish host species, and risky human food behaviours that include consuming raw or lightly processed or cooked fish, especially in Asia, but also Europe, Africa, Near East, and North and South America (WHO, 1995).

It has been estimated by WHO (2004) that heterophyids infect 40 to 50 million people worldwide, and that approximately 600 million are at risk for fish-borne flukes. Importantly, it is not possible to accurately determine the number of cases based on clinical and epidemiological data because of diagnostic confusion in distinguishing between heterophyid faecal eggs (the primary detection procedure) and those of the liver flukes in clinical and prevalence surveys. It is likely that under-reporting of intestinal flukes and the over-reporting of the liver flukes (commonly *Clonorchis sinensis* and *Opisthorchis* spp., especially in SE Asia and China). A second reason is that the milder clinical picture with intestinal infections may result in many "hidden infections".

Disease

Disease caused by intestinal flukes (heterophyidiasis) is generally not considered as significant in clinical importance as that of liver fluke infections. This may not be an accurate assessment because heterophyid infections, until recently, have not been widely recognized. More recent reports demonstrate that several heterophyid species can cause significant pathology, although infrequently fatal, in the heart, brain and spinal cord of humans (which may be related to invasion of the circulatory system by worm eggs). Disease is usually related to worm burdens (generally true for most helminth infections in the intestine) and although many infections are probably sub-clinical, heavy infections are often associated with diarrhoea, mucus-rich faeces, catarrhal inflammation, abdominal pain, dyspepsia, anorexia, nausea and vomiting, the most prominent symptoms being malabsorption and diarrhoea. A recent report on *Haplorchis taichui* infection in Thailand revealed that mucosal ulceration, mucosal and sub-mucosal haemorrhages, fusion and shortening of villi, chronic inflammation, and fibrosis of the sub-mucosa can occur.

Because the extent of intestinal fluke infections have only recently been recognized, there is little basis on which to estimate overall health impact. Case fatality rates especially have not been estimated because disease is usually related to worm burdens and while serious in heavy infections, the majority of epidemiological data suggests most infections are moderate to light, and hence most are probably sub-clinical. A recent estimate of intestinal trematode infections suggested morbidity estimates for DALYs as 83 699 (Fürst, Keiser and Utzinger, 2012). However, this was based on aggregation of all intestinal fluke infections, fish-borne and otherwise, and not specific to just heterophyids.

Trade relevance

Importing countries apply the regulatory standards for safety and quality relevant to parasite contamination similar to that imposed for anisakids and cestodes. For example of these regulations, these are detailed in the US FDA and EC-EUFSA regulations (EU, no date; and Chapter 5 in FDA, no date).

Impact on economically vulnerable populations

Impact is not easily estimated because the communities most at risk consume locally produced fish and are not commonly involved in the large-scale aquaculture that accounts for most exports of fish. However, as poverty levels are reduced in rural areas, the awareness and demand for higher quality and safer fish can be expected to rise; this could have a negative impact on fish farmers who produce for the local or national markets (WHO, 2004).

Other relevant information

Because of the importance in heterophyid epidemiology of non-human reservoir hosts (e.g. fish-eating birds, dogs, cats) (Anh *et al.,* 2009), attempts to change long-entrenched food behaviours of people (i.e. consumption of raw fish) or the application of human mass drug treatment strategies are not likely to have a sustainable impact on fish infections. Instead, efforts should be made to improve fish production practices to control risk of fish infections.

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A7.13 OPISTHORCHIIDAE

General information

Opisthorchiidae is a group of fish-borne zoonotic trematodes that includes the liver flukes *Opisthorchis viverrini*, *Clonorchis sinensis* and *O. felineus*. The life cycle of the liver fluke involves freshwater snails (*Bithynia* spp.) as first intermediate hosts, cyprinid fish as second intermediate hosts, humans as the definitive hosts, and cats and dogs as reservoir hosts. Humans are infected by consumption of undercooked fish containing viable metacercariae, and the infection induces hepatobiliary pathology that eventually leads to bile duct cancer, cholangiocarcinoma (CCA), the leading cause of death in Asia. Because of a strong link to CCA, *O. viverrini* and *C. sinensis* are known as type 1 carcinogens (IARC, 2012).

It is estimated that the number of people infected with liver fluke may be as many as 25 million with 10 million for *O. viverrini*, 15 million for *C. sinensis* and about 1 million for *O. felineus* (WHO 1995). Up to 700 million (10% of the global population) are at risk of infection when the third species, *O. felineus*, is considered (Keiser and Utzinger, 2005). Their contribution to the global disease burden in terms of disability-adjusted life years (DALYs) reflects substantial impact on health and well-being of the infected victims in developing countries (Fürst, Keiser and Utzinger, 2012). Infection by the liver fluke causes various non-specific gastrointestinal symptoms in some infected individuals, which are related to the intensity of infection. In *C. sinensis* alone, an estimated 2.5 million people may have some form of illness (Hong and Fang, 2012).

Geographical distribution (endemic regions)

Human liver flukes cause public health problems in many parts of the world, particularly in Asia and Europe. *C. sinensis* is endemic in southern China, Korea, Taiwan, northern Viet Nam and also in Russia. *O. viverrini* is endemic in the Lower Mekong Basin, including Thailand, Lao People's Democratic Republic (Lao PDR), Cambodia and central Viet Nam (WHO, 1995). *O. felineus* is found in the former USSR and in Central Eastern Europe, and a recent review indicated that it is endemic in 13 European countries (Pozio *et al.,* 2013).

Disease

Liver fluke infections primarily induce chronic inflammatory diseases of the hepatobiliary system and may subsequently cause bile duct cancer (cholangiocarcinoma). Benign hepatobiliary diseases are characterized by cholangitis, obstructive jaundice, hepatomegaly, periductal fibrosis, cholecystitis, and cholelithiasis. Most of these manifestations are mild and asymptomatic. However, once advanced CCA develops, clinical manifestation such as jaundice occurs in approximately half of the cases, while the other half may have no specific symptoms.

Severity of acute morbidity

There is little evidence of acute morbidity and it is rarely reported. This is probably due to the nature of low dose infection over many years rather than a heavy or massive infection. Acute symptoms may occur in cases with heavy infection, including epigastric pain and tenderness, fever, jaundice and diarrhoea.

Severity of chronic Morbidity

Chronic morbidity is more common in liver fluke infections since the parasite survives more than 10 years in humans. The illness may occur in a small percentage of infected individuals and includes weakness, flatulence or dyspepsia, and abdominal pain in the right upper quadrant (Upatham *et al.,* 1984). However, preclinical hepatobiliary abnormalities can be determined by radiological examination such as ultrasonography, MRI and CT. These include advanced periductal fibrosis, chronic cholecystitis, gall stones, pyogenic cholangitis, abscesses and cholangiocarcinoma.

Chronic illness fraction

Chronic illness occurs in a small fraction of infected people and some of the infected individuals (less than 10%) may develop severe disease and also cholangiocarcinoma (CCA). CCA is a complication of a liver fluke infection (opisthorchiasis or clonorchiasis) but once it develops, it is fatal and curative treatment is not available. Unlike hepatocellular carcinoma (hepatoma), a specific early marker or biomarker for diagnosis is not available for CCA. Several risk factors for CCA are documented and in addition to the liver fluke infection by *O. viverrini* or *C. sinensis*, cholangiocarcinoma associates with other conditions such as primary schlerosing cholangitis, gall stones as well as viral hepatitis.

Case fatality rates

Case fatality as a result of CCA is high and in the endemic areas of opisthorchiasis, such as in northeast Thailand, the district-based incidence of CCA varied from 90 to 300 per 100 000 (Sriamporn *et al.,* 2004). Most CCA cases have poor prognosis and even with surgical treatment survival is short, depending on the stage of cancer and also the health care system. Most CCA patients survive for less than 5 years.

Increase in human illness potential

Generally the risk of infection is confined to the endemic localities where active transmission occurs with ongoing transmission in human and intermediate hosts (snail and fish). However, with cross-border migration and aquaculture trading, there is a possibility that it may pose a threat outside endemic areas. Moreover, infection of the liver fluke is normally contracted by ingestion of native fish species (mostly cyprinid), but aquaculture fishery has been increasing and several species of cyprinid carps are cultured, and hence may have potential for transmission of the liver flukes.

Trade relevance

Currently, the liver fluke has little trade relevance because the main sources of infection are native species of fish circulated locally in endemic countries. Aquaculture of fresh-water cyprinid or fin fish (low-value aquaculture) are often operated by small-scale farmers to serve domestic consumers. Generally, this farm practice does not meet export standards set by importing countries such as EU, Japan and United States of America, and thus may have low or little relevance for international trade. However, evidence in aquaculture in Viet Nam and China indicated potential contamination with zoonotic fish-borne trematodes, including *C. sinensis* in aquaculture for international trade. Therefore, import of fishery products from the liver fluke-endemic areas, particularly Asia, may create a risk of infection to consumers. As such, prevention is required from the farm level and throughout the market chain.

Impact on economically vulnerable populations

The impact on vulnerable populations in endemic areas is high. There are potentially severe socio-economic consequences if the infected people finally develop CCA and if they are income earners in the family and community. Currently, no data on healthcare costs for CCA treatment in endemic countries (i.e. Thailand and Lao PDR) are available, although it can be expected that the cost of such healthcare might be high since treatment of CCA either by surgery or palliative care is costly.

Other relevant information

Concerted and comprehensive effort is required for sustainable prevention and control of the liver flukes and is vital for reduction of CCA. Although the liver fluke is recognized as one of the Neglected Tropical Diseases, the problem is difficult to solve because it links not only with public health aspects but also socio-economic and cultural dimensions. Therefore, in addition to conventional chemotherapy by mass drug administration, health education, including on food safety issues, to raise awareness starting at school-age-level as well as to community members is needed for successful outcomes.

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A7.14 *PARAGONIMUS* SPP.

General information

Paragonimiasis, also recognized as endemic haemoptysis, oriental lung fluke infection, etc., is a food-borne parasitic infection caused by the lung fluke of the family Paragonimidae that triggers a sub-acute to chronic inflammatory disease of the lung. Among the 30 species of trematodes (flukes) of the genus *Paragonimus* that are able to infect humans and animals, the most common agent for human infection is *P. westermani* (John and Petri, 2006: 198).

There are about 15 species of *Paragonimus* known to infect humans. *P. heterotremus* is the aetiologic agent of human paragonimiasis in P.R. China, Lao PDR, Viet Nam and Thailand. Species of *Paragonimus* are reported to infect humans in other places, including *P. africanus* in Africa and *P. kellicotti* in North America.

P. westermani was reported for the first time in the lungs of a human followed by recognition of the eggs in the sputum in 1880. The intermediate host and details of the parasite's life cycle were reported between 1916 and 1922 (Manson, 1881; Cox, 2002).

Paragonimus has two agents of intermediate hosts as well as humans in its life cycle. Intermediate hosts are various snails and crab species. Transmission of the parasite *P. westermani* to humans primarily occurs through the consumption of raw or undercooked seafood. Diagnosis is based on stool or sputum examination for the parasite's eggs until 2 to 3 months after infection. However, eggs are also occasionally encountered in effusion fluid or biopsy material. Antibody detection is useful in light infections and in the diagnosis of extrapulmonary paragonimiasis. Praziquantel is the drug of choice, with recommended dosage of 75 mg/kg per day, divided into 3 doses over 2 days (Pachucki *et al.*, 1984).

Geographical distribution

Human paragonimiasis occurs in three endemic focal areas: Asia (P.R. China, Japan, Korea, Lao PDR, Philippines, Viet Nam, Taiwan and Thailand); South and Central America (Ecuador, Peru, Costa Rica and Columbia); and Africa (Cameroon, Gambia and Nigeria) (Sripa *et al.*, 2010). There have been some reports of the disease in the United States of America during the past 15 years because of the increase in immigrants.

Approximately 200 million people have been exposed and 20 million people have been infected worldwide with this parasite (WHO, 1995). The total number of infections can be seen in Table 1. Some detailed prevalences (Sripa *et al.*, 2010) are: China, 4.1–5.1% in 24 provinces; Viet Nam, 0.5–15% in 10/64 provinces; Thailand, cases reported in 23/68 provinces; Japan, cases reported with over 200 cases; Philippines, 27.2–40% in some areas; and India, endemic to northeastern states, up to 50%.

Disease

Severity of acute morbidity

The acute phase consists of various manifestations, including diarrhoea, abdominal pain, fever, cough, urticaria, hepatosplenomegaly, pulmonary abnormalities and eosinophilia (CDC, no date).

Severity of chronic morbidity

The chronic phase might embrace pulmonary manifestations such as cough, expectoration of discoloured sputum, haemoptysis and chest radiographic abnormalities. It is possible that the disease could be confused with TB. Flukes occasionally invade and reside in the pleural space without parenchymal lung involvement. Extra-pulmonary locations of the adult worms result in more severe manifestations, especially when the brain is involved. Extra-pulmonary paragonimiasis is rarely seen in humans because the worms migrate to the lungs, but cysts can develop in the brain and abdominal adhesions resulting from infection have been reported. Haemoptysis is the most common sign of the disease.

Table 1 shows the number of cerebral infections in patients infected with paragonimiasis. Accordingly, the three parameters of Years Lost to Disability (YLD), Years of Life Lost (YLL) and Disbility-adjusted Life Years (DALYs) can be seen in this table which shows the importance of the disease.

Chronic illness fraction

No reports could be found on chronic illness cases, but column 3 in Table 1 depicts an estimation of cases that might result in chronic infection.

Case fatality rates

According to Table 1 and based on Global Burden of Disease (GBD) 2010 study regions, in 2005 the number of global deaths would have been 244 cases (Fürst, Keiser and Utzinger, 2012).

Increase in human illness potential

There are many reports that show the increasing risk of illness potential in endemic regions. Many cases of eating roast crabs in the field amongst schoolchildren have been reported, as well as frequent consumption of seasoned crabs by adult villagers, and papaya salad with crushed raw crab (Stanford University, no date; Song *et al.,* 2008). In addition to this characteristic feature of the villagers' food culture, area residents drink fresh crab juice as a traditional cure for measles, and this was also

TABLE 1 Summary of parasite-specific and region-specific modelled point estimates for paragonimiasis in 2005, based on Global Burden of Disease (GBD) 2010 study regions

Regions	Total no. infected	No. of heavy infections	No. of cerebral infections	No. of deaths	YLD	YLL	DALYs
Asia, east (China)	22 320 640	4 909 332	159 953	235	175 997	12 442	188 439
Latin America, Andean (Ecuador, Peru)	630 173	131 345	4420	8	6 960	443	7 403
Asia, southeast (Laos)	203 334	43 876	1 467	1	780	87	867
Asia Pacific, high income (South Korea)	957	176	20	0	1	0	1
Global	23 155 105	5 084 729	165 860	244	183 738	12 972	196 710

Notes: YLD = Years Lost to Disability; YLL = Years of Life Lost; DALY = Disbility-adjusted Life Years.
Source: Fürst, Keiser and Utzinger, 2012.

thought to constitute a route for infection. *Kung Plah*, *Kung Ten* (raw crayfish salad) and *Nam Prik Poo* (crab sauce) are popular and widely consumed dishes in Thailand. *Kinagang*, which is semi-cooked fresh-water mountainous crabs, are eaten as an appreciated dish in the Philippines. In Viet Nam, people have the habit of eating undercooked crabs. All these data show the increasing risk of the disease in regions where eating crab is a part of the culture.

When live crabs are crushed during preparation, the metacercariae may contaminate the fingers or utensils of the kitchen staff. Accidental transfer of infective cysts can occur via food preparers who handle raw seafood and subsequently contaminate cooking utensils and other foods (Yokogawa, 1965). Consumption of animals that feed on crustaceans can also transmit the parasite, such as eating raw boar meat. Food preparation techniques such as pickling and salting do not neutralize the causative agent. In some countries, crabs are soaked in wine for 3–5 minutes, and so called "drunken crabs" are eaten by people or cats and dogs; hence it is an important risk factor for transmission of the disease (Yokogawa, 1965). In the United States of America, significant behavioural and recreational risk factors include eating raw crayfish while on canoeing trips on local rivers, eating raw crayfish while on canoeing trips in Missouri, and eating raw crayfish while intoxicated (Diaz, 2011).

In addition, raw or undercooked meat of paratenic hosts such as boar, bear, wild pig or rat, where juvenile worms can survive in the muscles for years, is also an important source of human infection. Animals such as pigs, dogs and a variety of feline species can also harbour *P. westermani* (CDC, No date).

Trade relevance

Paragonimiasis is a neglected disease that has received relatively little attention from public health authorities. Interest in *Paragonimus* species outside endemic areas is increasing because of the risk of infection through consumption of crustaceans traded far from their point of origin in today's globalized food supply. No trade limitations currently exist with regard to *Paragonimus* spp., but it might be of importance for the international trade of seafood from endemic areas.

Impact on economically vulnerable populations

In many countries endemic for paragonimiasis, it is very difficult to change the habits of consuming raw or semi-cooked crabs and crayfish. Unfortunately, in some poor countries involved with this disease, intersectoral collaboration between governmental sectors, such as agriculture, aquaculture, public health and education and finance, is weak and this can cause an increase in the disease rate.

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A7.15 *SARCOCYSTIS* SPP.

General information

The genus *Sarcocystis* consists of obligate intracellular protozoan parasites with a two-host life cycle described as a prey-predator, herbivore-carnivore or intermediate-definitive host relationship. Humans can serve as intermediate hosts for some species of *Sarcocystis* and as definitive hosts for other species. Care must be taken to understand these roles and the potential sources of infection for each.

In the intermediate host, sarcocysts develop in skeletal muscles, tongue, oesophagus, diaphragm and cardiac muscle, and occasionally in spinal cord and brain (Fayer, 2004a, b). Mature sarcocysts of different species vary in size from microscopic to macroscopic, and in the structure of the wall that surrounds 100s to 1000s of crescent-shaped bodies called bradyzoites. After flesh (meat) from the intermediate host is eaten by the carnivore definitive host the sarcocyst wall is digested, bradyzoites are liberated and enter cells in the intestine. Each bradyzoite develops into a sexual stage and after fertilization the oocyst stage is formed. Mature oocysts (containing two sporocysts each with four sporozoites) are excreted in the faeces and contaminate the environment. When a susceptible intermediate host ingests the oocysts in water or food they pass to the small intestine, where the sporozoites are released. Sporozoites penetrate the gut epithelium and enter endothelial cells in blood vessels throughout the body giving rise to several generations of asexual stages. The number of asexual generations and their primary sites of development differ for each species of *Sarcocystis*. The terminal generation of asexual development occurs in muscle cells. Maturation varies with the species and can take 2 months or more until bradyzoites form and sarcocysts become infectious for the definitive host. Sarcocysts may persist for months or years.

Geographical distribution

Sarcocystis species have been found as sarcocysts in the muscles of fish, reptiles, birds, and mammals worldwide.

Prevalence in food animals

Prevalence data for all *Sarcocystis* infections must be interpreted carefully. They often reflect the findings of physicians, public health workers, veterinarians or scientists with specific interests. Much data are unreported and no truly large-scale population surveys have been conducted. Based on examination of tissues from abattoirs, a high percentage of cattle worldwide have been found infected with *S. cruzi* (infectious from cattle only to canines), the most prevalent species. Because *S. hominis* (infectious from cattle to humans) and *S. hirsuta* (infectious from cattle to felines) are difficult to distinguish except by electron microscopy, some prevalence data may be erroneous. *S. hominis* has not been detected in the United States of America, whereas up to 63% of cattle in Germany have been reported to be infected. *S. suihominis* (infectious from pigs to humans) was found more prevalent in Germany than Austria, but little information is available from other countries. In Brazil, all 50 samples of raw *kibbe* (beef) from 25 Arabian restaurants in Sao Paulo contained sarcocysts (Pena, Ogassawara and Sinhorini, 2001). Based on wall structure, *S. hominis, S. hirsuta* and *S. cruzi* were found in 94, 70 and 92% of the samples. The overall prevalence of *Sarcocystis* in pigs appears low, at 3–36% worldwide. *S. suihominis* and *S. hominis* have been reported in slaughtered pigs and cattle, respectively, raised in Japan (Saito *et al.,* 1998, 1999).

Although humans acquire gastrointestinal sarcocystosis by ingesting raw or undercooked meat from cattle or pigs harbouring mature cysts of *S. hominis* or *S. suihominis*, other species of meat animals that harbour *Sarcocystis* include sheep, goats, bison, water buffalo, yaks, a variety of wild ruminants, horses, camels, llamas and species of pigs other than the domesticated *Sus scrofa* (Dubey, Speer and Fayer, 1989). Many species of reptiles, birds, and mammals that harbour sarcocysts serve as food animals in various parts of the world (Dubey, Speer and Fayer, 1989).

Prevalence in humans

Based on limited, somewhat focal surveys, intestinal sarcocystosis in humans was reported as more prevalent in Europe than any other continent (Dubey, Speer and Fayer, 1989). A prevalence of 10.4% of faecal specimens was found in children in Poland and 7.3% of samples from Germany. Of 1228 apprentices from the Hanoi-Haiphong area of Viet Nam who worked in Central Slovakia in 1987–1989, 14 (1.1%) had sporocysts of *Sarcocystis* spp. detected in their stool (Straka *et al.,* 1991). *Kibbe* positive for *S. hominis* was fed to 7 human volunteers; 6 excreted sporocysts, 2 developed diarrhoea (Pena, Ogassawara and Sinhorini, 2001). After eating raw beef, a patient in Spain with abdominal discomfort, loose stools, and sporulated oocysts in the faeces was diagnosed with *S. hominis* (Clavel *et al.,* 2001). In Tibet, where *Sarcocystis* was detected in 42.9% of beef specimens examined from the marketplace, *S. hominis* and *S. suihominis* were found in stools from 21.8% and 0–7% of 926 persons, respectively (Yu *et al.*, 1991).

Muscular sarcocystosis in humans is rarely reported, with only about 100 cases until recently (Fayer 2004a, b). In such cases, humans harbour the sarcocyst stage and therefore serve as the intermediate host. Based on all other *Sarcocystis* life cycles, infected human tissues must be eaten by a carnivore to complete the life cycle. Because there is no known predatory or scavenging cycle in nature in which human tissues are eaten regularly by carnivores, humans most likely become infected accidentally by ingestion of food or water contaminated with faeces from a carnivore that participates in a primate-carnivore cycle involving an unknown species of *Sarcocystis*. Most have been from Asia and Southeast Asia, although cases from Central and South America, Africa, Europe and the United States of America have been reported (McLeod *et al.,* 1980; Mehrotra *et al.,* 1996). An outbreak in 7 persons of a 15 member military team occurred in Malaysia (Arness *et al.,* 1999). During 2011, 32 patients 21–59 years of age, all residents in Europe, complained of mild to severe myalgia with onset a median of 11 days after departing Tioman Island, Malaysia (Esposito, 2011). All cases consumed ice in beverages, 7 (70%) brushed teeth with tap water, and 6 (60%) ate fresh produce.

Disease

Humans serve as definitive hosts after eating undercooked or raw meat containing mature cysts. *S. hominis* is acquired from eating beef, and *S. suihominis* is acquired from eating pork. The cycles must be human-cattle-human and human-pig-human. Like most other species of *Sarcocystis*, *S. hominis* and *S. suihominis* are genetically programmed to complete their life cycles in specific intermediate hosts or within closely related host species. For example, sporocysts of *S. hominis* infect cattle and not pigs whereas those of *S. suihominis* infect pigs but not cattle.

Human volunteers that ate raw beef containing *S. hominis* became infected and shed oocysts in their faeces. One person who became ill 3 to 6 hours after eating the beef had nausea, stomach ache and diarrhoea (Aryeetey and Piekarski, 1976; Rommel and Heydorn, 1972). Other volunteers who ate raw pork containing *S. suihominis* had signs after 6 to 48 hours, including bloat, nausea, loss of appetite, stomach ache, vomiting, diarrhoea, difficult breathing and rapid pulse (Rommel and Heydorn, 1972; Heydorn, 1977).

Humans can also serve as intermediate hosts with asexual stages developing throughout the body and cysts forming in striated muscles. In such cases, humans apparently are accidental hosts because it is extremely rare that carnivores eat humans and unless that happens frequently a cycle cannot be maintained. Vasculitis, fever, myalgias, bronchospasm, pruritic rashes, lymphadenopathy, and subcutaneous nodules associated with eosinophilia, elevated erythrocyte sedimentation rate, and elevated creatinine kinase levels can last for weeks to several months (Fayer, 2004a, b). An American who, 4 years earlier, travelled extensively in Asia, had for over a year intermittent lesions on his arms, legs, soles of his feet, and trunk, beginning as subcutaneous masses associated with overlying erythaema (MacLeod *et al.,* 1980).

Trade relevance

Only those meat products that contain grossly visible cysts are recognized as infected. Although rarely reported in recent decades, they have been found predominantly in sheep in North America and recently in alpacas in Peru, but the impact on trade is unknown. Eosinophilic myositis (a greenish sheen on portions of beef carcasses that resulted in condemnation of parts or entire carcasses) was once attributed solely to *Sarcocystis* infections, but other causes may be possible. Some countries might have import restrictions related to sarcocysts in meat, which might complicate trade in animals or meat due to the lack of diagnostic tools.

Impact on economically vulnerable populations

Sarcocysts have been identified in carcasses of alpacas in the altiplano of Peru, which have been found unfit for consumption and of no commercial value, resulting in economic loss to local farmers (Vitaliano Cama, 2013, pers. comm.). Documentation of the impact is not available.

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A7.16 *SPIROMETRA* SPP.

General information

Sparganosis is one of the rare forms of metacestode infections caused by the pseudophyllidean tapeworms of the genus *Spirometra*. The plerocercoid larvae of three species of *Spirometra* namely *Spirometra mansoni* (or *Spirometra erinaceieuropaei*), *S. mansonoides* and *S. proliferum* are implicated in human disease (Khurana *et al.,* 2012).

The adult worm inhabits the small intestine of felines, which are the usual definitive hosts, although adult worms have also been reported in the human intestinal tract (Wang, Tang and Yang, 2012). The adult cestode worms are hermaphrodites and consist of scolex with a pair of grooves resembling lips and several proglottids. The terminal proglottid releases numerous ovoid eggs through the uterine pore. The eggs hatch in water to liberate the ciliated, free swimming larva called the coracidium. The coracidium is ingested by the freshwater crustacean *Cyclops*, the first intermediate host in which the procercoid larva is formed. The procercoid larva develops into the plerocercoid larva in the second intermediate hosts, the amphibians or reptiles that acquire the infection on ingesting the infected *Cyclops*. Humans contract sparganosis either by drinking water containing infected copepods or by the ingestion of inadequately cooked meat of the infected amphibians or reptiles containing the plerocercoid larva. Practices such as application of frog flesh or blood as poultices on open wounds can also cause sparganosis (Parija, 2011).

Geographical distribution

Although cases of sparganosis has been reported sporadically from numerous countries across the world, China and a few South East Asian countries, including Thailand, South Korea and Viet Nam, contribute the majority of the case load. From 1927 to 2011, more than 1000 cases of sparganosis have been reported from China (Li *et al.*, 2011). Thailand reported 52 cases in the period 1943 to 2010. The major reason for this geographical predilection is the local social and cultural practices (Anantaphruti, Nawa and Vanvanitchai, 2011).

Studies from China show that around 30% of the wild frogs and 30% of the frogs sold in markets for consumption were infected with any of the three species of *Spirometra*. Also, faecal examination of stray dogs and cats in one of the provinces of China showed that around 20% of the stray dogs and over 30% of the stray cats had eggs of *Spirometra* (Cui *et al.,* 2011).

Even though the worm, its hosts and the favourable ecological setting are present, sparganosis is a rare entity in India (Saleque, Juyal and Bhatia, 1990). Only five cases of sparganosis have been reported to date from India: two cases of cerebral sparganosis, two cases of visceral sparganosis and a case of ocular sparganosis. (Khurana *et al.,* 2012; Sundaram, Prasad and Reddy, 2003; Duggal *et al.,* 2011; Kudesia *et al.,* 1998; Sen *et al.,* 1989). The most probable reason for the low prevalence in India would be the absence of practices such as consumption and poulticing of frog meat.

Disease

The disease in humans is due to the migration of the plerocercoid larvae from the intestine to different sites of the body. Most common localizations of sparganum are in the subcutaneous connective tissue and superficial skeletal muscles, where it forms nodular lesions that are usually painful and associated with pruritis (Qin, Feng and Zheng, 2011). Other manifestations include ocular, cerebral and visceral sparganosis.

Ocular sparganosis clinically presents as redness and oedema of the eyelids and conjunctivas; forward displacement of the eyeball from the orbit (proptosis); subconjunctival granulomatous lesions; and migratory hyperaemic masses of the eyelid or conjunctiva (Ye *et al.,* 2012). The clinical manifestations of cerebral sparganosis resemble that of brain tumour, with seizures, headache or focal neurological disturbances (Finsterer and Auer, 2012). Migration of the larvae to internal organs leads to visceral sparganosis. Although the preferred localizations are the intestinal wall, perirenal fat and the intestinal wall, along with its peritoneal attachments (mesentry), virtually any organ can be affected. Sparganosis of liver, lung, pericardium, breast and scrotum have been reported (Khurana *et al.,* 2012; Huang, Gong and Lu, 2012; Lee *et al.*, 2011; Hong *et al.*, 2010). Disseminated sparganosis is a rare entity caused by *S. proliferum*, whose sparganum is pleomorphic with irregular branches and proliferative buds that detach and migrate to different sites, where they repeat the process and invade other organs (Stief and Enge, 2011).

While sparganosis is rarely fatal, it causes significant morbidity, which manifests acutely as in ocular and visceral forms, while cerebral sparganosis can result in chronic neurological sequelae (Qin, Feng and Zheng, 2011). In mainland China and Guangdong province, where most cases of the disease has been reported, sparganosis has been associated with significant morbidity and work absenteeism (Li *et al.*, 2011). Treatment includes the surgical removal of worm or nodule, with or without administration of anti-parasitic agents such as pyquiton or metronidazole (Anon., 1990).

Trade relevance and impact on vulnerable populations

Sparganosis is a significant disease of the eastern world due to the habit of eating frog meat and the usage of frog muscles as poultices. In other parts of the world it occurs as a result of drinking raw water containing infected *Cyclops*. As the disease has a wide variation in clinical presentation, it is often misdiagnosed or neglected (Cui *et al.,* 2011). Increased public awareness about the risks associated with eating or poulticing raw frog and strengthened food safety measures are needed to control the disease transmission in endemic regions (Li *et al.*, 2011). Export of frog meat from endemic regions to other parts of the world might be restricted due to *Spirometra* infections.

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A7.17 *TAENIA SAGINATA*

General information

Taenia saginata is an intestinal zoonotic cestode with humans as definitive hosts. Formerly defined as *Cysticercus bovis*, the metacestode larval stage occurs in the intermediate host (cattle) as cysts, causing *T. saginata* cysticercosis (Abuseir *et al.,* 2007). Upon ingestion of these cysticerci, an adult tapeworm will develop in the host's small intestine and will reach maturity within two to three months. An adult tapeworm can measure 3 m up to 12 m and will release gravid proglottids that contain between 30 000–50 000 eggs (Murrell *et al.,* 2005). These proglottids leave the host by active migration through the anus or in the stools. The eggs contain a larva (oncosphere) and are infective for the intermediate host (cattle) immediately after release from the human host. Cattle become infected orally during grazing when the environment is contaminated with eggs shed by human faeces directly (animal care takers) or via sewage plants after flooding or sewage sediment distributed on pastures (Cabarat, Geerts and Madeline, 2002). Eggs hatch in the intestine and the oncospheres liberated from the eggs, penetrate the intestinal wall and circulate through the lymphatic system and blood stream. Following migration in the animal's body, the larvae will develop into cysticerci after 8 to 10 weeks in muscle tissues, including the heart, and other predilection sites such as tongue, diaphragm and the masseter muscles (Abuseir *et al.,* 2007). Humans acquire the infection by consumption of raw or undercooked beef containing live cysticerci of *T. saginata*.

Geographical distribution

Globally, *T. saginata* is the most widely distributed human *Taenia* tapeworm, with an estimated 60 million human infections worldwide (Craig and Ito, 2007). Human tapeworm infections occur wherever cattle husbandry is prevalent and where human faeces are not disposed of properly. Despite this, *T. saginata* is also present in industrialized countries with good sanitary systems, because indirect transmission to cattle pastures via contaminated sewage sludge might also occur (Cabarat, Geerts and Madeline, 2002). (Cabarat, Geerts and Madeline, 2002) reported global human taeniasis prevalence results from the last 25 years ranging from less than 0.01 to 10% in Europe and up to 36% in Dagestan. It is unclear whether the data available reflects only *T. saginata* or also includes *T. solium* infections, since *Taenia* eggs of all species are morphologically alike.

Not many studies have been conducted in humans in many African countries, and in many instances there is difficulty in differential diagnoses with *T. solium* eggs. Bovine cysticercosis occurs in most of the African countries, but the epidemiological patterns in the African countries are far from being completely understood because there is a lack of surveillance systems, with consequent unavailability of data with which to quantify the disease burden.

In the Near East, the prevalence of human *T. saginata* (taeniasis) is infrequently reported, as is bovine cysticercosis from meat inspection. In Europe, every single carcass of bovines above 6 weeks of age needs to be examined for bovine cysticercosis, but this does not lead to accurate data of the prevalence in cattle due to low sensitivity of the method and poor reporting systems. In addition, no prevalence data have been reported in humans.

T. saginata has a global distribution, but the number of global food-borne illnesses is still not very clear due to difficulties in differential diagnosis with other *Taenia* infections, the asymptomatic nature of most of the infections, and rare complications, such as bowel obstructions (Craig and Ito, 2007). There are an estimated 12 million carriers in Africa, and an incidence up to 30% in some regions has been stated (Gracey, Collins and Huey, 1999). Based on meat inspection data in various European countries, the prevalence in cattle ranges between 0.01 and 7% (Abuseir *et al.,* 2007), but due to the lack of sensitivity of the post-mortem meat inspection there is an underestimation of the prevalence by a factor of 5 to 50 times (Dorny *et al.,* 2000).

In conclusion, despite the global distribution of *T. saginata*, the real prevalence of this tapeworm in humans and in cattle is underestimated due to imperfect diagnostic testing and poor reporting systems in cattle and the asymptomatic character of the disease in humans.

Disease

Patients harbouring adult *T. saginata* tapeworms are either asymptomatic or suffer from anal pruritis and discharge faecal proglottids. In some cases there might be non-specific symptoms like vomiting, nausea, epigastric pain, diarrhoea and weight loss. *T. saginata* is also a rare cause of ileus, pancreatitis, cholecystitis and cholangitis. In some endemic countries, *T. saginata* can cause an acute cholangitis (Uygur-Bayramiçli *et al.,* 2012).

Severity of acute morbidity

Low, with most infected people asymptomatic. In some cases there is more severe illness due to epigastric fullness, nausea, diarrhoea and vomiting. Rare cases of acute cholangitis have been reported.

Severity of chronic morbidity

Low. Weight loss can occur. In some patients there are more severe symptoms, as *T. saginata* have been reported as the cause of ileus, pancreatitis, cholecystitis and cholangitis.

Chronic illness fraction

Unknown, but asymptomatic carriers are most frequent.

Case fatality rate

Not known, but probably non-existent.

Increase in human illness

Unknown.

Trade relevance

In Europe, bovine carcasses require mandatory meat inspection under EC regulation No. 854/2004. In the event of positive findings during meat inspection, positive carcasses are condemned (heavily infected) or frozen if lightly infected, to inactivate cysticerci before consumption. Therefore, economic losses occur and, due to the global distribution of the parasite, might be relevant.

Impact on economically vulnerable populations

The impact in terms of number of infections might be high when beef is eaten raw or undercooked. This is of particular relevance in the absence of adequate hygienic conditions and appropriate veterinary public health control measures. However, since most infections in humans are asymptomatic, the impact in terms of number of reported illnesses is rather low.

The economic losses might be relevant due to carcass devaluation or condemnation in those vulnerable communities with poor hygiene when beef is traded, although data are lacking to show the relevance of this point.

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A7.18 *TAENIA SOLIUM*

General information on the parasite

Humans are definitive hosts of *Taenia solium* and will shed eggs in their stool (taeniasis). Ingestion of *T. solium* eggs will lead to the development of cysticerci in pigs, and also in humans (cysticercosis). Cysticerci can develop in almost any tissue, but involvement of the central nervous system, known as neurocysticercosis, is the clinically most important manifestation of the disease in humans and may lead to epilepsy and death (Sorvillo, DeGiorgio and Waterman, 2007). The presence of cysticerci in pork also makes pork unsafe for human consumption and greatly reduces its market value.

Humans acquire taeniasis (adult tapeworm infection) by eating raw or undercooked pork with cysticerci, the larval form of *T. solium* (Sorvillo, DeGiorgio and Waterman, 2007). The cysticerci evaginate and attach to the intestinal wall of the small intestine and within approximately two months develop into adult tapeworms, which can grow to more than 3 m long (Flisser, 1994). The distal proglottids detach from the worm when their eggs are mature and pass out into the environment with the human faeces. These eggs are infective to the same (auto-infection) or other humans as well as pigs if they are ingested following direct contact with tapeworm carriers, ingestion of infected faecal matter or from consuming water or food contaminated with human faeces (Garcia *et al.,* 2003).

Geographical distribution

T. solium cysticercosis is one of the most common parasitic diseases worldwide and the estimated prevalence is greater than 50 million people (Psarros, Zouros and Coimbra. 2003; Hawk *et al.,* 2005).

The prevalence of *T. solium* infection varies greatly according to the level of sanitation, pig husbandry practices and eating habits in a region. The parasite is endemic in several developing countries, including in Central and South America, sub-Saharan Africa, South East Asia and Western Pacific (Schantz, 2002). In developed countries, such as the United States of America and parts of Europe, *T. solium* cysticercosis is considered as an emerging disease due to increased immigration and international travel (Schantz, 2002; Pal, Carpio and Sander, 2000).

Disease

Clinical manifestations of *T. solium* cysticercosis are related to individual differences in the number, size, and topography of lesions, and the efficiency of the host's immune response to the parasites (Nash and Neva, 1984). Neurocysticercosis and ophthalmic cysticercosis are associated with substantial morbidity (Garcia, Gonzalez and Gilman, 2011). Epileptic seizures are the commonest presentation of neurocysticercosis and generally represent the primary or sole manifestation of the disease. Seizures occur in 50–80% of patients with parenchymal brain cysts or calcifications, but are less common in other forms of the disease (Schantz, Wilkins and Tsang, 1998; Chopra, Kaur and Mahajan, 1981; Del Brutto *et al.,* 1992).

Severity of acute morbidity

T. solium neurocysticercosis is considered responsible for over 10% of acute case admissions to the neurological ward of countries where it is endemic (Montresor and Palmer, 2006).

Severity of chronic morbidity

Seizure disorders raise the risk of injuries, and in New Guinea the introduction of cysticercosis was followed by an epidemic of serious burns when convulsions caused people to fall into open cooking fires (Bending and Cartford, 1983). The estimated economic consequences due to chronic disability are heavy (Flisser, 1988; Carabin *et al.,* 2006; Praet *et al.,* 2009).

Case fatality rates

Several large facility-based case series studies have reported that the number of deaths from cysticercosis is relatively low and that the case-fatality rate is <1% (Sorvillo, DeGiorgio and Waterman, 2007). Global deaths due to cysticercosis were estimated in 1990 to be 700 (Range (0 to 2800) and in 2010 1200 (Range 0 to 4300) for all ages and both sexes combined (Lozano *et al.,* 2012).

Increase in human illness potential

With the introduction of pigs into rural farming communities by donor agencies in most countries in Africa and the short reproductive cycle of pigs, human infection with *T. solium* should be considered emergent, and is spreading rapidly in this region. Public health efforts for its control in pig and human populations are active in many countries.

Trade relevance

Veterinary public health efforts for control of this parasite in pigs are active in many endemic countries. In most African countries carcasses may not be released even for domestic market unless they have been inspected or tested, or both, to ascertain the absence of infection. The challenge is in the enforcement of legislations on meat inspection in resource-poor communities rearing outdoor pigs.

In non-endemic regions veterinary public health measurements are in place.

Impact on economically vulnerable populations

Neurocysticercosis due to *T. solium* infection is one of the main causes of epilepsy in rural African communities (Pal, Carpio and Sander, 2000). This comes with social stigma to those affected by the parasite (Placencia *et al.*, 1995) and the disease has substantial global impact in terms of disability adjusted life years (DALYs) and monetary losses (Carabin *et al.,* 2006; Praet *et al.,* 2009; Lozano *et al.,* 2012).

T. solium is considered to have economic impact when it comes to monetary loss due to carcass devaluation or condemnation (Carabin *et al.,* 2006). The parasite has high prevalence in both pigs and humans where sanitation is poor, pigs are allowed to roam freely (free-range), or meat inspection is absent or inadequate (Garcia *et al.,* 2003; Bern *et al.,* 1999). These features are mainly associated with resource-poor communities or small-holder livestock farmers in the developing countries.

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A7.19 *TOXOCARA* SPP.

General information

Human toxocariasis is a zoonotic helminth infection caused by the migration of the larvae of *Toxocara canis* (mainly) and *T. cati* from dogs and cats respectively. Eggs of the parasite are shed in the faeces of dogs and cats, and the infective larvae then develop within the environmentally robust eggs until maturation of the infective stage larvae. Infective eggs can survive in soil for several years. Human infection primarily occurs upon ingestion of embryonated eggs. The larvae hatch in the intestine, penetrate the intestinal wall and migrate through the liver, lungs and heart, ultimately disseminating to other organs and the central nervous system (Hotez and Wilkins, 2009). The larvae do not develop further in humans, but remain under developmental arrest and can survive for many years. During their migrations they release antigens that result in systematic immune and local inflammatory responses, and commonly elicit eosinophilia and immunoglobulin E antibodies.

Other routes of infection include the consumption of raw vegetables grown in kitchen gardens contaminated with faeces of dogs and cats containing embryonated eggs, which may result in chronic low-dose infections. Rarely, the infection is associated with consumption of raw meat from potential paratenic hosts (in non-canid hosts, during migration, the larvae encyst in muscles and are infective), such as chicken (Nagakura *et al.*, 1989), lamb (Salem and Schantz, 1992) or rabbit (Stürchler, Weiss and Gassner, 1990).

Geographical distribution

Toxocariasis is a worldwide zoonosis (Utzinger *et al.,* 2012*).* Eggs of *T. canis* and *T. cati* are found worldwide in soil that is open to contamination by dogs and cats. The eggs of these species occur in 2 to 88% of soil samples collected in various countries and regions.

Seroprevalence surveys in Western countries of apparently healthy adults from urban areas indicate from 2 to 5% infection compared with 14.2–37% of adults in rural areas (Magnaval, Glickman and Dorchies, 1994a). In tropical countries the seroprevalence of *Toxocara* infection has been found to be higher, ranging from 63.2% (Chomel *et al.,* 1993) to 92.8% (Magnaval *et al.*, 1994b).

The proportion of human illness attributable to a food source is very low compared with that due to contact with soil (geophagia) and the global burden of disease attributable to toxocariasis is unknown (Utzinger *et al.,* 2012).

Disease

Toxocariasis manifests itself in three syndromes, namely visceral larval migrans (VLM), ocular larval migrans (OLM) and neurological toxocariasis. Ocular toxocariasis occurs when *Toxocara* larvae migrate to the eye. Symptoms and signs include vision loss, eye inflammation or damage to the retina. Typically, only one eye is affected. It can be mistakenly diagnosed as childhood retinoblastoma, with consequent inappropriate enucleation of the eye. Visceral toxocariasis occurs when *Toxocara* larvae migrate to various body organs, such as the liver or central nervous system. Symptoms of visceral toxocariasis include fever, fatigue, coughing, wheezing or abdominal pain. The clinical signs of neurological toxocariasis, as with VLM, are non-specific (Magnaval *et al.*, 1997), leading to possible under-diagnosis of this condition. Quattrocchi *et al.* (2012) has shown that there is a highly significant association ($p<0.001$) between people with epilepsy and levels of antibodies to *Toxocara* (Odds Ratio of 1.92). In addition, there have been studies associating *Toxocara* infections with allergic asthma (Tonelli, 2005; Pinelli *et al.,* 2008).

Severity of acute morbidity

Many people who are infected with *Toxocara* are asymptomatic, while others present mild or more severe symptoms after the infection, and may develop overt ocular and visceral toxocariasis**.** The most severe cases are rare, but are more likely to occur in young children, who often play in contaminated areas, or eat soil (pica) contaminated by dog or cat faeces (CDC, 2013).

Severity of chronic morbidity

Because of the occult nature of the infection and the non-specificity of the symptoms, the global scale of chronic morbidity is not known. Ocular toxocariasis is a particular exception to this, although prevalence appears to be relatively low and no data exists in many countries. In the United States of America between September 2009 and September 2010, 68 patients were diagnosed with ocular toxocariasis (CDC, 2011). Of these 30 had clinical data and of these 25 (83%) reported vision loss and 17 (68%) of these had permanent vision loss. VLM involving the brain is thought to be rare, but this may merely be because of under-recognition and -detection. Because toxocariasis tends to be an occult infection, the true incidence of infection and morbidity is probably greatly underestimated.

Increase in human illness potential

One of the main drawbacks to diagnosis of toxocariasis has been lack of diagnostic tools and clinical symptoms that are not specific to the disease condition in humans. Considering that dogs and cats are the hosts of *T. canis* and *T. cati*, the reporting of human cases may continue to increase as diagnostic methods improve and infection in dogs (e.g. 25% (Barriga, 1988) and cats 30-60% (Petithory *et al.,*

1996) remain high. In western countries, the above quoted seroprevalence surveys clearly demonstrate high infection rates, especially in children.

Trade relevance

Toxocariasis may have little trade relevance at present because the main vehicle of transmission remains through raw vegetables and meats from paratenic hosts. The embryonated eggs of *Toxocara* canis could develop at a low threshold temperature of 11.8°C and have been shown to survive for 6 weeks between +1 and –2°C (Azam *et al.,* 2012). The fact that the larval stages and eggs can survive under these environmental conditions and the increase in international trade of the food vehicles mentioned above would pre-empt the trade relevance for this food-borne parasite.

Impact on economically vulnerable populations

The population at risk is children under 7 years with geophagic or pica characteristics. In this section of the population, infection, though rarely resulting in death, can cause untold suffering if it develops into ocular and neurological forms. The costs of treatment and chronic disabilities associated with these two forms are the major losses to affected populations.

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A7.20 *TOXOPLASMA GONDII*

General Information

Toxoplasma is a protozoan parasite belonging to the Phylum Apicomplexa and is infectious to practically all warm-blooded animals, including humans, livestock, birds and marine mammals. There is only one species in the *Toxoplasma* genus: *Toxoplasma gondii*. Based on molecular analyses, in conjunction with mouse virulence information, *T. gondii* from Europe and North America has been classified into 3 genetic types (I, II, III), of which type I isolates are lethal to mice, irrespective of dose, while types II and III are generally avirulent for mice. In Europe, genotype II is predominant in humans and animals. Strains that did not fall into these three clonal types were previously considered atypical, but a fourth clonal type has been recently recognized, mostly in wildlife (Khan *et al.,* 2011). In South America, particularly Brazil, a greater diversity of genotypes has been detected that also tend to be more virulent (Clementino Andrade *et al.,* 2013; Carneiro *et al.,* 2013), with a heavier burden of clinical disease (Dubey *et al.,* 2012a, b).

The overall life cycle of *Toxoplasma* contains two distinct cycles: the sexual enteroepithelial cycle and the asexual cycle. The definitive hosts of *T. gondii* are members of the cat family (Felidae), thus the sexual cycle of the parasite occurs only within the intestinal epithelial cells of felids. Oocysts are the zygotic stage of the life cycle, and are excreted unsporulated in cat faeces. Speed of oocyst sporulation in the environment depends on factors such as temperature and humidity, but usually takes around three days. The oocysts are environmentally robust, and can retain infectivity in a cool damp environment for months (Guy, Dubey and Hill, 2012).

The asexual cycle occurs when consumption of tissue cysts (see below) or oocysts results in infection of the intestine, and the tachyzoite form of the parasite multiplies asexually in the cells of lamina propria by repeated divisions until the cells rupture. Tachyzoites from ruptured cells are released into surrounding tissues resulting in systemic infection. Circulating tachyzoites infect new cells throughout the body, with cells in cardiac and skeletal muscle and the central nervous system more often infected. After several more rounds of asexual division, tissue cysts are formed and these remain intracellular. Tissue cysts of *T. gondii* range from 5 μm to over 100 μm in size and contain bradyzoites, which are infectious when ingested with the tissue surrounding them. If ingested by a felid, then the sexual enteroepithelial cycle occurs; if ingested by any other host, then the asexual cycle, as described in the previous paragraph occurs. Additionally, if a female host is pregnant when first infected, then circulating tachyzoites may move through the placenta to the foetus (intrauterine or congenital transmission).

Geographical distribution

Toxoplasma gondii is perhaps the most widespread protozoan parasite affecting humans, and it has been estimated that between 1 and 2 billion of the world's population is infected at any one time (Montoya and Liesenfeld, 2004). It should be emphasized that the majority of these do not manifest clinical illness (see later).

Infection in humans occurs worldwide, but prevalence varies significantly between populations. Between 11 and 40% of adults in the United States of America and UK have been found to be seropositive, but in other countries in western Europe, typical seroprevalence rates vary from 11 to 28% in Scandinavia, to 42% in Italy, and up to 67% in Belgium (Guy, Dubey and Hill, 2012). In some regions of Brazil, infection rates of over 70% have been reported, while rates of around 40% have been reported from various African countries. In Asia, infection rates vary from less than 10% to over 70% (Guy, Dubey and Hill, 2012). With the exception of congenital transmission, the majority of infections with *T. gondii* are considered to be food-borne, as described below, although waterborne outbreaks can also be of local importance, and water-borne infection has been suggested to be the major source of *Toxoplasma* infection in developing countries (Petersen, Kijlstra and Stanford, 2012).

There are three potentially infectious stages of *Toxoplasma*: tachyzoites, bradyzoites and oocysts, two of which (bradyzoites and oocysts) are of particular relevance to food-borne transmission. Bradyzoites may be ingested with the tissue of an infected intermediate host, while oocysts may be ingested with any produce that has the potential to be contaminated with the faeces of an infected felid. In addition, though probably of less significance, tachyzoites excreted in the milk might result in milk-borne infection. Outbreaks of toxoplasmosis associated with consumption of unpasteurized goats' milk have been reported (Guy, Dubey and Hill, 2012), and consumption of such milk is considered a risk factor for *T. gondii* infection in the United States of America (Jones *et al.*, 2009).

Human infection via bradyzoites in meat is dependent on various factors, including prevalence of *Toxoplasma* infection in meat animals, cultural factors regarding meat consumption and meat preparation, and factors (such as age and immunological status) of the person exposed. Parasite factors are probably of relevance also. Virtually all edible portions of an animal can harbour viable *T. gondii* tissue cysts, and most species of livestock are susceptible to infection (Dubey, 2009a; Guy, Dubey and Hill, 2012). In some countries sheep and goats are the most important hosts of *T. gondii*, and the main source of infection to humans (Dubey, 2009b). In other countries, for example United States of America, lamb and mutton are considered relatively minor food commodities (Guy, Dubey and Hill, 2012). Of the major meat animal species investigated in United States of America to date, pig is the only species that has been found to frequently harbour the parasite (Dubey and Jones, 2008), although prevalence has declined in areas where they are predominantly raised indoors (Guy, Dubey and Hill, 2012). However, elevated infection in organic pigs indicates that consumption of under-cooked organic pork may represent an increasing infection route (Dubey *et al.*, 2012a, b). The risk of acquiring toxoplasmosis from beef also demonstrates regional variability, with some European studies suggesting that it can be a significant contributor to human infection (Cook *et al.,* 2000; Opsteegh *et al.,* 2011). Although poultry are also susceptible to infection with *T. gondii*, and theoretically pose a source of infection to humans, the relatively limited lifespan of poultry and the fact that they tend to be well-cooked before consumption, limits their importance as sources of infection for humans (Kijlstra and Jongert, 2008). Indeed, chickens have not been indicated as a source of human infection in the United States of America, despite high infection rates in some flocks (Guy, Dubey and Hill, 2012). Game animals are also considered to be potentially important sources of meat-borne toxoplasmosis, particularly as such meat is often consumed undercooked (Opsteegh *et al.,* 2011), with wild boar and venison particularly implicated in Europe (Kijlstra and Jongert, 2008). In other parts of the world, other game meats may be of equal or greater importance; for example, kangaroos are considered to be highly susceptible to *T. gondii* infection (Kijlstra and Jongert, 2008). In Arctic regions, consumption of undercooked game meat, particularly from marine mammals, seems to be an important risk factor for human infection (Davidson *et al.,* 2011).

Human infection via oocysts occurs when a person ingests something that has been contaminated with faeces from an infected cat. As *Toxoplasma* oocysts are not infective at excretion, direct infection from handling an infected cat or cleaning the litter box daily is unlikely. As oocysts are very hardy (and, unlike bradyzoites, can survive freezing), contamination of produce provides a route for transmission. It is possible that the importance of the oocyst infection route has been generally under-estimated previously. In various outbreaks, as well as individual infections, use of a test detecting sporozoites has indicated that oocysts have been the source of infection rather than bradyzoites, indicating the importance of this route of infection (Boyer *et al.,* 2012). Oocysts may also contaminate water, and can result in water-borne infections and outbreaks, or may contaminate fresh produce or other food items.

Disease

The clinical picture of infection with *Toxoplasma* is greatly influenced by the immune status of the infected person, and also by the virulence of the strain of parasite. In the immunocompetent, *T. gondii* infection is usually asymptomatic, but may cause a mild to moderate illness, in which typical symptoms include low grade fever, lymphadenopathy, fatigue, muscle pain, sore throat and headache. In some cases, ocular toxoplasmosis may occur, which may be accompanied by partial or total loss of vision. The rate of ocular toxoplasmosis seems to differ according to unknown factors, but is more common in South America, Central America, the Caribbean and parts of tropical Africa than in Europe and North America, and is quite rare in China (Petersen, Kijlstra and Stanford, 2012). In addition, ocular disease appears to be more severe in South America than in other continents, presumably due to the presence of extremely virulent genotypes of the parasite.

Although latent *Toxoplasma* infection is generally accepted as being generally benign in the immunocompetent, some studies have suggested that the parasite may affect behaviour (Flegr, 2007), perhaps being a contributory, or even causative, factor in various psychiatric disorders, including depression, anxiety and schizophrenia (Henriquez *et al.,* 2009; Flegr, 2013). It has been proposed that *Toxoplasma* may affect dopamine levels within the brain, resulting in alterations in CNS function (Flegr, 2013). Should the association between *Toxoplasma* infection and psychiatric dysfunction be proven, then the overall burden of disease and risk to health and well-being due to this parasite should be re-evaluated (Guy, Dubey and Hill, 2012; Flegr, 2013).

In the immunocompromised and immunodeficient (such as HIV-patients and those receiving profound immunosuppressive therapy), severe or life-threatening disease can result either from acute *Toxoplasma* infection or re-activation of a previously latent infection. Here, encephalitis is the most clinically significant manifestation, but retinochoroiditis, pneumonitis and other systemic disease may also occur. In patients with acquired immunodeficiency syndrome (AIDS), toxoplasmic encephalitis is the most common cause of intracerebral mass lesions and ranks highly on the list of diseases resulting in the death of AIDS patients.

Congenital toxoplasmosis is another serious potential manifestation of *T. gondii* infection; this is not food-borne infection *per se*, but may result from food-borne infection of the mother. In an immunocompetent mother, it is generally accepted that *Toxoplasma* is passed on to the foetus from an infection acquired immediately before or during pregnancy, i.e. prior to onset of the latent phase of infection. However, rare cases of transplacental infection have been reported in which the mother has had a previous latent infection. The risk of transplacental infection increases throughout pregnancy, but the risk of severe disease or foetal death decreases. Symptoms commonly associated with transplacental infection include spontaneous termination, foetal death, ventricular dilatation and intracranial calcification (Guy, Dubey and Hill, 2012). Neonates may present with hydrocephalus, seizures, retinochoroiditis, spasticity, deafness, hepatosplenomegaly, jaundice or rash, and children that are asymptomatic at birth, may suffer from mental retardation or retinochoroidal lesions later in life. Children who have been infected late on in the pregnancy are usually asymptomatic or have only mild complications. Again, there is variation according to strain of *Toxoplasma*, with more severe symptoms apparently associated with congenital toxoplasmosis in South America (Gómez-Marin *et al.,* 2011).

Trade relevance and Impact on economically vulnerable populations

As toxoplasmosis has a global distribution, the trade relevance is generally considered minimal. However, import and export of chilled (non-frozen) meat (including beef and horse) may enable spread of the different genotypes of *Toxoplasma*, with particular concern being the import of more virulent strains into new areas (Pomares *et al.,* 2011).

An elevation in vulnerable populations (e.g. immunologically compromised) who are more likely to experience clinical illness from infection with *T. gondii* may indicate that this parasite is of increasing importance.

Thus, the main concerns appear to be that populations that are vulnerable to clinical toxoplasmosis may be increasing, while more virulent strains may have the potential to spread with traded produce, meat, and animals.

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A7.21 *TRICHINELLA* SPP. OTHER THAN *T. SPIRALIS*

General information

Nematodes of the genus *Trichinella* are maintained in nature by sylvatic or domestic cycles. The sylvatic cycle is widespread on all continents, from frigid to torrid zones except Antarctica, and it is maintained by cannibalism and the scavenging behaviour of carnivorous and omnivorous animals. Twelve taxa are recognized in the genus *Trichinella*, three of them (*T. pseudospiralis, T. papuae, T. zimbabwensis*) are clustered in the non-encapsulated clade, and the other nine are in the encapsulated clade (*T. spiralis, T. nativa, T. britovi, T. murrelli, T. nelsoni, T. patagoniensis, Trichinella* T6, T8 and T9). All taxa infect mammals, while whereas, *T. pseudospiralis* infects also birds, and *T. papuae* and *T. zimbabwensis* infect also reptiles) (Pozio *et al.,* 2009).

Only humans show the clinical disease, trichinellosis, whereas animals are generally asymptomatic and only those experimentally infected with a huge number of larvae can develop the signs of the disease. Humans acquire the infection by the ingestion of raw or poorly cooked meat of domestic and wild swine, bears, walruses, horses, badgers, dogs, cougars, jackals and turtles. Meat and meat-derived products of all *Trichinella*-susceptible animals are a risk for humans if consumed raw or semi-raw (Pozio and Murrell, 2006).

Geographical distribution

Trichinella parasites are widespread in all continents, except Antarctica, with varying prevalence according to the environmental conditions (low temperature and high humidity versus high temperature and low humidity), wildlife, and human behaviour. For example, the common habit of hunters to leave animal carcasses in the field after skinning, or removing and discarding the entrails, increases the probability of transmission to new hosts (Pozio and Murrell, 2006). *T. spiralis* and *T. pseudospiralis* are the only two species with a cosmopolitan distribution for two different reasons: *T. spiralis* has been spread in the world by humans, while *T. pseudospiralis* is spread by birds. All the other taxa show a well defined distribution area: *T. nativa* in arctic and sub-arctic regions; *T. britovi* in Europe, western Asia, North and West Africa; *T. murrelli* in United States of America, southern Canada and northern Mexico; *T. nelson* in eastern and southern Africa; *T. patagoniensis* in South America; *Trichinella* T6 in arctic and sub-arctic regions of North America; *Trichinella* T8 in southwest Africa; and *Trichinella* T9 in Japan (Pozio *et al.,* 2009).

In 1998, it was estimated that the global prevalence of trichinellosis was about 11 million (Dupouy-Camet, 2000). This estimate was based on the assumption that the number of trichinellosis cases was similar to that of people affected by taeniasis/cysticercosis, because both diseases are transmitted through pork consumption. In

2007, an estimate of the yearly incidence suggested around 10 000 infections. This number was estimated by aggregating the highest incidence rate reported in the countries of the world in a ten-year period (Pozio, 2007). However, because of problems related to incomplete data from some regions, and to the quality of diagnostic criteria of infection, the World Health Organization's Food-borne Disease Burden Epidemiology Reference Group (FERG) requested a systematic review of the global incidence. The systematic review of the literature available worldwide from 1986 to 2009 founds reports of 65 818 cases and 42 deaths from 41 countries (Murrell and Pozio, 2011). Most of the infections (87%) have been documented in Europe, with about half of those being from Romania.

Disease

Severity of acute morbidity

In most persons, the onset of the acute stage is sudden, with general weakness, chills, headache, fever (up to 40°C), excessive sweating and tachycardia. In nearly all cases, symmetrical eyelid and periocular oedema occur, and oedema frequently affects the entire face. The blood vessels of conjunctivae become inflamed, and in some persons petechiae, intraconjunctival haemorrhages and haemorrhages of nail beds occur. These symptoms are accompanied by eosinophilia, and usually by leucocytosis. This symptomatology is followed by pain in various muscle groups, which may restrict motility. The intensity of muscle pain reflects the severity of the disease. Pain develops in nuchal and trunk muscles, in the muscles of the upper and lower extremities, and, less frequently, in masseter muscles. Pain occurs upon movement (Pozio, Gomez Morales and Dupouy-Camet, 2003).

Severity of chronic morbidity

It is quite difficult to distinguish what may be considered as "chronic trichinellosis". Nonetheless, there have been reports of persons who, months or even years after the acute stage, continued to suffer from chronic pain, general discomfort, tingling, numbness and excessive sweating, and who showed signs of paranoia and a syndrome of persecution. The persistence of these symptoms has been more frequently observed among persons who had suffered severe trichinellosis. Up to ten years from infection, there have been reports of impaired muscle strength, conjunctivitis, impaired coordination and the presence of IgG antibodies, and live larvae have been detected in muscles up to 39 years after infection, yet without clinical signs or symptoms (Pozio, Gomez Morales and Dupouy-Camet, 2003).

Chronic illness fraction

Chronic trichinellosis is very rarely documented; however, all cases in which trichinellosis has been defined as "chronic" have been reported in persons who had not been treated in a timely manner (i.e. early in the invasion of the muscles by larvae) (Pozio, Gomez Morales and Dupouy-Camet, 2003).

Case fatality rates

In a 24-year period (1986–2009), 42 deaths were reported worldwide, of which 24 were documented in Europe (Murrell and Pozio, 2011).

Increase in human illness potential

Social, political and economic factors; food behaviour; increase in animal populations susceptible to *Trichinella*; and the common habit of hunters to leave animal carcasses in the field after skinning or removing and discarding the entrails, are responsible for the reemergence of trichinellosis in humans.

Trade relevance

Trade was of important relevance for horse meat in the past (Liciardi *et al.,* 2009). Game meat (mainly from wild boar and bear) illegally imported from endemic to non-endemic countries was the source of infection for hundreds of people. Since *Trichinella*-infected pigs are backyard or free-ranging, they are consumed at the local level and do not reach the market. Most marketed pigs are reared in high containment-level farms and consequently are *Trichinella* free.

Impact on economically vulnerable populations

Trichinella spp. circulate at relatively high prevalence in backyard or free-ranging pigs of poor rural areas without efficient veterinary services. However, the behaviour of the human population and the environmental conditions play an important role in the circulation of these zoonotic parasites. In addition, since *Trichinella* spp. circulate in wildlife, the hunters, their relatives and friends consuming game meat of *Trichinella*-susceptible animals can be exposed to the infection regardless of their economic and social status if game is not tested by the veterinary services.

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A7.22 TRICHINELLA SPIRALIS

General information

Trichinella spiralis is an intracellular parasitic nematode of mammalian striated muscles. It is responsible for trichinellosis, a zoonosis resulting from consumption of raw or undercooked meat from infected animals (e.g. pork, game animals). Human outbreaks have been regularly reported during the last century (Ancelle *et al.,* 2005; Khumjui *et al.,* 2008). Trichinellosis is regarded as an emerging or reemerging disease in some parts of the world (particularly in Eastern Europe, Asia, etc.). *Trichinella* infections are mainly due to food or culinary habits, with pork being the major source of contamination for humans (Devine, 2003; Blaga *et al.*, 2009). The *Trichinella* genus is divided in two clades (Gottstein, Pozio and Noeckler, 2009) with (i) encapsulated species due to the production of a collagen capsule surrounding the parasite: *T. spiralis, T. nativa, T. britovi, T. murrelli*, *T. nelsoni, T. patagoniensis* (Krivokapich *et al.*, 2012) and 3 genotypes; and (ii) the non-encapsulated species that do not form a thick collagen capsule in muscle: *T. pseudospiralis, T. papuae* and *T. zimbabwensis*. Most of these species and genotypes are involved in human infections and clinical signs.

Geographical distribution

It was estimated that more than 11 million people are infected worldwide (Dupouy-Camet, 2000), but this figure should be carefully used as it is based on serological studies.

Even if *Trichinella* can be found worldwide in wild animals, the parasite is endemic in pig breeding in several countries in eastern Europe, Russia (in some areas), China (in various provinces), South Asia (Laos, Thailand) and in South America (except Brazil). For example, an overall study in China described more than 500 human outbreaks, numbering 25 161 reported cases with 240 deaths (Liu and Boireau, 2002). It was underlined that this reported quantity was probably significantly underestimated because adequate diagnostic techniques might not have been available in China at the time.

Disease

Severity of acute morbidity

In animals the disease is considered as asymptomatic, whereas in humans, trichinellosis is a serious disease that can cause much suffering and rarely may result in death. The symptoms follow the parasitic life cycle, with an enteric phase, a migratory phase and a muscle phase. During the invasion of intestinal epithelium by the worms, intestinal pains and diarrhoea can be observed (Gottstein, Pozio and Noeckler, 2009). Severe signs and symptoms such as fever (39–40°C) and facial oedema may result from the migration of the larvae within blood vessels.

The establishment of new-born larvae within the muscle cell and the encystment of muscle larvae (ML) are responsible for myalgia and asthenia. The most frequently affected muscles are the muscles of the cervix, trunk, upper and lower extremities, and also less frequently the masseters. Severe myalgia generally lasts for two to three weeks.

Severity of chronic morbidity and chronic illness fraction

A small percentage of trichinellosis cases become "clinically chronic" and may be associated with recurrent muscle pain, a difficulty in eye accommodation, and intestinal disorders in the case of repeated infection. Brain abnormalities were also reported by several authors (Gottstein, Pozio and Noeckler, 2009). The fraction of chronic illness is difficult to establish precisely as it depends on the initial infective dose of ML ingested and the density of ML spread in the organism. During large outbreaks, like those reported following the consumption of contaminated horse meat, less than 10% of human cases become chronic.

Case fatality rates

A study on the reported trichinellosis cases in China (Liu and Boireau, 2002) allowed for an estimate of mortality (0.9%). This figure confirmed the previous estimation for human mortality.

Increase in human illness potential

A recent report in India underlines the possibility of reaching 30% mortality in the absence of treatment during severe infection (Sethi *et al.,* 2012).

Trade relevance

Domestic pigs, horses and susceptible wild animals intended for human consumption are submitted to compulsory veterinary controls to ensure the meat is *Trichinella* free. The method for *Trichinella* detection is based on direct identification of the parasite after artificial digestion of muscle sample harvested on carcasses (Gajadhar *et al.,* 2009). The reference method is described in both EU regulation and ICT (EU, 2005; ICT, no date) recommendations. Briefly, EU regulation requests that pigs must be systematically sampled at slaughterhouses and submitted to *Trichinella* detection (1 g for domestic swine, 2 g for breeding sows and boars, taken in the pillar of the diaphragm). Other animals (horse meat, wild game meat and other species sensitive to *Trichinella* infection) must be analysed with at least 5 g of muscle from tongue or jaw muscle for horsemeat and at least 5 g of muscle from foreleg, tongue or diaphragm for wild boar. Derogations for meat of domestic swine are possible when pig holdings have been officially recognized as being controlled housing as defined by the competent authorities.

Impact on economically vulnerable populations

Few studies on trichinellosis have been performed in low- or middle-income countries and there is a need for research in this field.

Other relevant information

Critical control points in pre- and post-harvest raising of pigs are described in OIE and ICT guidelines and also derogations are given in the EU regulation. The main points are:

- *Prevention of livestock contamination* Feed must be purchased from an approved company that produces feed following good production practices. Feed and feed storage must be maintained in closed silos where rodents cannot enter. Feeding livestock with uncooked food waste, rodents or other wildlife are practices that expose animals to a risk of contamination by *Trichinella*.
- *Meat processing* Meat of domestic swine that has undergone a freezing treatment according to EU regulation or ICT recommendations and under the supervision of competent authorities can be exempted from *Trichinella* examination. For example, pork of a thickness up to 15 cm needs to be frozen at -15°C for at least 20 days to be considered safe. However, *Trichinella* found in game meats (mainly *T. nativa* and to a lesser extent *T. britovi*) may be resistant to freezing and therefore frozen meat may still pose a public health risk. If meat cannot be controlled by a fully implemented direct examination, ICT recommends adequate treatment by cooking the meat to an internal temperature of 71°C. Appropriate treatment of meat cannot be ensured by the use of microwaves, drying or smoking.

Prevention of human infection is accomplished by meat inspection, by meat processing and by prevention of exposure of food animals to infected meat. Game meats should always be considered as a potential source of infection, and therefore game meats should be tested or cooked thoroughly.

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A7.23 TRICHURIS TRICHIURA

General information

Trichuris trichiura is a nematode commonly known as the whipworm due to its particular shape (it looks like a whip with wider "handles" at the posterior end). Females are approximately 35–50 mm long, males 30–45 mm. The female *T. trichiura* produces 2000–10 000 single-celled eggs per day. Eggs are deposited from human faeces to soil where, after two to three weeks depending on the temperature and humidity (hot and humid climatic conditions are optimal for their development), they become embryonated and enter the "infective" stage. When these embryonated infective eggs are ingested by humans, they hatch in the small intestine, exploiting the intestinal microflora as hatching stimulus, where they grow and moult. The young worms move to the caecum and penetrate the mucosa with the cephalic end, and there they complete their development to adult worms. The life cycle from time of ingestion of eggs to development of mature worms takes approximately three months. During this time, there may be limited signs of infection in stool samples due to lack of egg production and shedding. The female *T. trichiura* begin to lay eggs after three months of maturity, and worms can live up to two to three years.

Geographical distribution

T. trichiura, together with *Ascaris lumbricoides, Ancylostoma duodenal* and *Necator americanus*, is a soil-transmitted helminth. It is distributed worldwide, infecting an estimated 600 million people, especially in tropical and subtropical areas, with the greatest numbers occurring in Africa, southern India, China, Southeast Asia and the Americas. In 2010, the global population at risk was estimated at 5 023 million (Asian Group Report, this publication), with a Global Burden of Disease (GBD) estimated at 1.0–6.4 million DALYs (WHO, 2102a) in the world (236 000 DALYs in Africa) (African Group Report, this publication).

Infection occurs through ingestion of eggs by eating raw, unwashed vegetables, by drinking contaminated water, or by not washing the hands after handling contaminated soil (a common transmission route for children).

Disease

Morbidity is related to the number of worms harboured (WHO, 2012b). Light infections (<100 worms) are frequently asymptomatic, while bloody diarrhoea and dysentery may occur in heavy infections, with rectal prolapse possible in severe cases. Vitamin A deficiency may also result due to infection. Mechanical damage to the mucosa may occur, as well as toxic or inflammatory damage to the intestines of the host. Trichuriasis is one of the seven most common Neglected Tropical Diseases (NTDs) (GNNTD, 2012).

Intensity of infection is classified by WHO according to the number of eggs per gram (epg) of faeces, excreted by infected persons: from 1–999 epg the infection is considered light, from 1000–9999 epg moderate, and >10 000 epg the infection is heavy intensity (WHO, 2011).

The burden of disease due to *T. trichiura* is mainly attributed to its chronic and insidious impact on the health and quality of life of those infected, rather than to the mortality it causes. Infections of heavy intensity impair physical growth and cognitive development and are a cause of micronutrient deficiencies, leading to poor school performance and absenteeism in children, reduced work productivity in adults and adverse pregnancy outcomes.

In countries of high endemicity of the soil-transmitted helminth parasites, preventive chemotherapy (i.e. repeated administration of anthelmintic drugs to at-risk populations) is the main strategy to control morbidity. However, rapid re-infection of humans occurs after successful de-worming, and therefore effective preventive measures are required to achieve public health goals with optimal efficiency and sustainability.

In 2001, the World Health Organization endorsed preventive chemotherapy as the global strategy to control soil-transmitted helminthiasis (WHO, 2012b). The key component of this strategy is regular administration of anthelmintic drugs to at-risk groups: children, women of childbearing age, and adults in high-risk occupations, such as nightsoil re-use and farming. Although this strategy reduces illness caused by soil-transmitted helminths, it does not prevent rapid re-infection. To interrupt transmission and to achieve local elimination of helminthiasis, integrated control approaches that include access to sanitation and other complementary interventions of a primary prevention nature are needed (Ziegelbauer, 2012).

Trade relevance

Currently this parasite is not considered an issue in trade. Due to the faecal-oral route of transmission for *T. trichiura*, the primary production and pre-harvest stage of the food chain are critical in terms of control of this parasite, and areas for cultivation of fresh produce, particularly for raw consumption, need to be assessed in terms of their susceptibility to faecal contamination.

Impact on economically vulnerable populations

Poor hygiene, especially lack of sanitation occurring wherever there is poverty, is associated with soil-transmitted helminthiases, such as *T. trichiura*, and also contributes to the faecal contamination of foods. People infected with soil-transmitted helminths have parasite eggs in their faeces. In areas where there are no latrine systems, the soil (and water) around the village or community becomes contaminated with faeces containing worm eggs. Children are especially vulnerable to infection due to their high exposure risk.

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A7.24 *TRYPANOSOMA CRUZI*

General information

Chagas disease, or American trypanosomiasis, a primarily vector-borne parasitic disease in the Americas, is a human infection caused by the protozoan parasite *Trypanosoma cruzi*. The disease can also be transmitted through transfusion, through transplant, congenitally and by oral transmission (WHO, 2003; Bern *et al.*, 2011). *T. cruzi* is a flagellate that belongs to the Kinetoplastida order, Trypanosomatidae family, characterized by the presence of one flagellum and a single mitochondrion, where the kinetoplast is located. The parasite *T. cruzi* is not a homogeneous population and is composed of a pool of strains which circulate both in the domestic and sylvatic cycles involving humans, vectors and animal reservoirs of the parasite (Bern *et al.*, 2011).

Geographical distribution

According to information from 21 countries located throughout Mexico, Central America and South America, where the disease is endemic, the number of infected people today is estimated at 7 694 500 (1.448% of the population) (PAHO/WHO, 2012). The number of new cases per year due to vector transmission is estimated at 41 200 (7775 per 100 000) and the number of new cases of congenital Chagas disease per year has been estimated at 14 385. In addition, in 2008, 11 000 people died from the disease (WHO, 207; PAHO/WHO, 2012; WHO. 2010).

Animal reservoirs

To date, over 100 mammalian species have been reported as natural hosts for *T. cruzi*, and all mammals are considered to be susceptible to infection. The epidemiologically important reservoirs vary geographically according to the biology and ecology of mammals and vectors, and how these interactions translate to risk of human exposure. Although *T. cruzi* has a wide host range, opossums and armadillos are important reservoirs throughout the Americas (Bern *et al.*, 2011).

Vectors

There are more than 130 triatomine species (blood sucking reduviid insects) in the Americas, many of which can be infected by and transmit *T. cruzi*. However, a small number of highly domiciliated vectors are important in the human epidemiology of the disease. The major triatomine species that colonize domestic and peridomestic environments and play an important role in the epidemiology of Chagas disease in Latin America are: *Triatoma infestans* in Argentina, Brazil, Chile, Paraguay, southern Peru and Uruguay; *Rhodnius prolixus* in Colombia, El Salvador, Guatemala, Honduras, southern Mexico, Nicaragua and Venezuela; *Triatoma dimidiate* in Belize, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, northern Peru and Venezuela;

Panstrongylus megistus in Argentina, Brazil, Paraguay, Uruguay; and *Triatoma brasiliensis* in north-eastern Brazil (WHO, 2003; Bern *et al.,* 2011).

Disease

In the Americas, *T. cruzi* infection is most commonly acquired through contact with faeces of an infected triatomine bug (vector-borne transmission) that can enter the human body through a bite wound, intact conjunctiva or other mucous membranes. Infection can also occur from: mother-to-baby (congenital), contaminated blood products (transfusions), transplanted organs from infected donors, laboratory accidents, food or drink contaminated with vector faeces (oral transmission) or consumption of raw meat from infected mammalian sylvatic hosts (Nóbrega *et al*., 2009; Dias, Amato Neto and Luna, 2011; Toso, Vial and Galanti, 2011; PAHO, 2009).

The acute phase of infection usually lasts around two months immediately after infection and is characterized by a variety of clinical manifestations and parasites that may be found in the blood. Most cases have no or few symptoms, but there may be a skin chancre (chagoma) or unilateral purplish orbital oedema (Romaña's sign) with local lymphadenopathy and fever over several weeks. More general symptoms include: headache, myalgia, dyspnoea, oedema in inferior extremities or face, abdominal pain, cough, hepatomegaly, rash, painful nodules, splenomegaly, generalized oedema, diarrhoea, multiple lymphadenopathy, myocarditis and, more rarely, meningoencephalitis

Following the acute phase, most infected people enter into a prolonged asymptomatic form of the disease (called 'chronic indeterminate') during which few or no parasites are found in blood, but with positive anti-*T. cruzi* serology. However, 10–40% will go on over the next decades to develop cardiac or digestive manifestations, or both. Cardiac sequelae include: conduction disorders, arrhythmia, cardiomyopathy, heart failure, cardiac aneurysm and secondary thromboembolism. Digestive lesions include megaoesophagus and megacolon (WHO, 2003; Bern *et al.,* 2011).

Chagas disease by oral transmission

Following advances in the control of vectors and transmission of Chagas disease via blood transfusion in the endemic regions of America, alternative mechanisms of transmission have become more important, and several outbreaks reported in Brazil, Colombia and Venezuela have occurred due to transmission of *T. cruzi* through an oral route and have been attributed to contaminated fruit, palm wine or sugar cane juice (Nóbrega *et al*., 2009; Alarcón de Noya *et al*., 2010; Dias, Amato Neto and Luna, 2011; Toso, Vial and Galanti, 2011; PAHO, 2009).

The clinical presentation of Chagas disease contracted through oral transmission is different from that observed in vector-borne infection, with more severe acute morbidity and higher mortality. After an incubation period of 5 to 22 days post-ingestion, the disease is expressed with acute manifestations of fever, gastric irritation, abdominal pain, vomiting, jaundice and bloody diarrhoea. As a result, in many cases patients develop severe myocarditis and meningeal irritation. Lethality can reach a relatively high level (up to 35.2%, with an average rate of 7.1%) (Alarcón de Noya *et al.*, 2010; PAHO, 2009; Bern *et al.,* 2011).

Trade relevance

The food-borne transmission route for *T. cruzi* is a new, emerging hazard, and the extent of the possible trade impact has not been fully assessed.

The precise stage of food handling at which contamination occurs is unknown, although various foods, such as fruit juice, sugar cane and açaí palm, are involved, possibly contaminated with infected triatomine faeces during processing. Oral transmission of Chagas disease is always dependent on infected vectors or reservoirs as *T. cruzi* does not multiply in food, therefore the disease is relevant in countries with vector-borne transmission and, additionally, outbreaks contracted through oral transmission have been detected. The adoption of good food hygiene measures, as well as proper cooking of wild meat from endemic areas minimizes the risk of transmission. In the case of prepared foods produced in areas with triatomine bugs, high standards of proper cooking or pasteurization become essential. Pasteurization of açaí pulp is being adopted for the product exported to other regions of the Amazon in Brazil and abroad (Dias, Amato Neto and Luna, 2011; PAHO, 2009).

Impact on economically vulnerable populations

Food-borne transmission of *T. cruzi* may occur more often than is currently recognized. Most outbreaks are small, often affecting family groups in rural areas, and unusually in urban populations of South America (Nóbrega *et al.*, 2009; Alarcón de Noya *et al.*, 2010; Dias, Amato Neto and Luna, 2011; Toso, Vial and Galanti, 2011). This form of transmission is considered an emerging threat to public health; the negative socio-economic impact is due to the high morbidity and mortality in the community affected by outbreaks.

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A7.25 GLOSSARY OF PARASITOLOGICAL TERMS

assemblage – the preferred term for a *Giardia duodenalis* genotype

bradyzoite – the slowly multiplying life cycle stage of some coccidian parasites (e.g. *Toxoplasma gondii*); found inside tissue cysts in host cells

cestode – tapeworm (Phylum Platyhelminthes, Class Cestoda); all are parasitic (e.g. *Diphyllobothrium* spp., *Echinococcus* spp., *Taenia* spp.)

coccidian – member of a group of protozoan parasites (Phylum Apicomplexa) that inhabit cells lining the host's intestinal tract (e.g. *Cryptosporidium* spp., *Cyclospora cayetanensis*, *Toxoplasma gondii*)

cyst – environmental life cycle stage of some protozoan parasites, containing trophozoites (e.g. *Entamoeba histolytica*, *Giardia duodenalis*,); may also refer to tissue cysts of *Toxoplasma gondii*, sarcocysts of *Sarcocystis* spp., or hydatid cysts of *Echinococcus* spp.

cysticercus (pl. cysticerci) – the infectious larval stage of some tapeworms (e.g. *Taenia* spp.)

DALY (or DALYs) – Disability-Adjusted Life Year; a measure of disease burden calculated by adding YLL and YLD

definitive host – the final host in the life cycle of a parasite and in which sexual reproduction occurs, resulting in the production of the infectious environmental stage (e.g. eggs, cysts or oocysts)

encyst (encystment or encystation) – the formation of an environmentally-resistant cyst around some protozoan parasites prior to their shedding with the host's faeces (e.g. *Giardia duodenalis*); a result of physiological and biochemical triggers within the host's digestive tract; also, the formation of a cyst around helminth larvae at the beginning of the dormant tissue phase of the life cycle (e.g. *Taenia* spp., *Trichinella* spp.)

excyst (excystment or excystation) – release of motile, infective life cycle stages of protozoan parasites following ingestion of cysts or oocysts by a host

genotype – a genetically distinct group of organisms within a species

genus – a taxonomic group of organisms with similar attributes consisting of one or more species; typically written in italics followed by the species name

helminth – worms belonging to four phyla: Nematoda (roundworms), Platyhelminths (flatworms e.g. cestodes and trematodes), Acanthocephala (spiny-headed worms) and Nemathophora (hairworms)

hexocanth – *see:* oncosphere

hydatid cyst – fluid-filled cyst containing larvae (protoscoleces) of the tapeworm, *Echinococcus* spp.; they develop in liver, lungs, brain and other organs of the intermediate host

incubation period – the period of time between exposure to a parasite and the first symptoms

intermediate host – a host in the life cycle of a parasite in which some specific developmental stage is reached, short of the sexually mature stage; the parasite is subsequently transmitted to the next intermediate host, or to the definitive host, through predation, accidental ingestion or free-living larvae

Loeffler's syndrome – a disease in which eosinophils accumulate in the lung in response to a parasitic infection (e.g. *Ascaris lumbricoides*)

metacercariae (sing. metacercaria) – encysted infectious larval stage of trematodes; found in the tissues of intermediate hosts (e.g. *Clonorchis sinensis*) or attached to aquatic vegetation (e.g. *Fasciola hepatica*)

merozoite – non-motile life cycle stage of coccidian parasites; produced during the asexual cycle in cells lining the host's intestinal tract

metacestode – the larval stage of a tapeworm found in an intermediate host (e.g. cysticercus, hydatid cyst)

nematode – roundworm (Phylum Nematoda); includes parasitic species (e.g. Anisakidae, *Ascaris* spp., *Toxocara* spp., *Trichinella* spp.)

OLM – ocular larval migrans

oncosphere – the embryo of some tapeworms (e.g. *Echinococcus* spp., *Taenia* spp.) which has six hooklets and is surrounded by a membrane and contained within an egg; also referred to as a hexacanth

oocyst – the infectious environmental stage of coccidian parasites, produced through the sexual stage of the life cycle

paratenic host – a host not necessary for the development of a parasite but which may facilitate the completion of its life cycle and its dispersion in the environment. In contrast to its development in a secondary host, a parasite in a paratenic host does not undergo any changes into the following stages of its development.

plerocercoid – a larval stage of some cestodes with aquatic life cycles (e.g. *Diphyllobothrium* spp.); found in tissues of the second intermediate host

procercoid – a larval stage of some cestodes with aquatic life cycles (e.g. *Diphyllobothrium* spp.); found in the first intermediate host

proglottids – the "segments" of tapeworms; mature proglottids contain both male and female reproductive organs, while gravid proglottids consist of uteri filled with eggs

protoscolex (pl. protoscoleces) – juvenile scolex of some tapeworms (e.g. *Echinococcus* spp.,*Taenia* spp.) which bud from the inner lining of the cyst

protozoan – single-celled eukaryotic organism; this group includes parasitic species (e.g. *Cryptosporidium* spp., *Cyclospora cayetanensis*, *Giardia duodenalis*, *Toxoplasma gondii*)

redia – a digenean trematode (fluke) in the larval stage developed from a sporocyst in the main intermediate host, and in turn forming a number of cercariae

scolex (pl. scoleces) – the "head" or anterior end of tapeworms; equipped with hold-fast structures such as suckers, grooves or hooks, or a combination

species (sing. sp., pl. spp.) – a taxonomic group of organisms within a genus which is distinct from other species based on morphological, biological, and molecular characteristics; the genus and species make up the "scientific name" (Latin binomial) of an organism, and are typically written in italics

sporocyst – structures containing sporozoites found within mature oocysts of some coccidian parasites; also, a cyst which contains the rediae larvae of some trematode parasites

sporozoite – motile, infective life cycle stage of coccidian parasites; released from mature oocysts upon ingestion by a host; may be contained within sporocysts

sylvatic – referring to diseases affecting and/or cycling through wild animals; distinguished from domestic or synanthropic cycles

synanthropic – referring to diseases or pathogens whose life cycles are ecologically associated with humans and domestic animals; distinguished from sylvatic cycles

tachyzoite – motile life cycle stage of some coccidian parasites (e.g. *Toxoplasma gondii*); undergo rapid multiplication in the host before developing into bradyzoites and forming tissue cysts

tissue cyst – cluster of *Toxoplasma gondii* bradyzoites surrounded by a cyst wall within cells of the host's organs and tissues

trematode – fluke (Phylum Platyhelminthes, Class Trematoda); all are parasitic (e.g. *Fasciola* spp., Heterophyidae, Opisthorchiidae, *Paragonimus* spp.)

trophozoite – the motile, asexually multiplying stage in the life cycle of many protozoan parasites; present in host cells or attached to cells lining the intestine

viscera – the internal organs of the body; particularly in the thoracic and abdominal cavities

VLM – visceral larval migrans

YLL – a metric describing the Years of Life Lost in a population due to different factors, including infectious diseases

YLD – a metric describing the Years Lost due to Disability in a population due to various factors, including infectious diseases

zoonosis (noun.) – a disease naturally transmitted from one species of animal to another (including those transmitted through a vector), especially to humans

zoonotic (adj.) – designating, causing or involving a zoonosis; transmitted from animals to humans

Annex 8

Regional Reports

The experts were grouped into seven geographical regions and were asked to prepare and bring to the meeting regional information that considered the current overall quantity and quality of data at the regional and global levels; burden of disease and food attribution; data on parasite prevalence; incidence and concentration in the main food categories; agri-food trade; consumer perception; social sensitivity; and risk management options. These reports were used by the experts in their deliberations during the meeting. The seven geographical regions represented were Africa, Asia, Pacific (primarily Australia), Europe, Near East, North America and South America. What little that was available for Central America was added to the North America section.

Note on information sources: The references for the Asia regional report were revised after the meeting, and a few were updated (2013).

Note on taxonomy: There has been confusion concerning the causative agent of giardiasis, and it has variously been named as *Giardia duodenalis*, *Giardia lamblia* or *Giardia intestinalis*. The general consensus is that the parasite should be identified as *Giardia duodenalis*, with *Giardia lamblia* and *Giardia intestinalis* considered synonyms.

ANNEX 8.1 – AFRICA

A8.1.1 Introduction

The group members (Erastus Kang'ethe, Kenya; Allal Dakkak, Morocco; and Samson Mukaratirwa, South Africa) were responsible for collating data on food-borne parasites relevant to the African region, deriving the information from the proposed list and based on their experiences and information available in the literature. Communication and exchange of information among members of the group was through e-mail.

Samson Mukaratirwa, as the Group leader, was responsible for compiling the contributions from members, following the specific guidelines from the Secretariat of the FAO/WHO Joint Expert Meetings on Risk Assessment (JEMRA).

A8.1.2 Data availability in humans, and food attribution

To some extent data is available on the prevalence of *Taenia solium*, *T. saginata*, *Echinococcus granulosus* and *Toxoplasma gondii*, but not enough to quantify the burden of the disease in humans in the region. In many African countries there is virtually no data on prevalence in humans, and there is a general lack of surveillance systems, which leads to no availability of data to quantify the burden of the disease. With the advent of the HIV-AIDS pandemic in sub-Saharan Africa there are reports of cases of cryptosporidiosis and toxoplasmosis, but mainly in immuno-compromised individuals. Efforts have been made in the last decade to estimate the burden of *T. solium* cysticercosis in sub-Saharan Africa, with some success in Cameroon and South Africa, and in Africa as whole the burden of ascariasis and trichuriasis has been estimated.

For other foodborne parasites, more prevalence studies are needed to quantify the disease burden. in humans Although parasites like *Toxoplasma gondii*, *Giardia* spp., *Cryptosporidium* spp. and *Trichinella* spp. have a global importance, they are still very much underreported in Africa, either because of lack of prioritization by relevant authorities or by being overshadowed by the importance of other parasites, such as *Plasmodium* spp. There is need to collect data on the prevalence of these parasites in order to estimate the burden of the disease in the region, especially for neglected rural communities, where the prevalence is assumed to be very high.

TABLE A8.1.1 Data availability on the burden of disease and food attribution at the regional and global level for Africa

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	Disease severity/ main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Main food sources and attributions
Ancylostoma duodenale	Yes [28, 33] North Africa: 0–1.9%; Central Africa: 10–20%; South and West Africa: 50-70%.	Yes [28, 30, 33] High prevalence in sub-Saharan Africa	Main mode of transmission is via skin penetration. Oral transmission through ingestion of contaminated vegetables and drinking water may occur. Children are at high risk [28, 32, 33]	Yes [28, 32]	Yes [28, 32]	[28, 32]
Ascaris lumbricoides	Yes [27]	Yes [27] 91333.5 000 DALYs in Africa	Contaminated water, fruits and edible plants [27]	Yes [27]	Yes [27] 1 851 000 DALYs in the world.	Contaminated water, fruits and edible plants [27]
Cryptosporidium spp.	Yes [21] Mainly in immuno-compromised individuals.	Yes Related to urban dwellers with poor supply of potable water and HIV-infected. High pathogenic effects in children aged 6 to 36 months, particularly those who are malnourished or positive for HIV infection.	Mainly contaminated water, fruits and edible plants	Yes [22, 23]	Yes [22]	Mainly contaminated water and edible plants [22]
Echinococcus granulosus	Yes [12, 13, 14, 15] Hydatidosis is highly prevalent and 3 to 7 surgical cases per 100 000 inhabitants a year in sub-Saharan Africa. There is rather conspicuous concentration of human cases in NW Sudan, NE Uganda, SE Ethiopia and extreme SE Sudan.	Yes [14, 15] Young children are most often affected because of their constant hand-to-mouth behaviour	Edible fruits, plants and water contaminated with eggs [14, 15]	Yes [16] Cystic hydatidosis is one of the most important zoonotic diseases	Yes [17] Global DALYs lost due to disease is estimated at 285 407	Edible plants, fruits and water contaminated with eggs

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	Disease severity/ main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Main food sources and attributions
Taenia saginata	Yes [9, 10] Not many studies conducted in humans and in many instances there is difficulty in differential Dx with T. solium eggs. Occurs in most African countries, but the epidemiological patterns in the African countries are far from being complete.	Yes [10, 11] Scanty reports for the disease in humans. Main populations at risk are rural communities with poor sanitation. Disease is not considered as severe in humans.	Meat [10, 11] (undercooked or raw beef)	Yes [11]	Yes [11] Population in areas where poor sanitation and animal husbandry facilitate parasite transmission	Meat [11] undercooked or raw beef
Taenia solium	Yes [1, 2] Except for the Muslim regions, where pork is not eaten for religious reasons, T. solium cysticercosis affects virtually all countries in Western and Central Africa West Africa: 0.6–17%; Central Africa: 0.6–20%; West Africa: 0.1–6.5%. Neurocysticercosis is considered to be the commonest parasitic disease of the human nervous system	Yes [3, 4, 5, 6] Underestimated because of lack of cheap and reliable Dx test. Monetary burden valued at US$ 34.2 million in the Eastern Cape Province of South Africa. 9.0 DALYs lost per 1000 persons in Cameroon.	Meat (undercooked or raw pork); edible raw plants and fruits contaminated with eggs; autoinfection	Yes [7, 8]	Yes [7]	Meat (undercooked or raw pork); edible raw plants and fruits contaminated with eggs; autoinfection [8]

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	Disease severity/ main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Main food sources and attributions
Toxoplasma gondii	Yes [18] Mainly in immuno-compromised individuals. Occurs in most African countries, where it seems to be frequent, but the epidemiological patterns in the African countries are far from clear. The prevalence of infection seems to be high and varies from 15 to 60%.	Yes [19] Reports related to HIV infection and congenital infections.	Yes Milk and raw or undercooked meat from livestock contaminated with tachyzoites and bradyzoites; drinking of water and ingestion of edible plants contaminated with oocysts.	Yes [8] High sero-prevalence in North America (10%) and UK (40%); 50 to 80% in continental Europe and Latin America. However, prevalence is steadily decreasing.	Yes Due to HIV-AIDS pandemic in sub-Saharan Africa.	Milk and raw or undercooked meat from livestock contaminated with tachyzoites and bradyzoites; drinking of water and ingestion of edible plants contaminated with oocysts [8]
Trichuris trichiura	Yes [27]	Yes [27] 236 000 DALYs in Africa	Contaminated water, fruits and edible plants [27]	Yes [27]	Yes [27] 1 012 000 DALYs in the world	Contaminated water, fruits and edible plants [27]
Trichinella spp	Yes [24] Sporadic cases reported in Africa. Species identification from cases not always done.	Yes Sporadic clinical cases confirmed in humans but species not determined.	Meat (undercooked or raw meat and products from wild pig, warthog, bush pig).	Yes [26]	Yes [26] About 11 million people may be infected	Meat [26] undercooked or raw meat and products from pigs, horses and wildlife of temperate regions, like bears and seals.

Notes: Dx = diagnostic; DALY = disability-adjusted life year

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TABLE A8.1.2 Data availability for parasite prevalence or concentration in the main food categories for Africa

Taenia saginata	
Beef	Yes [6–9]
Game	Yes [6–9]
Echinococcus granulosus	
Beef	Yes [10]
Game	Yes [11]
Other	Yes [10] Caprid meat
Taenia solium	
Pork	Yes [1–5]
Fruits	Yes [1–5] Contaminated with T. *solium* eggs.
Vegetables	Yes [1–5] Contaminated with T. *solium* eggs.
Other	Yes [1–5] Drinking water contaminated with T. *solium* eggs.

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A8.1.3 Agri-food trade

Most of the above parasites have minor regional or global trade implications, except for *T. solium*, *Trichinella* spp. in pork and pork products, and *T. saginata* in beef and beef products, which do have trade implications. In most countries, carcasses may not be released even for the domestic market unless they have been inspected and/or tested to ascertain absence of infection.

A8.1.4 Consumer perception

Because of lack of public awareness campaigns and education concerning the risks of eating certain foods, especially meat and meat products, in many African countries, consumers in Africa are ignorant of the prevalent of foodborne parasites. To some extent, consumers in some countries are aware of *T. solium* and saginata cysticercosis, but in some cases they are ignorant of the importance of meat inspection and hygiene. In some countries, consumers are aware of the effects of hydatid cysts of *Echinococcus granulosus* but are ignorant of not how the parasite is transmitted. The risk of human infection from infected meat and vegetables is reduced by cooking, which destroys the pathogen, because of the reduced use of raw vegetables this has limited transmission.

A8.1.5 Social sensitivity

Neurocysticercosis due to *T. solium* infection is one of the main causes of epilepsy in rural African communities. This comes with social stigma for those affected by the parasite. Another disease that might have social sensitivity in the African context is congenital toxoplasmosis, which might cause abortions and foetal deformities, creating a variety of social problems within a community. The disease has substantial global impact in terms of disability adjusted life years (DALYs) and monetary losses. Furthermore, in most reports, between 1 and 2 hydatid cysts in humans are fatal, depending on their location, and the DALYs are substantial.

T. solium, *T. saginata* and *E. granulosus* are considered to have economic impact when it comes to monetary loss due to carcass devaluation or condemnation, which is recognized by a lot of the people. This affects not only human and animal health directly, but also agriculture in general.

A8.1.6 Risk management

TABLE A8.1.3 Data availability for risk management options for main parasite-commodity combinations in Africa.

NOTE: The authors were asked to consider all combinations of the particular parasite and the main food categories, namely Beef, Dairy, Pork, Poultry, Game, Seafood, Fruit, Vegetables and Other.

***Cryptosporidium* spp.**	
Beef	Yes [9]
Fruits	Yes [12, 13]
Vegetables	Yes [12, 13]
Other	Yes [12, 13]
Echinococcus granulosus	
Beef	
Other	Yes [9–11]
Taenia solium	
Pork	Yes [1–4]
Other	Yes [1–4]
Taenia saginata	
Beef	Yes [6]
Pork	Yes [5]
Other	Yes [5, 6]
Trichinella spiralis	
Pork	Yes [7, 8]
Game	Yes [7, 8]

Sources used for Table A8.1.3:

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ANNEX 8.2 – ASIA

A8.2.1 Introduction

Foodborne Parasitic diseases are widely distributed in south-east, east and south Asia, and have been major public health problem for the population in the countries and regions. Distribution and endemicity of individual foodborne parasitic diseases vary greatly among countries and regions. While a majority of foodborne parasitic diseases are restricted to a few countries, or even local areas, there are some diseases prevalent much more widely. This section tries to summarize the current status of foodborne parasitic diseases in Asia.

The information for Asia was collected by Nguyen Van De, Viet Nam; Tomoyoshi Nozaki, Japan; Subhash Parija, India; and Paiboon Sithithaworn, Thailand.

One should note that some of statistics regarding endemicity were based on serology and/or microscopy, and thus potentially erroneous due to lack of proper objective diagnostic methods such as PCR and antigen detection of parasites, and confounded by potential cross-reactivity of sera from individuals infected with other parasites in tests using crude or undefined antigens.

A8.2.2 Description of individual foodborne parasitic diseases

The foodborne parasitic diseases are considered hierarchically as, firstly, meat-, fish-, shellfish- and plant-borne infections, secondly as protozoan and helminth infections, and thirdly in alphabetical order.

A8.2.2.1 Meat-borne parasite infections

Sarcocystosis (intestinal)

Intestinal sarcocystosis domestically is distributed in some countries, including China (29.7%), Malaysia (19.7% of 243 persons had antibodies to sarcocystis), India (11 case reports from 1990 to 2004), Thailand (1.5%) and Japan (case reported). In Viet Nam none were reported. In Japan, a case that may be relevant to international trade has recently emerged. Sarcocystis infection through consumption of raw horse meat ("Basashi") is becoming an important social health problem, with 37 clinical complaints related to consumption of fresh market horsemeat reported, mainly from the producing centres in Japan. The *Sarcocystis* species responsible for cases has been determined by rRNA sequencing to be closest to *S. fayeri*. Both horse meat imported unfrozen and live horses imported (mainly from North America) and raised in Japan were proven to be infected with the species at high possibility. Proper freezing (-20°C for >48 hours) can eliminate live parasites.

Toxoplasmosis

Toxoplasmosis, caused by the protozoan parasite *Toxoplasma gondii*, is prevalent in

Asia. However, data on most the serious form of toxoplasmosis, congenital toxoplasmosis, is largely unavailable.

In China, the first human case of toxoplasmosis was reported in 1964 in Jiangxi Province. Many human cases have been were reported in China since the first epidemic survey on toxoplasmosis was carried out in Guangxi Province in 1978. Between 2001 and 2004, a national serological survey of 47 444 people in 15 provinces and autonomous regions estimated a mean prevalence of 7.9% by using enzyme-linked immunosorbent assay (ELISA). High seroprevalence of latent *T. gondii* infection has been found among immunocompromised patients. Prevalence of *T. gondii* infection in cancer patients ranged from 24% to 79%. Surveys of *T. gondii* infection in individuals with tuberculosis and hepatitis B showed that the prevalences were 35.3% and 19.3%, respectively. In India, in the general population, seropositivities were 10.8–51.8% for IgG and 2–5% for IgM. In females with a bad obstetric history IgG was 49.5%. In HIV-infected subjects, seropositivity for IgG was 70%. In Thailand, the prevalence of toxoplasmosis was 2.6%. In Viet Nam, some cases of toxoplasmosis were reported. In Sri Lanka, the prevalence of toxoplasmosis was 27.5%. In Japan, the prevalence of toxoplasmosis was 1.8–5.6%. In Malaysia, the prevalence of toxoplasmosis was 10–50%. In Nepal, the prevalence of toxoplasmosis was 45.6%. In Viet Nam, some cases were reported. Food attribution to toxoplasmosis in Asia remains not well understood.

Taeniasis/cysticercosis

Human *Taenia*sis refers to foodborne infections with adult tapeworms: *Taenia solium*, *Taenia asiatica* (from pigs) or *Taenia saginata* (from cattle). Cysticercosis is a tissue infection with the larval cysticercus or metacestode stage of tapeworms, and occurs most commonly in pigs and cattle. The larval stage of *Taenia solium* can also infect humans and cause cysticercosis/neurocysticercosis, which is considered widespread in the developing countries of Latin America, Africa and Asia.

In Viet Nam, the infection rate of *Taenia* (serology) was 0.5–2% in the plains area, 3.8% in the highlands and 2–6% in mountain areas. Most taeniasis was due to *T. saginata* and *T. asiatica* (78–80%) or *T. solium* (20–22%). Cysticercosis is distributed in many provinces (over than 50 provinces), the prevalence was 5–7% in some villages. In China, the emergence of cysticercosis as a serious public health problem was recognized by the Chinese Government. Human cysticercosis caused by the larval stage of *T. solium* occurred in 29 provinces/autonomous regions/municipalities, and about 7 million people were estimated to be infected. Currently, *T. solium* and cysticercosis are highly endemic, primarily in Yunnan, Sichuan and Guizhou in the south-west, and in Qinghai province and Inner Mongolia in the north-west and northern regions. In Thailand, the prevalence of *Taenia*sis varies from 0.6 to 5.9%, and cysticercosis was 4% (based on serology). In Japan, 446 cysticercosis cases were reported up to 2004. In the Philippines, the reported prevalence of *Taenia*sis varied greatly, from 0.56 to 10% and cases reported. Indonesia, the prevalence of *Taenia* was 8–9% and cases reported of cysticercosis. In Bangladesh, case reports identified *Taenia* spp. In Nepal, the prevalence of *Taenia* spp. was 43% and cases reported for cysticercosis. In India, the prevalence of *T. solium* (18.6%), prevalence of neurocysticercosis (NCC) in asymptomatic individuals (15.1%), prevalence of NCC in active epileptics (26.3–56.8%) and prevalence of *T. saginata* was 5.3%. Note that these statistics regarding endemicity were often based on serology, and thus potentially erroneous due to cross-reactivity. In addition, as these infections occur mostly with domestically, but not internationally, traded meats, these diseases may not currently be a serious issue in Asia.

Trichinellosis

Trichinellosis in Asia is restricted to China and a few south-eastern countries. In China, more than 500 outbreaks in 12 of 34 provinces were reported, with 25 685 persons affected and 241 deaths. In Viet Nam, 5 trichinellosis outbreaks were reported, in the province of Yen Bai in 1970, Dien Bien in 2002 and 2004, Son La in 2008 and Thanh Hoa in 2012, with 114 cases and 8 deaths in total. In Thailand, the prevalence of trichinellosis was 0.9–9% (based on serology). In Japan, only one case was reported of trichinellosis. In India, there have been very few case reports, but recently a point source outbreak involved 42 cases. Note that these statistics regarding endemicity were mostly based on serology, and thus potentially erroneous due to cross-reactivity. In addition, as these infections occur mostly with domestically, but not internationally traded meats, these diseases may not currently be a serious issue in Asia.

A8.2.2.2 Fish- and shellfish-borne parasites

Anisakiasis (including *Pseudoterranova* sp.)

Anisakiasis is endemic in eastern Asian countries and regions, including Japan, Korea, mainland China and Taiwan. Due to the increasing popularity of Sushi and Sashimi, its worldwide distribution has potentially some relevance to the present FAO/WHO consultation. The worm species most commonly involved in human infections is *Anisakis simplex*. In Japan, 2 511 cases were reported between 2001 and 2005, and it is estimated—based on a survey using medical practitioners' receipts for health insurance claims—that a few to several thousand cases occurred annually in Japan. Anisakiasis has not been reported in South-East and South Asian countries, including India, Thailand and Viet Nam. The only cases reported of *Pseudoterranova decipiense* were from Japan and Taiwan.

Capillariasis

Capillaria philippinensis was reported in the Philippines, Japan, Thailand, Taiwan, Indonesia and India, with 3 case reports up to 2012.

Clonorchiasis

The oriental liver fluke, *Clonorchis sinensis*, is of socioeconomic importance in East and South-East Asia, including China, Taiwan, Viet Nam, Korea, and, to a lesser extent, in Japan. It is estimated that about 35 million people are infected globally, of whom approximately 15 million are in China in 27 provinces, which is a three-fold increase in the last decade. In Korea there have been 2 million infected, with a prevalence of 1.4–21.0%. In Japan, the prevalence was 1.0–54.2% (1960) and 10.9–66% (1961), but now has almost disappeared. In Viet Nam, the prevalence is 19.5% (0.2–40%) in 15 of 64 provinces in the north of the country. In Taiwan, prevalence is 10–20%. India has had very few cases reported. Note that these statistics regarding endemicity were very often based on serology, and thus potentially erroneous due to cross-reactivity. In addition, as these infections occur mostly with domestically but not internationally traded meats, these diseases may not currently be a serious issue in Asia.

Gnathostomiasis

Gnathostomiasis is restricted to South-East Asian countries. Cases reported of *Gnathostoma* spp. include 40 cases in Japan (2000–2011), 86 in China, and 34 in other Asian countries. Cases have been reported in China, Thailand, Viet Nam, India, Laos PDR, Myanmar, Cambodia, Bangladesh, Malaysia, Indonesia, Philippines and in India, with 14 cases reported up to 2012.

Echinostomiasis

Reported prevalences of *Echinostoma* spp. were 0.04–55.3% in Thailand, 1.5–20.1% in China (based on serology), a single case in Viet Nam and a few cases in India.

Kudoa infections

Kudoa infections from consumption of unfrozen raw flatfish ("Hirame") have been reported only recently in Japan. However, the number of cases is growing since the identification and notification of the causative agent. By 2011, 33 incidents involving 473 cases had been reported, with outbreaks also common. Food poisoning associated with flatfish consumption can be prevented by freezing at -20°C for 4 hours or heating at 90°C for 5 minutes, which inactivates *Kudoa septempunctata*. However, in view of the high market value of live flatfish, the Fishery Agency is currently taking measures towards Kudoa-free flatfish aquaculture. Currently, unfrozen flatfish is consumed only in East Asia, including Japan and Korea, but *Kudoa* may have an impact on food trade when flatfish consumption becomes more widely popular.

Opisthorchiasis

Opisthorchiasis is restricted to a few SE countries, where eating raw freshwater fish is common. In Thailand, prevalence of opisthorchiasis was 15.7%. In Lao PDR, the prevalence of opisthorchiasis was 37–86%. In Cambodia, opisthorchiasis was found in some cases. In Viet Nam, the prevalence of opisthorchiasis was 1.4–37.9% in 9/64 provinces in the south. In Malaysia, one case was reported of opisthorchiasis. In India, no cases have yet been reported. As opisthorchiasis occurs mostly in a domestic context, it is irrelevant to international trade in Asia.

Paragonimiasis

Paragonimus westermani has major socioeconomic importance in some restricted SE Asian countries and China. The parasite is transmitted via snails to freshwater crabs or crayfish, then to humans and other mammals, such as cats and dogs, and causes paragonimiasis. Thus, paragonimiasis is restricted to countries and regions where easting raw crab meat, which is locally distributed, is practised. In China, species of medical importance are *Paragonimus westermani*, *P. szechuanensis*, *P. heterotremus*, *P. huetiungensis* and *P. skrjabini*. *P. westermani* has been reported in humans from 24 provinces of mainland China, with a prevalence of 4.1–5.1%, with the population at risk of paragonimiasis being about 195 million. In Viet Nam, prevalence was 0.5–15% in 10/64 provinces based on serology. Adult worms found in dogs and infected cats, identified by morphology and molecular methods, were *P. heterotremus*. In Thailand, cases were reported in 23/68 provinces. In Japan, over 200 cases have been reported, but only a few recent cases. In Philippines, prevalence was 27.2–40% by serology in some areas. In India, it is endemic to the northeastern states of Manipur, Nagaland and Arunachal Pradesh, where *P. heterotremus* is the common species, with up to 50% seroprevalence in these regions. Note that these statistics regarding endemicity were mostly based on serology and thus potentially erroneous due to cross-reactivity. In addition, as these infections occur mostly through domestically but not internationally traded meats, these diseases may not currently be a serious issue in Asia.

Small intestinal flukes

Small intestinal flukes reported included Heterophiydae (*Haplorchis taichui, H. pumilio, H. yokogawai, Metagonimus* spp, *Centrocestus* spp, Lecitodendriids) and Echinostomatidae (*Echinostoma* spp., *Echinochasmus* spp.). Many cases were reported of small intestinal flukes in Korea, with 19 species identified. In Viet Nam, small intestinal flukes were widely distributed with a high prevalence (over 50% in some endemic areas), with 6 species in humans. Flukes are common in Thailand, with cases reported from China, Japan and India.

Sparganosis

A case was reported of *Spirometra erinacei* causing sparganosis in humans in Japan (an imported case), and Viet Nam and India have had few cases reported.

A8.2.2.3 Plant (fruit and vegetable)-borne parasites

Amoebiasis

Entamoeba histolytica is widely distributed in Asia. For instance, in Viet Nam, prevalence is 2-6% in children; in India, intestinal amoebiasis with *E. histolytica* or *E. dispar* (1–58%), intestinal amoebiasis with proven *E. histolytica* (34.6% of all the samples found to be positive for *E. histolytica* or *E. dispar*), extra-intestinal amoebiasis – amoebic liver abscess (3–9% of all the cases of intestinal amoebiasis). In Japan, in contrast, *E. histoltyica* infections are restricted to faecal spread though anal intercourse or faecal smearing by persons with intellectual disabilities, and thus its impact on foodborne transmission of the disease is very limited. In addition, as its transmission is primarily local and domestic in all endemic countries and regions, amoebiasis may be irrelevant to international trade. Furthermore, as transmission occurs locally and domestically in all endemic countries and regions, amoebiasis is irrelevant to international trade.

Cryptosporidiosis

In Viet Nam, an infection rate of cryptosporidiosis was 2.8% reported on a national basis. In India, the infection rate of Cryptosporidiosis was 18.9% in children, who had diarrhoea. In Japan, no foodborne case of cryptosporidiosis has been reported. In China, the infection rate of Cryptosporidiosis was 1.36–13.3%. Note that some of these numbers may not be reliable. As its transmission occurs locally and domestically in all endemic countries and regions, cryptosporidiosis is probably irrelevant to international trade. In addition, the main route of transmission is drinking water, and food attribution is not well understood.

Giardiasis

Giardiasis is caused by *Giardia duodenalis* (syn. *G. lamblia, G. intestinalis*), which constitutes the most common intestinal protozoan worldwide. Contaminated water is an important source of human infection, either through direct consumption or through the use of contaminated water in food processing or preparation. Human infection with *Giardia duodenalis* has been documented in every province of mainland China. The infection rate ranged from 8.67% to 9.07%, which were extracted from 13 areas out of 35 cities at the provincial level. Giardiasis is more common in children (<10 years old), and the prevalence varied from 5.0% in children aged 5–9 years to 4.2% in children aged 10–14 years. In Viet Nam, the prevalence was 1–10%. In India, countrywide distribution was 8.4–53.8%. However, as its transmission is principally local and domestic in all endemic countries and regions, giardiasis is irrelevant to international trade. In addition, the main route of transmission is drinking water, and food attribution is not well understood.

Ascariasis

Ascariasis is among the most common helminth infections worldwide, including Asia. However, as its transmission is local and domestic in all endemic countries and regions, ascariasis is irrelevant to international trade. In China, a recent nationwide survey suggested that *Ascaris lumbricoides* infection was the most common helminthiasis, with an overall prevalence of 47% and an estimated 531 million infections, and was most prevalent in children between 5 and 19 years old. In Viet Nam, the prevalence of ascariasis in communities in most provinces was 10–95%, with the greatest endemic infection rates being 80–95% in the Red River delta region, and least in the south and highland regions (10–40%). In Japan, the prevalence of Ascariasis was 8.2% in 1956, and is currently very low. In India, countrywide it is the commonest intestinal helminth ((28.4–68.3%). However, since its transmission is local and domestic in all endemic countries and regions, ascariasis is irrelevant to international trade.

Angiostrongyliasis

Angiostrongyliasis caused by *Angiostrongylus cantonensis* is a potentially fatal parasitic disease. The biggest outbreak in China thus far could be attributed to a freshwater snail and took place in the capital Beijing in 2006. Of the 160 infected individuals involved in this outbreak, 100 were hospitalized. In Thailand, case reports showed 484 cases from 1965 to 1968. In Viet Nam, over 60 cases were reported from many areas, most of them in children. In Japan, there have been 54 cases reported. In India, there is a single case report. Angiostrongyliasis is regionally restricted and irrelevant to international trade.

Coenurosis

Cerebral coenurosis or, more appropriately, central nervous system coenurosis (CNSc), is caused by infection with the larval stage (Coenurus cerebralis) of Taenia multiceps. This disease is very rare in humans and only about 100 cases have ever been recorded in China. Most human cases occur in developing countries, including India.

Echinococcosis

Echinococcosis, including cystic echinococcosis (CE) caused by the cestode *Echinococcus granulosus* and alveolar echinococcosis by *E. multilocularis* are regarded as among the most serious parasitic zoonoses. In China, the recent nationwide ELISA survey estimated that 380 000 people were infected with echinococcosis and ca. 50 million at risk of infection. In Japan, 373 cases (26 deaths) of alveolar echinococcosis were reported in 1997. Infection of wild foxes still persists, which may pose a public health risk for foodborne transmission of echinococcosis. Cases have been reported in South Korea, Mongolia, Thailand, Bangladesh, Nepal and India. Despite the fact that food attribution of echinococcosis is not well understood in Asia, it may have some relevance to international trade due to the severity of disease outcomes.

Fasciolopsiasis

Fasciolopsis buski is an intestinal trematode of humans and pigs that is acquired by consumption or handling of aquatic plants Fasciolopsiasis is restricted to some part of SE and East Asia, and irrelevant to international trade. In China, the first national survey between 1988 and 1992 revealed that fasciolopsiasis was distributed across 16 provinces and affected a total of 9531 infected people with 10.2–92.9% in some areas. The prevalence of infection in children ranged from 57% in mainland China to 25% in Taiwan. In Viet Nam, the prevalence of fasciolopsiasis was 0.5–3.8% in 16/64 provinces. In Thailand, its prevalence was 10% in children, who had intestinal parasites. Cases have been reported in Taiwan, Cambodia, Laos, Malaysia, Indonesia, Myanmar and India with a prevalence of 0–22.4%.

Fascioliasis

Fascioliasis is restricted to some part of SE Asia, and irrelevant to international trade. In Viet Nam, fascioliasis has been found in 52 of 63 provinces of the country, including 26 provinces in the south and 26 provinces in the north. Samples of *Fasciola* eggs and adult worms collected from the patients were analysed and identified by molecular methods as *Fasciola gigantica*. It is suggested that the Vietnamese *F. gigantica* has been hybridized with *F. hepatica*. In China, a national survey between 1988 and 1992 found 148 people were infected with *F. hepatica* and 9 with *F. gigantica*. Cases have been reported in Thailand, Korea, Islamic Republic of Iran, Japan, Malaysia, Singapore, Laos, Cambodia, Philippines and India.

Hookworm disease

In Viet Nam, the hookworm infection rate of was 30–85% in the north and 47–68% in the south, most of them being *Necator americanus* (95–98% of cases). Country-wide distribution in India was 28.9–43%. Cases have been reported in China, Korea and Japan. Significance of foodborne transmission of hookworms in Asia is not known.

Toxocariasis

In India, it is endemic in the northern states, up to 33% in Kashmir and with seropositivity of 6–23% in other northern states. In Viet Nam, one case report indicated hundreds of cases. In Japan, some cases have been reported. Foodborne attribution is not known.

Trichuriasis

In Viet Nam, distribution of trichuriasis is as wide as ascariasis, with a prevalence rate of 0.5–89% in surveys, with the infection rate in the north higher than in the south. In Thailand prevalence was 70%, and in Laos it was 41.5%.

A8.2.3 Risk management strategies

The strategies for control of foodborne parasites are combination of the regulation of an entire food chain from production to consumption. They also include creation of consumer perception and agri-food trade regulation. For some foodborne parasitic diseases, food habits of eating raw materials (e.g. freshwater fish) are the primary cause of endemicity and national, regional, and local activities to increase public awareness are essential. However, these diseases are mostly local and consequently not addressed as part of the meeting.

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TABLE A8.2.1 Data availability on the burden of disease and food attribution at the regional and global level for Asia

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	Disease severity/ main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Main food sources and attributions
Ancylostoma duodenale, Necator americanus	Yes [92, 126–129] Viet Nam: – all country (3–85%) China, Korea, Japan India – countrywide (28.9–43%)	Yes [127–129] Anaemia	Yes [92, 126–129] Vegetables, soil	No data	No data	Vegetables, soil
Angiostrongylus spp.	Yes [24, 121–123] Thailand –484 cases reported from 1965 to 1968 China – 160 Cases reported in many areas Viet Nam – >60 cases reported in many areas Japan – 54 cases reported India – one case report	Yes	Yes [24, 121] Snails, vegetables	Yes	Yes	Snails/ vegetables
Anisakis simplex	Yes [79] Japan a case reported China – cases reported Not reported in India	No data	Yes [79] Marine fish	No data	No data	Yes Fish
Ascaris lumbricoides	Yes [59, 92, 112, 126, 128, 144] Viet Nam – countrywide (5–95%) Japan – 8.2% in 1956 China – 47% India – countrywide (commonest intestinal helminth) – 28.4–68.3%	Yes [112, 144] Intestinal obstruction, mostly in children	Yes [112, 144] Poor sanitation and hygiene	No data	No data	Vegetables, food transmision
Capillaria philippinensis	Yes [45, 65] Cases reported in Philippines, Japan, Thailand, Taiwan, Indonesia; India – 3 case reports till 2012	Yes [65] Diarrhoea, liver dysfunction	Yes Raw fish			Fish

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	**Disease severity/ main populations at risk**	**Main food source and attribution**	**Disease in humans**	**Disease severity/ main populations at risk**	**Main food sources and attributions**
Clonorchis sinensis	Yes [24, 46, 48–52] China – 15 million Korea – 2 million infected, prevalence of 1.4–21.0% Japan – prevalence of 1.0–54.2% (1960); 10.9–66% (1961); now almost disappeared Viet Nam – prevalence of 19.5% (0.2–40%) in 15/64 provinces in the north Taiwan – prevalence of 10–20% China – 15 million infected in 27 provinces India – Almost absent. Very few case reports	Yes [46, 48, 51, 52] 601 million Acute disease	Yes [48, 50] Raw & under-cooked fish.	Yes [46, 47]	Yes [46] 601 million	Raw & under-cooked fish (freshwater)
Cryptosporidium spp	Yes [92, 95] Viet Nam – 2.8% and case reported (national) India – 18.9% in children with diarrhoea Japan – case reported China – 1.36–13.3%	No data [95]	Yes [92–94] Vegetables, water raw meat (*yukke*)	No data [91]	No data [91]	Yes [91] Water, vege-tables HIV-related
Diphyllobothrium spp.	Yes [81–87] Cases reported of *D. nihonkaiense, D. latum, D. pacificum, D. cameroni, D. yonagoense* in Japan Few cases of *D. latum* reported from south India	Yes [81, 82]	Yes [81–87]	No data	No data	No data
Diplogonoporus bala-enopterae	Yes [66, 89] Case reported in Japan Not reported in India, Viet Nam or Thailand	Yes [66, 89]	Yes [89]	No data	No data	No data
Echinococcus spp.	Yes [59, 135–140] Cases reported in Japan, China (380 000 cases), Korea, Mongolia, Thailand, Bangladesh, Nepal India – prevalence not clearly known; endemic in both rural and urban areas of southern and central states.	Yes	Yes vegetables	No data	No data	Vegetables
Echinostoma spp	Yes [73–75] Japan – 22.4% Thailand – 0.04–55.3% China – 1.5–20.1% Viet Nam – a case reported India – very rare; very few case reports	Yes	Yes [73] Raw snail & fish	No data	No data	Yes Snail; fish

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	Disease severity/ main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Main food sources and attributions
Entamoeba histolytica	Yes [92, 148–152] Viet Nam – 2–6% in children India – intestinal amoebiasis with E. histolytica or E. dispar (1–58%); intestinal amoebiasis with proven E. histolytica (34.6% of all samples found +ve E. histolytica or E. dispar); extra-intestinal amoebiasis – amoebic liver abscess (3–9% of all the cases of intestinal amoebiasis)	Yes	No data	No data	No data	Vegetables, water, food transmission
Enterobius vermicularis	Yes [92, 111, 112, 157] Viet Nam – 29–43% in the north; 7.5–50% in the centre; 16–47% in the south; 51.2% in children 1–5 years old India – countrywide in children (0.5–12.6%); more common in rural than urban areas	Yes	Yes [111, 112] Over-crowding	No data	No data	
Fasciola spp	Yes [79, 92. 96, 99] Viet Nam – >20 000 cases from 52/64 provinces Cases reported in China (148 cases), Thailand, Korea, Iran, Japan, Malaysia, Singapore, Laos, Cambodia & Philippines India – A few case reports	No data	Yes [79, 92, 96] Water, raw vegetables	No data	No data	Yes [79] water, vegetables
Fasciolopsis buski	Yes [73, 92, 102, 103] Viet Nam – 0.5–3.8% in 16/64 provinces China – 10.2–92.9% in some areas Thailand – 10% in children with intestinal parasites Cases reported in Taiwan, Cambodia, Laos PDR, Malaysia, Indonesia & Myanmar India – endemic in E & NE states – prevalence of 0–22.4%	Yes [102] Abdominal pain, diarrhoea, intestinal obstruction	Yes [73, 92, 102] Water, raw vegetables	No data	No data	Water, raw vegetables

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	Disease severity/ main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Main food sources and attributions
Giardia duodenalis (syn. *G. lamblia*, *G. intestinalis*)	Yes [92, 110, 154] Viet Nam – 1–10% China – infection rate ranged from 8.67%–9.07%, found in 13 areas of 35 cities at the provincial level India – countrywide distribution (8.4–53.8%)	Yes [110, 154]	No data	No data	No data	Vegetables, water, food transmission
Gnathostoma spp	Yes [70–72, 90] Cases reported in Japan with 3 225 cases, including 86 from China and 34 from other Asian sources. Cases reported in China, Thailand, Viet Nam, India, Laos PDR, Myanmar, Cambodia, Bangladesh, Malaysia, Indonesia and Philippines. India – 14 cases reported until 2012	Yes [71, 72] Ocular and cerebral manifestations	Yes [70] Raw fish, amphibian reptile			Fish, amphibian reptile
Heterophyids	Yes [53–55] Thailand – 0.3–7.8% Viet Nam – 0.5–64.4% in >18 provinces China – 1–2% Japan – 11% India – Not yet reported	Yes [55]	Yes [53, 55] Raw fish dishes	Yes	Yes	Raw Fish
Kudoa septempunctata	No data Not reported in India	Yes Acute and self-limiting	Yes [88] Raw flat fish (Paralichthys olivaceus) 100% food-borne transmission	No data	No data	Yes Fish; food-borne transmission
Metagonimus spp.	Yes [57, 76, 78] Many cases reported in Korea & China India – very rare. Very few case reports of Metagonimus yokogawai	Yes [76, 78] Acute diarrhoea	Yes [76, 78] Undercooked freshwater fish	No data	No data	Yes Fish

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	Disease severity/ main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Main food sources and attributions
Opisthorchis viverrini	Yes [42, 44, 45] Thailand – 15.7% Lao PDR – 37–86% Cambodia – some cases Viet Nam – 1.4–37.9% in 9/64 provinces in the south. Malaysia – a case reported India – No cases yet reported.	Yes [42, 44] 67 million	Yes [42, 44] Raw fish dish	Yes [43] 10 million	Yes [43] 67 million	Yes [42] Koi pla; Lap pla; Pla som; Raw-fish
Paragonimus spp.	Yes [56–62] Thailand – cases reported in 23/68 provinces Viet Nam – 0.5–15% in 10/64 provinces Japan – case reports with >200 cases Philippines – 27.2–40% in some areas China – 4.1–5.1% in 24 provinces India – endemic to NE states (Manipur, Nagaland and Arunachal Pradesh); Paragonimus heterotremus is the common species; up to 50% seroprevalence in these regions.	Yes [60–62] Cough, dyspnoea, recurrent haem-optysis	Yes [56, 60–62] Raw crab; freshwater crab, wild boar meat in Japan	Yes	Yes	Freshwater crab; wild boar meat [56]
Pseudoterranova decipiense	Yes [79] Case reported in Japan Not reported in India	No data	Yes [79] Marine fish	No data	No data	Yes Fish
Sarcocystis fayeri	Yes Case reported in Japan [158]	Yes [158] Acute and self-limited	Yes [158] Raw horse meat 100% food-borne			
Sarcocystis spp.	Yes [1, 2, 4, 6] Thailand (1.5%) India – 11 case reports from 1990 to 2004. A few earlier reports. China (29.7%) 46 cases reported by 1990 in Asia, including China, Malaysia and India. In Malaysia, 19.7% of 243 persons had antibodies to Sarcocystis	No data	Yes [2,–4, 6] Meat (pork and beef) Raw pork muscle and offal	No data	No data	Yes Meat (pork and beef)

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	Disease severity/ main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Main food sources and attributions
Spirometra erinacei-europaei (sparganosis)	Yes [66–69] Japan – case reported Viet Nam – case reported India – a few case reports	Yes [66–69] Abdominal, cerebral & ocular manifes-tations	No data	No data	No data	Frog
Taenia spp.	Yes [8, 10–19] Thailand – Taeniasis (0.6–5.9%) & cysticercosis (4%). Viet Nam – Taeniasis (0.5–12%) & cysticercosis (7%) in more than 50/64 provinces. Japan – cysticercosis 446 cases up to 2004. China – 7 million people infected in 29 provinces. Philippines – Taeniasis (0.56–10.26%) & case reported of cysticercosis. Indonesia – Taeniasis (0.56–10.26%) & case reported of cysticercosis. Bangladesh – case reported. Nepal – Taeniasis (43%) & case reported of cysticercosis. India – T. solium Taeniasis prevalence 18.6%; NCC prevalence in asymptomatic individuals 15.1%; NCC prevalence in active epileptics 26.3–56.8%; T. saginata Taeniasis prevalence 5.3%.	Yes [13, 17] Taeniasis – No NCC – Yes Epilepsy	Meat (pork & beef)	Yes [9] DALY: 2–5 ×106	Yes [9]	Beef, pork, pig viscera [9]
Toxocara spp.	Yes [92, 126. 132, 133] Viet Nam – one case report Japan – one case report India – endemic in northern states; up to 33% in Kashmir; seropositivity of 6–23% in other northern states	Yes [133]	Yes [133] Vegetables, food trans-mission	No data	No data	Vegetables

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	Disease severity/ main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Main food sources and attributions
Toxoplasma gondii	Yes [30, 31, 33–41] Thailand – 2.6% China – 12-45% and 12.7–15.1% Viet Nam – some cases reported Sri Lanka – 27.5% Japan – 1.8–5.6% Malaysia – 10–50% Nepal – 45.6% India – seropositivity for IgG in general population – 10.8–51.8% and for IgM – 2–5%; in females with bad obstetric history – IgG was 49.5%; in HIV-infected cases seropositivity for IgG 70%.	Yes [33, 36–38] CNS disease in HIV infected	Raw meat, pork, chicken, fruit, vegetables [30]	Yes [32]	Yes [32]	Yes [30, 32] Beef, pork, goat, horse, sheep, chicken; contaminated fruit & vegetables; raw mussels, clams & oysters
Trichinella spiralis	Yes [20–28] Thailand – 0.9–9% Viet Nam – 5 outbreaks in north mountainous provinces, with >100 patients and 8 deaths up to 2012. China – >500 outbreaks in 12/34 provinces, with 25 685 persons affected (241 deaths). Japan – 1 case reported. India – very few case reports. Recently a point source outbreak of 42 cases.	Yes [25, 27] High mortality	Yes [21, 26, 27, 29] Meat; consumption of inadequately cooked wild boar meat	Yes [21, 26, 29]	Yes [21, 26, 29]	Yes [21, 26, 29] Domestic pigs, wild boar, raw horse meat 100% foodborne transmission
Trichuris trichiura	Yes [105, 108–112] Thailand – 70% Laos PDR – 41.5% Viet Nam – 70–80% in the north and 5–10% in the south India – adults 2–6.6%; children 8–26.4%	Yes [106–109] Rectal prolapse	Yes Vegetable, personal hygiene	Yes	Yes [107] For 2010, global population at risk: 5023.3 (millions)	Foodborne

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TABLE A8.2.2 Data availability for parasite prevalence or concentration in the main food categories for Asia

NOTE: Please read table in close association with Table A8.2.1. Game could include fish as sources are unclear.

Ancylostoma duodenale, Necator americanus	
Game	Yes. Viet Nam – country-wide (3–85%); China, Korea, Japan.
Vegetables	Yes
Other	Yes [22] Vegetables, soils contact, walking barefoot on soil.
***Angiostrongylus* spp.**	
Game	Yes. Thailand – 484 cases from 1965 to 1968; China – cases reported in many areas; Viet Nam – >50 cases in many areas; Japan – event reported with 54 cases.
Other	Yes [13] Snails, vegetables, raw frogs.
Anisakis simplex	
Beef	Yes [17]
Pork	Yes [17]
Game	Yes. Case reported.
Other	Yes. Marine fish.
Ascaris lumbricoides	
Game	Yes. Viet Nam – country-wide (5–95%); Japan – 8.2% in 1956.
Vegetables	Yes. Vegetables, improperly washed vegetables.
Other	Yes [24, 25] Vegetables, food transmision.
Capillaria philippinensis	
Game	Yes. Cases reported in Philippines, Japan, Thailand, Taiwan, Indonesia.
Other	Fish [14] Undercooked freshwater fish.
Clonorchis sinensis	
Game	Yes. China – 35 million; Korea – 2 million infected, prevalence of 1.4–21.0%; Japan – prevalence of 1.0–54.2% (1960) & 10.9–66% (1961); Viet Nam – prevalence of 19.5% (0.2–40%) in 15/64 provinces in the north; Taiwan – prevalence of 10–20%.
Other	Yes [3, 4] Fish.
***Cryptosporidium* spp.**	
Pork	Yes.
Game	Yes. Viet Nam – 2.8% prevalence and case reported (national); India – 18.9% found in children with; Japan – case reported.
Fruits	Yes [8]
Vegetables	Yes [8] Grown in contact with soil
Other	Yes [8] Water; vetgetables; HIV-related. Water contaminated with human & animal excreta.
***Echinococcus* spp.**	
Game	Yes. Cases reported in Japan, China, Korea, Mongolia, Thailand, Bangladesh, Nepal, India
Vegetables	Yes. Vegetables, but very little data.
Other	Yes [28] Vegetables, water and food contaminated with infected dog faeces, fingers as fomites on contact with dogs.

***Echinostoma* spp.**	
Game	Yes. Japan – 22.4%; Thailand – 0.04–55.3%; China – 1.5–20.1%; Japan – 22.4%.
Other	Yes [18] Undercooked snails & freshwater fish.
Entamoeba histolytica	
Game	Yes. Viet Nam – 2-6% in children.
Vegetables	Yes [26] Improperly washed vegetables.
Other	Yes [26] Food transmision, food contaminated with human faeces.
***Fasciola* spp.**	
Pork	Yes. Water, raw vegetables.
Game	Yes. Viet Nam – >20 000 cases from 52/64 provinces; Cases reported in China, Thailand, Korea, Iran, Japan, Malaysia, Singapore, Laos, Cambodia, Philippines.
Vegetables	Yes. Vegetables.
Other	Yes [20] Water, vegetables, aquatic plants, watercress.
Fasciolopsis buski	
Dairy	Yes
Game	Viet Nam – 0.5–3.8% in 16/64 provinces; China – 10.2–92.9% in some areas; Thailand: 10% in children with intestinal parasites; Cases reported in Taiwan, Cambodia, Laos, Malaysia, Indonesia, Myanmar, India.
Vegetables	Yes. vegetables; vegetables from aquatic plants.
Other	Yes [21] Water, vegetables, aquatic vegetation.
Giardia duodenalis (syn. G. lamblia, G. intestinalis)	
Game	Yes. Viet Nam – 1–10%.
Vegetables	Yes [27] Vegetables, improperly washed vegetables.
Other	Yes [27] Vegetables, food transmision, food contaminated with human faeces.
***Gnathostoma* spp.**	
Game	Yes. Case reports from Japan (3225 cases including 86 in China and 34 in other Asian areas); Cases reported in China, Thailand, Viet Nam, India, Laos PDR, Myanmar, Cambodia, Bangladesh, Malaysia, Indonesia, Philippines.
Other	Fish & amphibian reptiles. [16] Raw or undercooked freshwater fish, amphibians, birds and mammals.
Heterophyids	
Game	Yes. Thailand – 0.3–7.8%; Viet Nam – 0.5–64.4% in >18 provinces; China – 1–2%; Japan – 11%.
Other	Yes. Fish.
***Metagonimus* spp.**	
Game	Cases reported in Korea and Japan.
Other	Yes [19] Fish, undercooked freshwater fish.
Opisthorchis viverrini	
Game	Thailand – 15.7%; Lao PDR – 37–86%; Cambodia – some cases; Viet Nam – 1.4–37.9% in 9/64 provinces in south.
Other	Yes. Fish.

***Paragonimus* spp.**	
Game	Yes. Thailand – reported in 23/68 provinces; Viet Nam – 0.5–15% in 10/64 provinces; Japan – >200 cases reported; Philippines – 27.2–40% in some areas.
Other	Yes [9] Raw freshwater crab. Almost all Potamiscus manipurensis crabs found in streams in Nagaland contained metacercariae.
***Sarcocystis* spp.**	
Beef	Yes [6]
Pork	Yes [7] Raw muscle and offal.
Game	Yes. Thailand – 1.5%.
Other	Yes [6, 7] Meat (pork, beef); wild boar.
Spirometra erinaceieuropaei	
Beef	Yes. Japan – case reported; Viet Nam – case reported.
Other	Frog [15] Drinking water with infected copepods; raw frog.
***Taenia* spp.**	
Beef	Yes.
Pork	Yes [5] 7–20% of slaughtered pigs have cysticerci in their muscles.
Game	Yes. Thailand – 06–3.4%; Viet Nam – 0.5–12% in >50/64 provinces.
Vegetables	Improperly washed vegetables eaten raw in salads.
Other	Yes. Pork, beef.
Toxoplasma gondii	
Beef	Yes [11, 12]
Dairy	Yes [11, 12]
Pork	Yes [11, 12] Raw pork.
Poultry	Yes [11, 12]
Game	Yes. Thailand – 2.6%; China – 12–45%; Viet Nam – some cases reported; Sri Lanka – 27.5%; Japan – 1.8–5.6%; Malaysia – 10–50%; Nepal – 45.6%.
Other	Yes. Beef, pork, goat, horse, sheep, chicken; contaminated fruit, vegetables; raw mussels, clams, oysters.
Trichinella spiralis	
Beef	Yes [1]
Pork	Yes. Raw or undercooked.
Game	Thailand – 0.9–9%; Viet Nam – 5 outbreaks with over 100 cases (8 deaths); China – >500 outbreaks in 12/34 provinces, with 25 685 persons affected (241 deaths).
Other	Yes [2] Under-cooked wild boar meat.
Trichuris trichiura	
Game	Yes. Vegetables, personal hygiene.
Other	Yes [10] Drinking water contaminated with human faeces.
***Toxocara* spp.**	
Game	Yes. Viet Nam – case reported; Japan – case reported.
Vegetables	Yes. Vegetables, improperly washed vegetables.
Other	Yes [23] Vegetables, food transmision.

Sources used for Table A8.2.2, but read in conjunction with references cited in the main text and in Table A8.2.1

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TABLE A8.2.3 Data availability for risk management options for each parasite-commodity combination in the Asia context.

NOTE: The authors were asked to consider all combinations of the particular parasite and the main food categories, namely Beef, Dairy, Pork, Poultry, Game, Seafood, Fruit, Vegetables and Other.

***Angiostrongylus* spp.**	
Other	Yes [18] Proper cooking of frogs and snails
Ancylostoma duodenale, Necator americanus	
Other	Yes [28] Hookworm larvae were in areas 2.1–5.2% on vegetables. Vegetables & food transmission, so use sanitary disposal of human excreta; avoid walking barefoot.
Anisakis simplex	
All	No substantive data found.
Ascaris lumbricoides	
Vegetables	Yes. *Ascaris* eggs were in areas reported as 2.1–2.7% in vegetables.
Other	Yes [30] Vegetables & food transmission; hand washing; washing of vegetables before consumption; proper sanitation.
Capillaria philippinensis	
Other	Yes [19] Proper cooking of freshwater fish.
Clonorchis sinensis	
Dairy	Very little data [4]
Game	Yes [4] Viet Nam – 44.4–92.9% freshwater fish infected by Clonorchis sinensis larvae.
Other	Yes. Proper cooking of freshwater fish.
***Cryptosporidium* spp.**	
Beef	Yes [11]
Other	Yes. Vegetables, food, water transmission; hand washing, boiling or filtration of drinking water
***Echinococcus* spp.** [34]	

Vegetables	Yes.
Other	Yes [34] Proper care of pet dogs; avoid close contact with stray dogs; hand washing; thorough washing of vegetables before consumption.
***Echinostoma* spp.** [23]	
Other	Proper cooking of freshwater snails.
***Fasciola* spp.**	
Other	Yes [25, 26] *Fasciola* larvae in areas reportedly 0.4% in vegetables. Avoid eating uncleaned aquatic plants and vegetables.
Fasciolopsis buski	
Other	Yes [27] Avoid eating uncleaned aquatic plants and vegetables.
Entamoeba histolytica	
Game	Yes.
Vegetables	Yes. *E. histolytica* cysts in areas reportedly 1.8–6.7% in vegetables.
Other	Yes [31] Vegetables & food; water transmission; hand washing; thorough washing of vegetables before consumption; proper sanitation.
***Giardia duodenalis* (syn. *G. lamblia, G. intestinalis*)**	
Game	Yes.
Vegetables	Yes. *Giardia* cysts were in areas reportedly 2.7–13.9% in vegetables.
Other	Yes [32, 33] Vegetables & food; water transmission; hand washing; thorough washing of vegetables before consumption; proper sanitation.
***Gnathostoma* spp.**	
Game	Yes. *Gnathostoma* larvae were in areas reportedly 6.7–11.4% in eels.
Other	Yes [22] Fish, eel, amphibians. Proper cooking of freshwater fish & frogs.
Heterophyids	
Game	Yes [12] Heterophyid larvae 7.4–62.8% in various fish species.
Other	Yes. Fish.
***Metagonimus* spp.**	
Other	Yes [24] Proper cooking of freshwater fish.
Opisthorchis viverrini	
Game	Yes [4] Viet Nam – 10–29% freshwater fish infected by O. viverrini.
Other	Yes. Fish.
***Paragonimus* spp.** [13]	
Pork	Yes. Wild boar meat.
Game	Viet Nam – rate of *Paragonimus* larvae was 9.7% to 98.1% in *Potamicus* crab.
Other	Yes [14] Freshwater crab, wild boar meat – proper cooking of crabs.
***Sarcocystis* spp.**	
Pork	Yes [9] Proper cooking.
Other	Yes. Proper cooking of wild boar meat.
Spirometra erinaceieuropaei	
Game	Yes. 8–10% frogs reportedlt infected by *S. erinaceieuropaei* larvae.
Other	Yes [21] Frogs & amphibians; boiling or filtration of drinking water; Yes [17] Proper cooking. Proper cooking of frogs
***Taenia* spp.** [6]	
Beef	Yes [7, 8] Discard infected meat in abattoir; proper cooking.

Pork	Yes. Discard infected meat in abattoir; proper cooking.
Game	Yes. Viet Nam – 0.02–0.9% of pigs infected by T. solium larvae.
Vegetables	Yes. Proper washing before eating raw.
Other	Yes. Pork, beef.
***Toxocara* spp.** [15]	
Vegetables	Yes [29]
Other	Thorough washing of vegetables before consumption.
Toxoplasma gondii	
Beef	Yes [17] Proper cooking.
Dairy	Yes [17] Proper cooking.
Pork	Yes [17] Proper cooking.
Poultry	Yes [17] Proper cooking.
Trichinella spiralis	
Pork	Yes. Proper cooking
Game	Yes [1, 2] Viet Nam – 70–879 *Trichinella* larvae per gram pork; China – 0.06%–5.6% infected in pigs, 16.2% in dogs, 0.7% in cattle and 0.8% in sheep.
Other	Yes [3] Livestock meat – proper cooking.
Trichuris trichiura [15]	
Game	The rate of *Trichuris* eggs in vegetable was 1.8–2.4%.
Other	Yes [16] Vegetables, food transmission. Pit latrines and potable drinking water would reduce prevalence.

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ANNEX 8.3 – AUSTRALIA

A8.3.1 Preparation

The information for Australia was compiled by Dr Rebecca Traub, Senior Lecturer in Veterinary Public Health, School of Veterinary Sciences, The University of Queensland, Gatton. In developing this section of the report, Dr Traub used literature searches using PubMed (search terms used = "Parasite Name" + Australia) together with personal communications with experts in academia and the Department of Agriculture, Fisheries and Forestry (DAFF), Queensland Health, and Food Standards Australia.

A8.3.2 Data availability in humans and food attribution

Surveillance systems in place include the National Animal Health Information System (NAHIS) and National Notifiable Diseases Surveillance System (NNDSS), which collect, collate, analyse and report on data on animal and human health status. In general, information with regard to the incidence or burden of foodborne parasites in humans and animals in Australia is lacking, but is assumed to be negligible. Although limited, most data is generated from research-based surveys conducted by academic institutes, together with published hospital case reports. Surveillance (end product testing for foodborne parasites) is usually not considered necessary due to the low perceived risks to public health, based on:

- High standards of food safety and inspection practices that utilize a 'whole-of-chain' approach, which includes implementation of risk-based hazard analysis and HACCP. In addition to this, all exported food must comply with the Export Control (Prescribed Goods - General) Orders 2005, and the Export Control (Plants and Plant Products) Orders, 2005. Exporters must meet both the requirements of relevant export legislation and of any importing country requirements for the Australian Quarantine and Inspection Service (AQIS) to provide the necessary documentation to enable products to be exported.
- The dietary habits of most Australians, namely eating medium- to well-cooked meats.
- The absence of many of the foodborne parasites of public health concern in Australia (exotic pathogens).

Except for *Cryptosporidium*, no other foodborne parasites are listed in the human notifiable diseases list. For example, cystic hydatid disease in humans is no longer notifiable on a state or national level, despite its enzootic nature in rural settings. Many of the fish- and plant-borne parasites (e.g. Anisakiasis, plant- or vector-borne protozoa and helminth infections) may be missed unless an 'obvious outbreak' has been detected and reported to the State Public Health Unit. Primary means of surveillance of foodborne parasites are performed through abattoirs due to export certification requirements, such as data on the incidence of suspect *Cysticercus bovis* lesions in beef and *Trichinella* in game meat, and exports would be well documented.

TABLE A8.3.1 Data availability on the burden of disease and food attribution at the regional and global level for Australia

Parasite species	Data availability on human-disease-related parameters					
	Regional level			Global level		
	Disease in humans?	Disease severity and main population(s) at risk	Main food source and attribution	Disease in humans?	Disease severity and main populations at risk	Main food sources and attributions
Angiostrongylus cantonensis	Yes – qualitative – case reports [21]	Yes – qualitative – case reports [21]	Yes – anecdotal from case history [21]			
Anisakis spp.; *Contracaecum* spp.	Yes [12]	No data	Yes [13] Yellow eye mullet, tiger flathead, sea mullet, King George whiting, bream, sand flathead, pilchard			
Cryptosporidium spp. (including *C. hominis* and *C. parvum*)	Yes [22]	Yes [22]	Yes. Most outbreaks water-borne recreational swimming. Other sporadic outbreaks 'Unknown' source [22]			
Echinococcus granulosus	Yes – retrospective hospital cases. Not notifiable since 2000 [19]	Yes	Yes – quantitative data on prevalence in wild and farm dogs [20] No attribution to food.			
Enteric protozoa *Giardia*, *Cyclospora*, *Blastocystis*, *Dientamoeba fragilis*, *Isospora belli*	No data	Yes Indigenous Australians [23] Immuno-suppressed HIV/AIDs patients [24]	No data			
Enteric helminths; *Ascaris*; *Trichuris;* hookworms	No data	Yes Indigenous Australians [23]	No data			
Spirometra or sparganosis	No data	No data	Wild boar, snake			
Taenia saginata	No data	No data	Beef – 100% meat-borne [11]			Cattle – 100% foodborne

Parasite species	Data availability on human-disease-related parameters					
	Regional level			Global level		
	Disease in humans?	Disease severity and main population(s) at risk	Main food source and attribution	Disease in humans?	Disease severity and main populations at risk	Main food sources and attributions
Toxoplasma gondii	0.6% posterior uveitis – Aboriginal Australians [14] 3.5% of encephalitis hospitalizations; down since 1990s (HIV peak) [15] 2 reported outbreaks (raw lamb and kangaroo) [16]	No data	Yes – quantitative serological data [17] Kangaroo meat; lamb (sheep); pigs [16, 18]			
Trichinella papuae in Torres Strait Islands	Yes – qualitative anecdotal reports[1, 2]	No data	Wild boar (*Sus scrofa*) [3] Imported crocodile meat from PNG 4]	Yes [5, 6]	Yes [5, 7]	Domestic and wild boar [5] Crocodile meat, turtle meat [8] 100% foodborne
Trichinella pseudospiralis – Tasmania	No data	No data	Dasyurids (quolls; Tasmanian devil,) and carrion-feeding birds (marsh harrier, masked owl) [9] Purely sylvatic cycle	Yes [6, 10]	Yes [7, 10]	Domestic and wild boar [9] 100% foodborne

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TABLE A8.3.2 Data availability for Australia for parasite prevalence or concentration in the main food categories

Angiostrongylus cantonensis	
Other	No direct data. Some snail surveys. Anecdotal evidence of increase in incidence in domestic pets and wildlife in urban areas of Brisbane and Sydney. Human case reported from ingesting slugs while intoxicated [1]
***Anisakis* spp., *Contracaecum* spp.**	
Seafood	Little data. Prevalence in Yellow eye mullet, flathead, sea mullet, King George Whiting, Bream, sand flathead, pilchard described and endemic off coastal Australia. Most larvae in viscera post-harvest and not muscle [2, 3].
Other	Yes. Wild caught and commercial fish at post-harvest level.
***Cryptosporidium* spp. (including *C. hominis* and *C. parvum*)**	
Beef	Yes
Dairy	Yes
Pork	No data
Game	No data
Seafood	Yes [4]. Reported *Cryptosporidium* oocyst contamination of some high-risk foods.

Fruits	Yes [4]. Reported *Cryptosporidium* oocyst contamination of some high-risk foods.
Vegetables	Yes [4]. Reported *Cryptosporidium* oocyst contamination of some high-risk foods.
Other	Goat meat (India)
Echinococcus granulosus	
Vegetables	No data
Other	No direct data. Abattoir reports suggest hydatid disease is still highly endemic among livestock. Prevalence studies in dogs, esp. in rural areas, also demonstrate high prevalence among farm dogs [5, 6]
Enteric helminths: *Ascaris, Trichuris,* Hookworms	
Fruits	No data
Vegetables	No data
Enteric protozoa: *Giardia, Cyclospora, Blastocystis, Dientamoeba fragilis, Isospora belli*	
Fruits	No data
Vegetables	No data
***Spirometra erinacei* or sparganosis** Quantitative data may be obtained from Biosecurity Queensland records. Endemic in tropics, esp. wild boar, native frogs, feral cats, dogs.	
Pork	No data
Game	No data
Other	Wild boar Northern Australian Quarantine Strategy (NAQS) surveys
***Taenia saginata* or bovine cysticercosis**	
Beef	Incidence estimated to be less than 1 in 500 000 head according to a recent national survey [7]. However sporadic cases or outbreaks, although rare, are known to occur and have subsequently been confirmed as *C. bovis* [8, 9].
Toxoplasma gondii	
Beef	Yes [10]. Most cited references in report from 1975 and 1980s.
Dairy	Yes [10]. Most cited references in report from 1975 and 1980s.
Pork	Yes [10]. Most cited references in report from 1975 and 1980s.
Poultry	Yes [10]. Most cited references in report from 1975 and 1980s.
Game	Yes [10]. Most cited references in report from 1975 and 1980s.
Fruits	No data
Vegetables	No data
Other	Pademelons, wallabies, lamb. 15.5% kangaroos from WA positive by ELISA [11].
Trichinella papuae, T. pseudospiralis	
Pork	No data

Poultry	No data
Game	Yes. All horse, crocodile and wild pig exported to EU from mainland Australia undergoes pooled Artificial Digestion technique (AD). To date no larvae detected on mainland. Recent research-based survey using AD and polymerase chain reaction (PCR) detected 2 pigs positive for larvae/DNA of *T. papuae* on a remote island of the Torres Strait [15]. Moreover, recent serological evidence for *Trichinella* on mainland [12, 14].
Other [14]	Foxes and wild dogs on mainland. Tasmanian quolls, possums, raptoral birds [19, 20]. Limited indicator species testing on mainland (200 rats; 60 foxes, 31 wild dogs, 9 cats, 27 quolls) tested by AD, all negative [16–18].

Sources used for Table A8.3.2

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A8.3.3 Agri-food trade

Foodborne parasites that currently have implications for the meat industry in terms of extra costs associated with inspection and testing are primarily restricted to *C. bovis* in the domestic and exported beef industry, and *Trichinella* testing of game meat (farmed crocodile, wild boar and horses) destined for the EU. However, for example, were anisakidosis to become an emerging public health problem in Australia, the fish industry would have to bear the costs of additional end-product inspection (e.g. candling, pooled PCR) to certify high-risk marine species safe for consumption.

Bovine cysticercosis

Although rare, sporadic cases of *C. bovis* continue to be reported in the beef industry. Carcasses heavily positive for suspect *C. bovis* lesions are condemned, whereas those with low levels of infection are excluded from the export chain. Any visible lesions are trimmed at boning under veterinary supervision, freeze certified and sold on the domestic market. At present the abattoirs (industry) bear the cost of positively inspected carcasses. There is a move to reform this and place more cost and responsibility on the farmer by bringing in on-plant monitoring schemes that feed back to the farm level, providing incentive for modification or improvements in farm management. Given the low incidence of bovine cysticercosis and poor positive predictive value of organoleptic inspection, a risk-based system for inspecting *C. bovis* is being proposed and reviewed (Webber *et al.*, 2012).

Trichinella spp.

At present, game meat (wild boar, horse, crocodile) destined for the EU (primary consumers) is required to undergo pooled artificial digestion and examination for *Trichinella* larvae, and results in a direct cost to the game meat industry. To date, testing of ~3.2 million wild boars and 300 000 horses over 22 years has yielded no *Trichinella*-positive carcasses. However, wildlife surveys in indicator species (foxes, feral cats, crocodiles, turtles and wild boar in high-risk areas, e.g. northern Queensland, are limited. Detection of *Trichinella* on mainland Australia will most likely have most impact on the domestic pork industry in relation to more intensive pre-harvest control measures required to meet domestic and overseas certification of pig farms as *Trichinella*-free. At present, domestic pork exported is freeze-certified for *Trichinella*.

A8.3.4 Consumer perception

Consumer perception is difficult to assess and is largely dependent on approaches taken by the media and government in the form of risk communication to the public in the case of an 'outbreak' or discovery of a previously 'exotic' or 'undetected' foodborne parasite. At present, Australians are generally aware of governmental responsible for regulating the quality and safety of food, and consumers display considerable trust in government (and farmers) to protect food safety. There is little evidence of the politicization of food, reflecting a level of trust in the Australian food governance system that may arise from a lack of exposure to major food scares. Consumers tend to be more critical of the role of the food industry in food safety, believing that profit motives will undermine effective food regulation. Most Australians would associate foodborne illness with 'take-away' foods from retail outlets or a problem associated with overseas travel. Consumers usually perceive the risk of 'parasites' in game meats like kangaroos and feral pigs higher than traditional meats. Australians are generally aware of personal responsibility for food safety practices (Henderson, Coveney and Ward, 2010). Consumers (public) in overseas markets are likely to have a similar level of 'trust' in foods exported from Australia.

A8.3.5 Social sensitivity

If an 'outbreak' of a foodborne parasitic disease due to non-compliance with current food safety regulations or due to consumers harvesting their own food sources (in the case of home-grown vegetables, home-made fish sashimi or undercooked foods, hunted feral pig or crocodile meat, etc.) should occur, this has the potential to lead to a substantial decline in the level of consumer trust placed in the food safety management system of Australia. This will have significant repercussions on the industry in some cases (e.g. outbreak of anisakiasis may lead to loss of business for Japanese restaurants or sea-food retailers). An outbreak of trichinellosis may have similar consequences, but to a lesser extent as the public is more likely to associate the pathogen with consumption of self-butchered game meat rather than commercially supplied meats.

A8.3.6 Risk management

Data are summarized in Table A8.3.3.

A8.3.7 Sources cited in the discussion

Henderson, J.A.B., Coveney, J.A. & Ward, P.A. 2010. Who regulates food? Australians' perceptions of responsibility for food safety. *Australian Journal of Primary Health,* 16(4): 344–351.

Webber, J.J., Dobrenov, B., Lloyd, J. & Jordan, D. 2012. Meat inspection in the Australian red-meat industries: past, present and future. *Australian Veterinary Journal*, 90(9): 363–369.

TABLE A8.3.3 Data availability for risk management options for each of parasite-commodity combinations for Australia.

NOTE: The authors were asked to consider all combinations of the particular parasite and the main food categories, namely Beef, Dairy, Pork, Poultry, Game, Seafood, Fruit, Vegetables and Other.

Angiostrongylus cantonensis	
Fruits	No data
Vegetables	No data
Other	No – snails
Anisakids	
Seafood	Little data. Extensive surveys performed for the Australian marine fish/anisakid species. No experimental studies to determine post-harvest migration or larvae for Australian species. Preliminary research surveys (see Table A8.3.1) indicate larvae primarily in viscera, current FSANZ food safety Standard 4.2.1[5] stipulates chilling (-1°C to 5°C or lower) post-harvest. All exported fish frozen to inactivate larvae.
***Cryptosporidium* spp. (including *C. hominis* and *C. parvum*)**	
Other	The prevalence or intensity of protozoa, helminth and cestode stages contaminating fresh produce along the production chain is not readily available. However, in general, risk is mitigated by producer obligations to follow standards outlined by the Codex Code of Hygienic Practice for Fresh Fruits and Vegetables.
Echinococcus granulosus	
Fruits	No data
Vegetables	No data
Enteric helminths	
No data.	

Enteric protozoa, including *Giardia, Cyclospora, Blastocystis, Dientamoeba fragilis* and *Isospora belli*	
No data.	
***Taenia saginata* or bovine cysticercosis**	
Beef	Yes [1, 2]. See also Table A8.3.1
Other	Low incidence and poor PPV of inspection of predilection sites – more emphasis on farm-level management to reduce risks.
Toxoplasma gondii	
Regionally, a risk profile [3] was conducted by New Zealand Food Safety Authority, based on outdated prevalence data for retail raw meats. Globally, the requirements for inactivation of tissue cysts in meat have been well studied and documented.	
Beef	Yes qualitative. Quantitative lacking on % positive retail meats with viable tissue cysts lacking.
Dairy	Food Standards Australia New Zealand (FSANZ) Standard 4.2.4 – Primary Production and Processing Standard for Dairy Products
Pork	Yes qualitative. Quantitative lacking on % positive retail meats with viable tissue cysts lacking
Poultry	Yes qualitative. Quantitative lacking on % positive retail meats with viable tissue cysts lacking
Game	Yes qualitative. Quantitative lacking on % positive retail meats with viable tissue cysts lacking
Fruits	No data
Vegetables	No data
Trichinella papuae, T. pseudospiralis	
Pork	No data
Game	No extensive surveys in 'hot-spots' Experimental studies in pigs for *T. papuae* lacking to assess survivability, freeze tolerance
Other	No surveys on the mainland. A small-scale survey in feral pigs by Cuttell [4] (see Table A8.3.1) allowed a qualitative risk assessment to be attempted.

Sources cited in Table A8.3.3

01. **Pearse, B.H.G., Traub, R.J., Davis, A., Cobbold, R. & Vanderlinde, P.B.** 2010. Prevalence of *Cysticercus bovis* in Australian cattle. *Australian Veterinary Journal*, 88(7): 260–262;

02. **Webber, J.J., Dobrenov, B., Lloyd, J. & Jordan, D.** 2012. Meat inspection in the Australian red-meat industries: past, present and future. *Australian Veterinary Journal*, 90(9): 363–369.

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ANNEX 8.4 – EUROPE

A8.4.1 Preparation

The information was compiled by a group comprising Lucy Robertson, Norway (Group leader-*cum*-coordinator); Pascal Boireau, France; Joke van der Giessen, The Netherlands; Malcolm Kennedy, Scotland, UK; and Patrizia Rossi, Italy, although Patrizia was away during report writing, and thus contributed only information.

Communication among the group members was largely by e-mail, and the final version (following inclusion of comments on and modifications to the draft) was submitted on 20 August.

The different group members used their own approaches to data gathering, accessing:

- published scientific papers (identified using their knowledge and experience of the topic, coupled with appropriate database searches;
- national reports or risk assessments, or both;
- the European Union Reference Laboratory for Parasites (EURLP) in Rome (http://www.iss.it/crlp/),
- scientific reports submitted to European Food Safety Authority (EFSA);
- reports from World Organisation for Animal Health (OIE), World Health Organization (WHO), and European Centre for Disease Prevention and Control (ECDC);
- reports from EU research groups (e.g. MedVetNet, Echinorisk);
- Codex Alimentarius Commission reports; and
- books and book chapters.

A8.4.2 Data availability in humans and food attribution

Data from Europe is patchy. EFSA has had initiatives in which data concerned with meat-borne parasites (*Sarcocystis* spp., *Toxoplasma* spp., *Trichinella* spp., *Taenia solium* and *Taenia saginata*), *Echinococcus* spp. and fish-borne parasites (particularly *Anisakis simplex*) have been reported, including proposals for harmonized monitoring tools.

These reports give a relatively good overview of the data available in EU member states.

Although *Sarcocystis* spp. is probably widespread, the low public and zoonotic health impact means that *Sarcocystis* spp. should not be considered a parasite of major concern in Europe.

Data on distribution regarding *Taenia* spp. is patchy, but taeniosis and/or cysticercosis caused by *T. solium* in humans in Europe is considered rare.

Data on *Toxoplasma gondii* and *Trichinella* spp. is relatively good, particularly for the latter parasite and for *Toxoplasma* spp. if mandatory screening is in place; both, particularly *T. gondii* in high risk groups, are considered of importance.

Data on *Echinococcus* (*E. granulosus sensu lato* and *E. multilocularis*) are patchy; this is largely due to lack of notifications, diagnostic difficulties and uneven distribution of infection around Europe, although evidence suggests that *E. multilocularis* infection is spreading in foxes in Europe, resulting in greater infection risk in humans.

Data on infection with intestinal protozoa such as *Cryptosporidium, Giardia* and *Cyclospora* are patchy, being, relatively good in some places (e.g. United Kingdom), but poor in others, but whether sporadic infections are foodborne or not is usually impossible to ascertain; some outbreaks have been shown to be foodborne.

Data on infection with trematodes and nematodes is patchy unless associated with specific outbreaks.

It can be assumed that many foodborne parasitic infections in Europe are not diagnosed, due to non-specific symptoms, or, if they are diagnosed, foodborne transmission is not recognized, particularly for sporadic cases not associated with outbreaks.

A8.4. 3 Data on the burden of disease and food attribution

See Table A8.4.1.

A8.4.4 Data on parasite prevalence, incidence and concentration in the main food categories

The data are summarized in Table A8.4.2.

A8.4.5 Agri-food trade

Agri-food trade is affected when parasite contamination is found in imported products, particularly if: a) the imported parasite does not exist in the region previously and/or b) an outbreak of infection results.

Meat

Meat on the market must be free of *Trichinella* larvae, and metacestodes of *Taenia* and *Echinococcus*. Some countries also regulate against *Sarcocystis,* such as the

Italian requirement from 1992 for restaurants to freeze fishes to be served raw or undercooked. Meat inspection is used for metacestodes (and sarcocysts). For *Trichinella*, a specific lab analysis (digestion) is used. For the EU there are definitive regulations (EU legislation on the hygiene of foodstuffs). There is a meat inspection on target hosts. Only *Trichinella* needs a specific laboratory analysis. The cost and reliability of this analysis is important to take into account in the balance of cost vs benefit. Some one-third of European countries impose individual carcass control for *Trichinella* as a requirement for exportation. *Trichinella* "negligible risk" areas were defined in Europe to reduce the cost of individual carcass control. However, for trade in pig meat, countries ask for individual carcass control even from negligible risk areas. Currently, harmonized risk-based control strategies are evaluated by OIE, Codex and EU bodies. Exotic meats are also subject to these controls (e.g. crocodile meat and *T. zimbabwensis*).

Although *Toxoplasma* is a high risk in meat, it is so widespread that it does not affect the agri-food business at present. Currently, no specific regulations are in place to identify *Toxoplasma* in meat.

Seafood

There has been a significant increase in fish or seafoodborne parasitic diseases in Europe, caused either by infection following ingestion of viable parasites or as an allergenic reaction against parasite antigens (hypersensitivity). Due to modern cooking habits, there is a need to harmonize control measures for fish to decrease the risk of fish-borne parasites. In the EU, raw fish meant for human consumption (herring, salmon) should be frozen before consumption, but more and more raw or undercooked fish (which is unregulated for parasites) is being consumed nowadays.

In Europe, the most important fish parasites causing illness in humans are from the Anisakidae family, with 24 genera, although the species most commonly associated with human infection is *Anisakis simplex*, followed by *Pseudoterranova decipiens*. Nevertheless *A. simplex* is the primary instigator of the different forms of allergy, triggered by infection by live larvae. However, it is not known if this increase in parasitic disease has affected agri-food trade. Human outbreaks of *Opisthorchis* infection have been identified (e.g. Italy, the Netherlands), but it is not clear whether this has affected agri-food trade.

Fresh produce

Outbreaks associated with contaminated fresh produce may affect agri-food trade (as exemplified by the raspberries/*Cyclospora* impact on import to North America from Guatemala). Although there have been outbreaks of parasitic infection associated with imported fresh produce in Europe (e.g. in Sweden, *Cyclospora* on sugarsnap peas from Guatemala; *Cryptosporidium* on parsley from Italy), there do not appear to have been long-term effects on agri-food trade. Similarly, it is unclear whether outbreaks associated with local fresh-produce (e.g. *Fasciola* on watercress in France) have affected agri-food trade exports.

Conclusion

Important parasite-commodity combinations that could affect agri-food trade in Europe include: meat+*Trichinella*; meat+*Taenia*; meat+*Echincoccus*; fish+all parasites, including flukes; fresh produce+*Cryptosporidium*; fresh produce+*Cyclospora*; fresh produce+*Giardia*; and fresh produce+*Fasciola*. Current concern seems to be more for public health and food import than for trade and export. However, this situation is likely to change should an extensive outbreak be associated with an exported European food product.

A8.4.6 Consumer perception

There have been no specific surveys at EU level to analyse consumer perceptions regarding the risks generated by parasites in food, although there have been various general surveys performed in Europe or specific countries. One of the most relevant is from 2005 (Anon. 2006), in which the then 25 countries of the EU (without Romania and Bulgaria, which joined the EU in 2007) were interviewed to assess consumer risk perceptions, particularly regarding food safety. Although foodborne parasitic infections were not specifically addressed, the survey demonstrated that the major concerns regarding food safety in the EU were directed towards pesticide residues in fruit, vegetables and cereals; residues such as antibiotics and hormones in meats; unhygienic conditions in food processing plants, shops or restaurants' contamination with bacteria (food poisoning); pollutants such as mercury or dioxins; genetically modified products; and additives such as colours, preservatives or flavourings. According to the survey results, on a country basis, the Greeks, Italians and Cypriots were the biggest worriers about food contamination issues, but respondents in Sweden and Finland worried the least. Nordic countries also appeared to have greater confidence in public authorities concerning provision of information on specific food safety issues, with Finland demonstrating the greatest confidence in the authorities.

Globally, consumers tend to have more trust in vegetables and fruits than meat products when it comes to safety (Anon., 2004). Fewer respondents thought that food was become worse with regard to safety. A locally or regionally adapted food-risk communication is preferred by EU consumers, and may be more efficient that a pan-European communication, due to different culinary habits across Europe and differing parasite densities transmitted in different regions.

However, harmonized communication on the risks for foodborne parasites, e.g. *Echinococcus multilocularis,* is needed, as risk communication is currently scattered and inconsistent.

Outbreaks obviously affect consumer perceptions considerably (perhaps out of proportion to the risk), and this again means that communication is important.

A8.4.7 Social sensitivity

The presence of Anisakis in fish meat is not acceptable. Even if the meat is frozen there is a risk of allergenicity. This secondary danger is not well known by consumers. In addition, the finding of parasites in fish food during consumption (visual) engenders emotional reactions, and even if the public health risk is low, it is unacceptable to European consumers.

Consumers expect meat to be parasite-free. For parasites in meat that are not visible to the naked eye (*Sarcocystis, Toxoplasma*), restrictions are important if local culinary habits (raw or undercooked meat consumption) increase infection risk. The detection and reporting of a parasite risk in meat (or probably any other food commodity) induces an immediate drop in consumption. This was particularly well studied during trichinellosis in France (1986–1998) after infection of consumers eating horse meat.

The increased risk of parasitic infections when organic meat is consumed is not well understood by the public. In general, people believe that organic products are more healthy, which is usually not the case regarding parasitic risks. Some 'organic products' may, however, be perfectly acceptable produce, but it should also be recognized that specialist producers are most likely to be affected should an outbreak reported in the media be specifically associated with their specialization, regardless of their own standards, epitomized by the recent furore over alfalfa sprouts and bacterial infection.

Food sovereignty is an important concept regarding developing countries exporting produce (meat, fish, fresh produce) to wealthier countries that may ultimately reject on microbiological grounds or for other reasons. This concept is being explored in some research projects (e.g. Veg-i-Trade, *see*: www.vegitrade.com).

The parasite-commodity combinations that are probably most relevant from a European perspective are: meat+*Trichinella*; meat+*Taenia*; meat+*Echincoccus*; fish+all parasites, including flukes; fresh produce+*Cryptosporidium*; fresh produce+*Cyclospora*; and fresh produce+*Giardia*. Concern is more for public health and food imports than for trade and exports.

A8.4.8 Risk management

The data are summarized in Table A8.4.3.

A8.4.9 Sources cited in the text of the Europe section discussion

Anon[ymous]. 2004. Consumer Trust in Food. A European Study of the Social and Institutional Conditions for the Production of Trust. The TRUSTINFOOD project (2002-2004) is supported by the European Commission, Quality of Life and Management of Living Resources Programme (QoL), Key Action 1 Food, Nutrition and Health (contract no. QLK1-CT-2001-00291). For further information sSee: http://www.academia.edu/307738/Trust_and_Food._A_Theoretical_Discussion

Anon. 2006. Risk Issues. Special Eurobarometer 238 / Wave 64.1. prepared by TNS Opinion & Social for Directorate-General Health and Consumer Protection as well as the European Food Safety Authority and coordinated by Directorate-General. *See:* http://ec.europa.eu/food/food/resources/special-eurobarometer_riskissues20060206_en.pdf

TABLE A8.4.1 Data availability on the burden of disease and food attribution at the regional (European) and global levels

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	Disease severity/ main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Man food sources and attributions
Alaria alata	Yes -very rare. Humans can be paratenic hosts.	no	Yes [26, 27] Consumption of wild boar meat contaminated with larvae. Consumption of frog is questionable.	no	no	
Anisakis spp. (and other anisakids)	Yes [32, 33]	Yes [32, 33] Hypersensitivity risk and infection risk	Yes [32, 33] Infection risk: uncooked, lightly salted/smoked/pickled fish Hypersensitivity risk: as above, but also cooked or frozen fish	Yes [32, 33] Hypersensitivity risk and infection risk	No data	Yes [32, 33] Infection risk: uncooked, lightly salted/smoked/ pickled fish Hypersensitivity risk: as above, but also cooked or frozen fish
Ascaris lumbricoides, Toxocara spp. and other STH	Yes	Yes *Toxocara* infection may result in ocular problems; association with allergy	Yes Fresh produce – fruit, vegetables	Yes	Yes May result in ocular problems. May exacerbate other problems such as malnutrition	Yes Fresh produce – fruit, vegetables
Cryptosporidium parvum, Crypto-sporidium hominis & other *Crypto-sporidium* spp. Note A.	Yes [32, 38–42]	Yes [32, 38–42] Immuno-compromised, young	Yes [32, 38–42] Water and food (fresh produce, milk) contaminated by oocysts	Yes [42]	Yes [42] Immuno-compromised, young	Yes [42] Water and food (fresh produce, milk, apple juice, raw meat) contaminated by oocysts

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	Disease severity/ main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Man food sources and attributions
Cyclospora cayetanensis	Yes [47]	Yes [47]	Yes [47] Fresh produce (salad, mange tout)	Yes [47]	Yes [47]	Yes [47] Fresh produce (salad, raspberries)
Diphyllobothrium latum and other *Diphyllobothrium* spp.	Yes [34–37]	Yes [34–37] No data (vitamin B12 deficiency anaemia possible)	Yes [34–37] Undercooked freshwater fish	Yes [36, 37]	Yes [36, 37] No data (vitamin B12 deficiency anaemia possible)	Yes [36, 37] Undercooked freshwater fish
Echinococcus granulosus	Yes [17, 25]	Yes [17, 25]	Yes [17, 25] Food contaminated by eggs excreted by infected dogs (note that control can aim at meat in the transmission cycle – not feeding viscera to dogs – reducing prevalence in intermediate hosts)	Yes	Yes	Food contaminated by eggs excreted by infected dogs (note that control can aim at meat in the transmission cycle – not feeding viscera to dogs – reducing prevalence in intermediate hosts)
E*chinococcus multi-locularis*	Yes [17–23]	Yes [17, 19–22]	Yes [17, 19–22] Food (particularly berries) contaminated by eggs excreted by infected canids (dogs, foxes and raccoon dogs)	Yes [19]	Yes [19]	Yes [19] Food (particularly berries growing at ground level) contaminated by eggs excreted by infected canids (dogs, foxes and raccoon dogs)
Echinoccocus (non-European species)	No data			Yes	Yes	Yes [17] Food contaminated by eggs excreted by carnivorous

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	Disease severity/ main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Man food sources and attributions
Fasciola hepatica and other *Fasciola* spp.	Yes	Yes People eating watercress	Yes Watercress	Yes [53, 54]	Yes [53, 54]	Yes [53, 54] Lettuce, watercress
Giardia duodenalis	Yes [45, 46]	Yes [44–46] Rate of 5.6 per 100 000 in 2009. Age group 0–4 years	Yes [43, 45, 46] Water, fresh produce	Yes [46]	Yes [46]	Yes [46] Water, fresh produce
Linguatula serrata	No data	No data	No data	Yes [30, 31]	Yes [30, 31]	
Sarcocystis spp.	Yes [28]	Yes [28]	Yes [28] Pork or beef, depending on species	Yes [29]	Yes [29]	Yes [29] Depends on species
Taenia saginata (syn. *Taeniarhynchus saginata*)	Yes [7]	Yes [7] Taeniosis not severe but considered unacceptable.	Yes [7] Bovine meat	Yes [8]	Yes [8] Taeniosis not severe but considered unacceptable.	Yes [8] Bovine meat
Taenia solium	Yes [7, 10] (E. Europe only?)	Yes [7] Taeniosis not severe but considered unacceptable. Cysticercosis is severe.	Yes [7] Pork (adult *T. solium* infection) Contaminated vegetables, etc. (cysticercosis)	Yes [8, 9]	Yes [8] neurocysticercosis	Yes [8] Pork (adult *T. solium* infection) Contaminated vegetables, etc. (cysticercosis)
Toxoplasma gondii	Yes [11, 13–15]	Yes [11, 13–15] Pregnant women, immuno-compromised)	Yes [11–13–15] Meat (esp. lamb), vegetables contaminated with oocysts (food hygiene)	Yes [16]	Yes [16] Pregnant women, immuno-compromised)	Yes [16] Meat from domestic animal and wild mammals (pork, mutton, venison); milk; food contaminated by oocysts

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	Disease severity/ main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Man food sources and attributions
Trichinella spiralis	Yes	Yes	Yes [1, 3] 100% foodborne transmission. Meat (infected muscles from mammals (rarely birds))	Yes [1, 2, 4, 5]	Yes [1, 2, 4, 5]	Yes [1–6] 100% foodborne transmission Backyard domestic pork, horse meat, wild carnivores/ omnivores (boar, bear, walrus, etc.).
Other *Trichinella* spp.	Yes	Yes	Yes	Yes	Yes	Yes [6] Wild carnivorous meat. Horse meat possible (infrequent <1/300 000). Sea-mammals (walrus) in Arctic areas (freeze-resistant *T. nativa*)
Trypanosoma cruzi	Yes [49–52] Little data	Yes [49–52] Imported cases in Europe (under-diagnosed) – particularly countries with large Latin American communities	Yes [49–52]	Yes [48, 49]	Yes [48. 49]	Yes [48] Fresh juices

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TABLE A8.4.2 Data availability for Europe for parasite prevalence or concentration in the main food categories

***Anisakis* spp.**	
Seafood	Yes if unfrozen
Ascaris [12]	
Fruits	Yes
Vegetables	Yes
***Cryptosporidium parvum* (zoonotic); *Cryptosporidium hominis* (mainly anthroponotic), other *Cryptosporidium* spp.**	
Dairy	Milk has been associated with outbreaks – no survey data
Seafood	Yes [5, 10, 11] Shellfish.
Fruits	Yes [5, 12–15]
Vegetables	Yes [5, 12–15]
Other	Water – considerable data available from a range of sources
Cyclospora cayetanensis [12, 18]	
Fruits	Yes
Vegetables	Yes

***Diphyllobothrium latum* and *Diphyllobothrium* spp.** [8, 9]	
Seafood	Yes
Echinococcus granulosus	
(*E. granulosus* is transmitted to humans via eggs in dog faeces. However the occurrence of *E. granulosus* in slaughter animals is an important part of the transmission cycle, and thus the prevalence of *E. granulosus* infection in these food animals is of relevance.)	
Beef	No data as a food vehicle
Pork	No data as a food vehicle
Game	No data as a food vehicle
Fruits	Yes – little data available
Vegetables	Yes – little data available
Other	Water – little data available
Echinococcus multilocularis	
Fruits	Yes – little data available
Vegetables	Yes – little data available
Other	Water – little data available
***Giardia duodenalis* (syn. *G. lamblia, G. intestinalis*)**	
Seafood	Yes [5, 11, 16] Shellfish.
Fruits	Yes [12–14, 17]
Vegetables	Yes [12–14, 17]
Other	Water – considerable data available from a range of sources.
Sarcocystis bovihominis [6,7]	
Beef	Yes
Sarcocystis suihominis [6,7]	
Pork	Yes
Taenia saginata	
Beef	Yes
Taenia solium	
Pork	Yes. Eastern European countries or illegally imported meat.
Toxoplasma gondii	
Beef	Yes [1]
Dairy	Yes [1] In meat of dairy cattle, but not in milk.
Pork	Yes. Mainly outdoor pigs.
Poultry	Yes, but not relevant.
Game	Yes [1] Regional in wild boar.
Seafood	Possible. Sea mammals can be infected too. Data limited. [5]
Fruits	Yes [2]
Vegetables	Yes [2]
Other	Lamb and mutton; water [1–3]
Trichinella spiralis	
Pork	Yes. Outdoor pigs, pig breeding in area of high endemicity.
Game	Yes (wild boar and other game).
Other	Horse meat <1/300 000 carcasses.

Other *Trichinella* species	
T. nativa – freeze resistant, important for game and sea mammals. *T. britovi* and *T. murelli* also important.	
Pork	Yes Outdoor pigs, pig breeding in area of high endemcity.
Game	Yes (wild boar, bears).
Seafood	Sea mammals (seals, walrus).
Other	Horse meat <1/300 000 carcasses.

Main Sources used in Table A8.4.2

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02.	**Guy, E.C., Dubey, J.P. & Hill, D.E.** 2012. *Toxoplasma gondii*. pp 167–188, *in:* L.J. Robertson and H.V. Smith (editors). *Foodborne Protozoan Parasites*. Nova Science Publishers.	Global with regional foci
03.	**Halos, L., Thebault, A., Aubert, D. and 10 others.** 2010. An innovative survey underlining the significant level of contamination by *Toxoplasma gondii* of ovine meat consumed in France. *International Journal for Parasitology,* 40(2): 193–200.	Regional
05.	**Robertson, L.J.** 2007. The potential for marine bivalve shellfish to act as transmission vehicles for outbreaks of protozoan infections in humans: A review. *International Journal of Food Microbiology*, 120(3): 201–216.	Global problem
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07.	**Rosenthal, B., Yang, Z. & Yuan, L.K.** 2012. *Sarcocystis* spp. pp. 151–166, *in:* L.J. Robertson and H.V. Smith (editors). *Foodborne Protozoan Parasites*. Nova Science Publishers.	Global problem
08.	**Scholz, T., Garcia, H.H., Kuchta, R. & Wicht, B.** 2009. Update on the human broad tapeworm (genus *Diphyllobothrium*), including clinical relevance. *Clinical Microbiology Reviews,* 22(1): 146–160.	Global with regional foci
09.	**EFSA** [European Food Safety Authority]. 2011. Scientific Opinion on assessment of epidemiological data in relation to the health risks resulting from the presence of parasites in wild caught fish from fishing grounds in the Baltic Sea. Prepared by EFSA Panel on Biological Hazards (BIOHAZ). *EFSA Journal*, 9(7): Art. No. 2320 [40 p.].	Regional
10.	**Robertson, L.J. & Fayer, R.** 2012. *Cryptosporidium* spp. pp. 33–64, *in:* L.J. Robertson and H.V. Smith (editors). *Foodborne Protozoan Parasites*. Nova Science Publishers.	Global with regional foci
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15.	**Rzezutka, A., Nichols, R.A., Connelly, L., Kaupke, A., Kozyra, I., Cook, N., Birrell, S. & Smith, H.V.** 2010. *Cryptosporidium* oocysts on fresh produce from areas of high livestock production in Poland. *International Journal of Food Microbiology,* 139(1-2): 96–101.	Regional
16.	**Gomez-Couso, H. & Ares-Mazas, E.** 2012. *Giardia duodenalis*. Contamination of bivalve molluscs. pp. 133–150, *in:* L.J. Robertson and H.V. Smith (editors). *Foodborne Protozoan Parasites.* Nova Science Publishers.	Global with regional foci
17.	**Cook, N. & Lim, Y.A.L.** 2012. *Giardia duodenalis*. pp. 107–132, *in:* L.J. Robertson and H.V. Smith (editors). *Foodborne Protozoan Parasites*. Nova Science Publishers.	Global with regional foci

TABLE A8.4.3 Data availability for risk management options for each of parasite-commodity combinations

NOTE: The authors were asked to consider all combinations of the particular parasite and the main food categories, namely Beef, Dairy, Pork, Poultry, Game, Seafood, Fruit, Vegetables and Other.

Ascaris suum	
Pork	Yes – qualitative assessment [5]
Cryptosporidium	
Vegetables	Yes – quantitative & semi-quantitative [15–17]
Other	Water [11–14]
***Cyclospora cayetanensis* –** No data	
Fish parasites (*Anisakis*)	
Seafood	Yes [18]
	Qualitative risk analysis
Giardia duodenalis	
Vegetables	Yes [16, 17]
	Quantitative & semi-quantitative
Other	Water [14]
Taenia solium, Taenia saginata	
Game	Qualitative risk analysis for the pork freezing [4]
Toxoplasma spp. [5, 8–10]	
Beef	yes
Dairy	yes
Pork	yes
Game	yes
Trichinella spiralis [1–6]	
Pork	No data, GIS mapping in the USA. [1] Qualitative risk analysis for pork freezing [4]

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05.	**EFSA** [European Food Safety Authority]. 2011. Scientific Opinion on assessment of epidemiological data in relation to the health risks resulting from the presence of parasites in wild caught fish from fishing grounds in the Baltic Sea. Prepared by EFSA Panel on Biological Hazards (BIOHAZ). *EFSA Journal*, 9(7): Art. No. 2320 [40 p.].	Regional
06.	**Pozio, E., Alban, L., Boes, J. and 19 others.** 2010 Development of harmonised schemes for the monitoring and reporting of *Trichinella* in animals and foodstuffs in the European Union. Scientific Report submitted to EFSA. 47 p. Available at http://www.efsa.europa.eu/en/supporting/doc/35e.pdf	Regional
07.	**Opsteegh, M., Langelaar, M., Sprong, H., den Hartog, L., De Craeye, S., Bokken, G., Ajzenberg, D., Kijlstra, A. & van der Giessen, J.** 2010. Direct detection and genotyping of *Toxoplasma gondii* in meat samples using magnetic capture and PCR. *International Journal of Food Microbiology,* 139(3): 193–201.	Regional
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ANNEX 8.5 – NEAR EAST

A8.5.1 Compilation of data availability on food borne parasites relevant to the Near East

The group comprised Mohammad B. Rokni, Islamic Republic of Iran; Said Shalaby, Egypt; and Darwin Murrell, Denmark (who acted as group leader).

The region was subdivided into three groups of countries and each assigned to the group member with the greatest experience with the particular area. After review of the literature covering all those parasites that had been reported from the area, the group selected those parasites for which a reasonable amount of data was available, and these are listed below and in the three tables. After compiling the tables, the group then wrote this report that summarizes the information displayed in the tables, and offers opinion on research gaps and relative importance of the parasites listed.

The group selected the following parasites to be given priority:

- *Ascaris* spp
- *Cryptosporidium parvum*
- *Echinococcus granulosus* & *E. multilocularis*
- *Entamoeba histolytica*
- *Fasciola* spp.
- *Giardia duodenalis* (syn. *G. lamblia, G. intestinalis*)
- *Haplorchis pumilio*
- *Heterophyes heterophyes*
- *Taenia saginata*
- *Toxoplasma gondii*
- *Trichuris trichiura*

The prevalence of water- and foodborne parasites in the area (*Enatamoeba, Cryptosporidium, Giardia* and *Toxoplasma*) is generally high, as evident from the numerous prevalence surveys that have been conducted (Tables A8.5.1 and A8.5.2). These parasites are also of global importance. Overall, the availability and quality of these reports is good. However, studies on disease burden (e.g. morbidity/mortality or sequelae) are generally lacking, which makes estimating very difficult. Similarly, quantitative epidemiology studies are also limited, although a few recent studies on risk factors have appeared for all of these species.

For helminths, the availability of reports on prevalence is good for certain of the parasites (e.g.,, *E. granulosus*—see Torgerson *et al.,* 2010). Although data are available from hospital records, it may not be sufficient to permit reliable estimates of disease burden.

Fasciola spp. are second only to *Schistosoma* spp. as the most common trematode infection, especially in Egypt, Yemen and Iran, and account for more than one-third of the world's cases of fascioliasis. As a proportion of the global burden of disease, fascioliasis, ascariasis and trichuriasis in Near East countries account for 36%, 3% and 1%, respectively, of the total global prevalence (Hotez, Savioli and Fenwick, 2012).

In contrast, the prevalence of human *Taenia saginata* (taeniosis) is infrequently reported, as is bovine cysticercosis from meat inspection. This is in contrast to some countries in Africa. Meat inspection data, which would be valuable in estimating risk from this parasite, are not readily available, although such data might be obtained from the grey literature.

Reports on the fish-borne intestinal flukes (e.g. *Haplorchis pumilio* and *Heterophyes heterophyes*) indicate that these parasites are common in the Nile Delta region of Egypt, where the food habit of eating improperly cooked fish is well established.

There are numerous prevalence and epidemiology reports on the soil-borne parasites, *Ascaris* spp. and *Trichuris* spp. These parasites are very common throughout the region.

Overall, the specific food sources for many of the zoonotic parasites are poorly documented.

A8.5.2 Agri-food trade

Normally, due to low income and geographical situation, many countries of the region are not exporters of meat and meat products; the greatest income in most of the countries is from oil. The same may also be true for exports of high-risk fruits and vegetables, but this needs further inquiry. A potential future obstacle for some countries in attempting to export beef and lamb could be bovine cysticercosis and echinococcosis. In some countries of Africa, income from export of beef is negatively affected by bovine cysticercosis. One study on the economic impact of echinococcosis relevant to area was found (see Table A8.5.2).

A8.5.3 Consumer perception and social sensitivity

There is limited information on knowledge, attitude and behaviour of consumers related to foodborne parasites in region. In Iran there are several studies on echinococcosis, and the results show that general perception is not good.

This topic has not been widely discussed in the region compared with other regions, judging by the global literature. Local awareness of parasitic disease is poor, although there are limited studies in Iran. Continued turmoil in many countries of the region prevents governments from raising social sensitivity on this topic, and accordingly people are not interested or aware.

A8.5.4 Risk management

The strategies for the reducing the risk from foodborne parasites vary considerably, reflecting the diversity of these parasite's life histories and their epidemiology, and so are not easily generalized. Although regional reports are few, there are numerous recommendations in the global literature, as noted in Table A8.5.3.

A8.5.5 Sources cited in the discussion

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TABLE A8.5.1 Data availability on food borne parasites relevant to the Near East

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	Disease severity/main population at risk	Main food source and attribution	Disease in humans	Disease severity/main population at risk	Main food sources and attributions
Ascaris lumbricoides	Yes [10, 44–55] Saudi Arabia – 0.4–22.2%; Iran – 0.57–1.5%; Qatar – 0.6%; UAE – 6.6%; Egypt – 23%; Libya – 0.1%; Sudan – 47.7%	Yes [10, 44–52] Nearly all studies have data on this topic in the region	No Contaminated salad	Yes	Yes [53, 54] Poor children in tropical countries, with overcrowded slums and inadequate sanitation	Yes
Cryptosporidium parvum	Yes [8, 14,19, 35–43] Reported human prevalence: Gaza - 16.3%; Jordan - 8.3%; Yemen - 24–44%; Saudi Arabia – 2.3–16%; Iraq – 5–9.7%; Kuwait – 3.4%; Egypt – 9% Libya – 2.5% Sudan – 16%.	Yes [8, 14,19, 35–43]	Yes Water, some transmission by contaminated plant material.	Yes Considerable data from hospital and clinic records	Yes	Vegetables washed with contaminated water
Echinococcus granulosus.	Yes [58] Iraq – 2/100 000; Iran – 0.6-1.2/100 000 and prevalence 1.2–24%; Yemen – 26–140 cases/year during 2001–2008; Egypt – 10%; Libya – 1.4%; Sudan – 0.5%.	Yes [58] shepherds followed by farmers	No data Multiple sources.	Yes [25, 59–70]	Yes [25, 59–70] Hydatid cysts are very serious and difficult to treat.	Yes Man is an intermediate host, and likely is infected by ingestion of eggs in contaminated soil and water.

Parasite species	Data availability on human disease related parameters Regional level Disease in humans	Disease severity/main population at risk	Main food source and attribution	Global level Disease in humans	Disease severity/main population at risk	Main food sources and attributions
Entamoeba. histolytica	Yes [1–9] Reported human prevalence ranges: Lebanon– 14.0–19.5%; Gaza – 70%; Jordan – 22–80%; Syria – 22%; Yemen – 17%; Saudi Arabia – 0.14–30.3%; Iran – 1–9%; Oman – 0.5–2.4%; Qatar – 0.12%; Egypt >21%; Libya – 4.2%; Sudan – 54%	Yes [1–9] Nearly all studies have data on this topic in the region	No data Epidemiological studies on major source inadequate to determine.	Yes	Yes	Vegetables, water and soil. Relative importance of water- or foodborne uncertain; may vary in different circumstances.
Fasciola spp.	Yes [44, 72–76] Iran: – >7000 (1989) & 10 000 (1999) cases in massive outbreaks in north, and 17 cases in Iran in Kermanshah outbreak. Now less than 0.1%. Egypt has most prevalence (2.8%), followed by Yemen and Iran	Yes [44, 72–76] Iran and Egypt. In Iran there are considerable data.	Yes [72–74, 85] Two waterplants – *Nasturtium microphyllum* and *Mentha longifolia* Watercress (local name *boolagh oti*) contaminated with *Fasciola metacercariae Mentha pulegium* (local name *khlivash*) and *Mentha piperita* (local name *bineh*)	Yes [44, 72–76]	Yes [44, 72–76]	Yes [71, 76]

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	Disease severity/main population at risk	Main food source and attribution	Disease in humans	Disease severity/main population at risk	Main food sources and attributions
Giardia duodenalis (syn. *G. lamblia, G. intestinalis)*	Yes [1, 3, 6, 8, 10–24] Reported human prevalence ranges: Jordan – 3.9–42.6%; Gaza – 10.3–62.2%; Lebanon – 20.7%; West Bank – 9,7%; Syria – 14.0–31.0%; Yemen – 19.7%; Saudi Arabia – 0.1–37.7%; Iran – 3.7–14.5%; Oman – 3.4–10.5%; Qatar – 1.6%; Bahrain – 4%; Iraq – 38.5%; Egypt – 42%; Libya – 1.7%; Sudan – 12.3%.	Yes [1, 3, 6, 8, 10–24] Bakery workers [82] Nearly all studies have data on this topic in the region	Yes [24] Probably mostly waterborne. Fish	Yes	Yes Children have especially high prevalence	Yes
Intestinal fishborne trematodes *Heterophyes heterophyes* *H. nocens* *Haplorchis pumilio*	Yes [45, 57, 58] Hyperendemic, especially in delta region of the Nile Egypt – 33.8%; Iran – 0.24%; Sudan – 11%.	Yes [45, 57, 58] Common in fishers, and others consuming improperly cooked fish.	Yes Fish meat (esp. uncooked)	Yes	Yes	Improperly cooked fish

Parasite species	Data availability on human disease related parameters					
	Regional level			Global level		
	Disease in humans	Disease severity/main population at risk	Main food source and attribution	Disease in humans	Disease severity/main population at risk	Main food sources and attributions
Taenia saginata [12, 16, 77–81]	Yes Human prevalence in the region 0.4 and 6.0% in the few studies reported. Saudi Arabia – 0.01–0.2%; Iran – 0.1%; Qatar – 0.4%; Egypt – 0.6%; Libya – 2%; Sudan – 0.9%.	No data	Yes, beef.	No data	Yes	beef
Toxoplasma gondii	Yes [26–34] Human prevalence: Lebanon – 62%; Saudi Arabia – 3.78–4.9% and 42.3%; Qatar – 29.8%; Bahrain – 4%; Egypt – 11.7%; Libya – 43.4%; Sudan – 44.4%.	Yes [26–34] Nearly all studies have data on this topic in the region	Yes [26–34] However, direct ingestion of oocysts disseminated by infected cats are also important risk [83, 84] *Toxoplasma gondii* DNA was detected in 25% of salami, 20.3% of sausage, 21.8% of hamburger and 32.8% of kebab [29]	Yes [25]	Yes [25]	Yes Pork, lamb.
Trichuris trichiura	Yes [1, 10, 46, 55–57] Saudi Arabia – 0.36–28.8%; Qatar – 26.3%; UAE – 6.2%; Egypt – 49.7% Sudan – 46%.	Yes [1, 10, 46, 56, 57] Nearly all studies have data on this topic in the region	No data	Yes	Yes	Yes

Sources used for Table A8.5.1

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TABLE A8.5.2 Data availability for parasite prevalence or concentration in the main food categories in the Near East

Ascaris lumbricoides	
Fruits	Via municipal recycling of waste-water in farming.
Vegetables	Yes [3, 34] Via municipal re-cycling of waste-water in crops.
Other	Accidental ingestion of mature *Ascaris* eggs through contaminated food or water.
Cryptosporidium parvum [6,22]	
Fruits	Yes. If contaminated with water containg oocysts
Vegetables	Yes. As for fruit.
Other	Mostly waterborne.
Echinococcus granulosus [30]	
Fruits	Yes [32]
Vegetables	Yes [31, 33]
Other	The eggs may be eaten in foods (e.g. vegetables, fruits or herbs, or drunk in contaminated water
Entamoeba hystolytica	
Fruits	Yes 2, 4]
Vegetables	Yes [1–3]
Other	Water [1-2]
***Fasciola* spp.** [23–25]	
Vegetables	Yes [3, 26}
Other	Primarily leafy greens raised in water (ponds, streams). Some infective stages (metacercariae) may be transmitted by water.
Fish-borne trematodes	
Seafood	Ingestion of improperly cooked fresh and brackish-water fish
Giardia duodenalis* (syn. *G. lamblia, G. intestinalis)	
Fruits	Yes [10]
Vegetables	Yes [1, 5–7]
Other	Yes [1, 5–9] Water, fish.

Taenia saginata [27–28]	
Beef	Yes
Toxoplasma gondii	
Beef	Yes [17]
Dairy	Yes [15–16]
Pork	Yes [11–14]
Poultry	Yes [19]
Game	Yes
Fruits	Yes [20]
Vegetables	Yes [11–14] When cat faeces deposited in vegetable farm.
Other	Yes [11–14, 18] Soil and water; pork and oocyst contaminated water, fruits and vegetables have been implicated; *T. gondii* DNA was detected in 25% of salami, 20.3% of sausage, 21.8% of hamburger and 32.8% of kebab samples. [18]

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33.	**Bourée, P.** 2001. Hydatidosis: dynamics of transmission. *World Journal of Surgery,* 25(1): 4–9.	Global
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Table A8-5-3 Data availability for risk management options for each of parasite-commodity combinations in the Near East

Read in close conjunction with Tables A8.5.1 and A8.5.2

NOTE: The authors were asked to consider all combinations of the particular parasite and the main food categories, namely Beef, Dairy, Pork, Poultry, Game, Seafood, Fruit, Vegetables and Other.

Ascaris lumbricoides, Trichuris trichiura

The main source of infection is vegetables, so the best management would be to prevent use of night soil on vegetable farms, and improving composting techniques for manure.

Fruits	Yes
Vegetables	Yes [27]

Echinococcus granulosus

Control of dog populations in endemic areas is necessary. There are possible implication for fruits and vegetables. See references 15–22.

Beef	Yes
Pork	Yes
Game	Yes
Fruits	Yes
Vegetables	Yes

Entamoeba hystolytica, Giardia duodenalis* (syn. *G. lamblia, G. intestinalis*) and *Cryptosporidium parvum

The parasites *Entamoeba*, *Giardia* and *Cryptosporidium* can be grouped as primarily waterborne. Risk reduction involves the supply of potable, safe water for not only drinking, but also for food preparation and washing mouth and hands. Relevant publications linked to these parasites are in Table A8.5.2.

Fruits	Yes [1–10]
Vegetables	Yes [1–10]
Other	Yes. All are water-borne.

Fishborne trematodes: *Heterophyes heterophyes, Haplorchis pumilio, Procerovum* spp.

Only fish and humans are important in the control of this zoonosis. Dogs may play a role as alternative definitive host in endemic areas. Major risk factors include the use of fish from infested regions and improper cooking, or even eating fish raw with spices. Strict fish muscle examination is needed, especially for imported fish. Deep freezing on board is mandatory for imported fish. Examination by veterinary and health authorities and application of national standards is obligatory.

Seafood	Yes

***Fasciola* spp.**

Risk management programmes are described in numerous publications, specific for humans or for livestock. See references 23–24.

Beef	Yes
Dairy	Yes
Pork	Yes
Game	Yes
Vegetables	Yes

Taenia saginata

Because of strict host specificity, only cattle and humans are important in the epidemiology and control of this zoonosis. Major risk factors include exposure of animals to faecal waste. For humans, exposure to inadequate meat inspection, inadequate cooking temperatures. Considerable information on this available in the WHO/FAO/OIE Guidelines[28].
For mitigation of risk in cattle and consumer meats, see reference 25.
For control in humans and egg contamination of the environment (by cattle), see reference 26.

Beef	Yes
Dairy	Yes?

Toxoplasma gondii

Recent evidence that *Toxoplasma* could be transmitted by contaminated fruits and vegetables is covered in references 11–14, *q.v.* See Table A8.5.2 for references on meat and water transmission. Risk management will require improvement in water safety as well as prevention of exposure of livestock to infected cats.

Beef	Yes [11–14]
Dairy	Yes [11–14]
Pork	Yes [11–14]
Poultry	Yes [11–14]

Fruits	Yes [11–14]
Vegetables	Yes [11–14]
Other	Yes [11–14]

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ANNEX 8.6 – NORTH AMERICA WITH NOTES ON CENTRAL AMERICA

A8.6.1 Report preparation

This summary of data availability on foodborne parasites relevant to the North American region was compiled by Ronald Fayer, USA; Brent Dixon, Canada; and Ynes Ortega, USA, who acted as leader. Communication via e-mail and telephone served to compile information and complete the tables used to draft this report.

A8.6.2 Data availability on human occurrences and food attribution

Four parasite genera are of most importance in North America: *Toxoplasma*, *Cryptosporidium*, *Cyclospora* and *Giardia*. Data relevant to these parasites are available in published reports on cases, outbreaks, surveys and public records. There is insufficient or lack of data from exporting countries (fresh produce, meats, fish and shellfish) and where parasites are endemic. There was limited information on good agricultural practices, water quality, and worker hygiene (sanitation). Information that could be used for trace-back investigations is not readily available, which delays outbreak investigations.

In addition, an attempt was made to identify appropriate sources from Central America. The meagre information available is summarized in Table A8.6.4.

A8.6.3 Data on the burden of disease and food attribution

The data accessible has been summarized in Table A8.6.1.

The estimated costs (in US dollars) of illness caused by the four pathogens of concern in North America are: *Cryptosporidium* ($47 million), *Cyclospora* ($2 million) and *Toxoplasma* ($2.973 billion). *Toxoplasma* is considered the fourth leading cause of hospitalizations (n=4428) and the second cause of deaths (n=327) associated with foodborne illnesses in the USA. Annually the estimated number of illnesses attributed to *Cyclospora* in the USA is 11 407, 57 616 for *Cryptosporidium*, 86 686 for *Toxoplasma* and 76 840 for *Giardia*.

Data on parasite prevalence, incidence and concentration in the main food categories are summarized in Table A8.6.2

A8.6.4 Agri-food trade

From the high-profile *Cyclospora* outbreaks in North America, consumers are aware of the risks of eating fresh produce from developing countries, especially raspberries, mesclun lettuce and basil. The economic impact on producers if their food item is implicated in a foodborne outbreak is significant. That was the case of *Cyclospora* in 1995, where the outbreak was incorrectly attributed to California strawberries. This resulted in a $20 million loss to that industry. Outbreaks associated with *Cyclospora* in 1996 and 1997 caused illness in more than 2000 individuals in North America. Contaminated raspberries from Guatemala were identified. As result of these outbreaks, imports of Guatemalan raspberries to the USA and Canada were restricted, resulting in significant losses to the berry industry.

A8.6.5 Consumer perception

As result of widely publicized foodborne outbreaks in North America, consumers are aware of risks associated with eating fresh produce, especially from developing countries. Washing fresh produce is common practice and thoroughly cooking or freezing of meats is common practice. Consumers expect government inspection to keep food safe, but pre- and post-harvest points of contamination for fruits and vegetables consumed raw has largely been the responsibility of the food industry. Wildlife and other uncontrollable sources of parasites make treatment of wash water and drinking water essential. Parasites are highly resistant to chlorination and many disinfectants. *Cryptosporidium* is susceptible to UV, ozone, drying and extreme temperatures. Limited information is available with other parasites, particularly *Cyclospora*.

It should be a priority for the food industry to address pre- and post-harvest points of contamination for fruits and vegetables that are intended to be consumed raw.

A8.7.6 Social sensitivity

As a result of high-profile outbreaks involving fresh produce from developing countries, consumers are concerned about working conditions for food handlers and their access to sanitation facilities.

Seafoodborne trematode infections, not yet a major problem, are associated with immigrants from SE Asia; likewise for fascioliasis and hydatidosis there is concern concerning food contamination from immigrant food handlers from Central and South America. Toxoplasmosis and trichinellosis from poorly cooked game meats (bear, wild boar, marine mammals, etc.) are primarily associated with social groups like hunters and native peoples (such as Inuit), who often consume raw or dried meats. Toxoplasmosis is a recognized concern of physicians for women during pregnancy, but emphasis for prevention is placed on potential contamination from cats rather than from foodborne infection.

A8.6.7 Risk management

Risk management is summarized in Table A8.6.3.

TABLE A8.6.1 Data availability on the burden of disease and food attribution at the regional and global level

Parasite species	Regional			Global		
	Disease in humans	Disease severity/main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Main food sources
Alaria spp.	Yes [1, 5] Rare 3 cases	Yes [1, 5] Hives and bronchiospasms in a hunter	Yes [1, 5] Raw or undercooked frog meat, undercooked wild goose meat			
Anisakis spp.	Yes [26–28] 3 cases reported in Canada since 1989	Consumers of raw marine fishes	Raw marine fishes			
Blastocystis spp.	Yes [10, 11] 23% of 2896 patients in 48 USA states; 2.6% of 216 275 stool specimens	Yes Associated with irritable bowel syndrome		Yes Argentina 25% and 43%; Switzerland 16.7-19%; Chile 61.8%	Yes [12] Associated with irritable bowel syndrome	Yes [13] Well water, tap water, leafy vegetables, food vendors
Cryptosporidium spp. (*C. parvum*, *C. hominis* and several other spp.)	Yes [7, 9] Annual domestically acquired foodborne mean cases in USA: 57,616. 90% credible interval: 12,060-166,771	Yes Immunocompromised persons, children, elderly, travellers	Yes [8] 1999-2008 USA: Beverages 50%; Complex foods 50% 3 outbreaks associated with apple cider in US; also green onions, other raw produce, and prepared foods			

Parasite species	Regional			Global		
	Disease in humans	Disease severity/main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Main food sources
Cyclospora cayetanensis	Yes [7, 9] Annual domestically acquired foodborne mean cases in USA: 11 407 (90% credible interval: 137 – 37 673) Foodborne outbreaks in North America yearly since 1995 (spring/summer)	Yes [8] Immunocompromised persons, travellers	Yes [8, 9 1999–2008 USA: Complex foods 21.4%; Produce 78.6% Imported fresh raspberries, mesclun lettuce, basil			
Diphyllobothrium spp. [14–16] (*D. dendriticum*, *D. latum*, *D. ursi*, *D. nihonkaiense*)	Yes Up to 80% prevalence of *D. dendriticum* in some Inuit communities in Canada. Case of infection with *D. ursi* reported in British Columbia, Canada in 1973 One case of infection with *D. nihonkaiense* in Canada	Yes, Consumers of raw freshwater and anadromous fishes	Yes, Raw freshwater and anadromous fishes			
Echinococcus granulosus [17]	No data Number of cases specifically associated with consumption of contaminated foods is unknown	Residents of Arctic Canada; close association with dogs	No data, Contamination of foods with eggs from faeces of dogs, wolves, coyotes			

Parasite species	Regional Disease in humans	Disease severity/main populations at risk	Main food source and attribution	Global Disease in humans	Disease severity/ main populations at risk	Main food sources
Echinococcus multilocularis [17]	No data, Number of cases specifically associated with consumption of contaminated foods is unknown	Residents of Arctic Canada and Alaska, as well as Canadian prairie provinces and 13 American states; close association with dogs	No data, Contamination of foods with eggs from faeces of dogs, cats, foxes, coyotes			
Echinostomidae	Yes [1, 2] 23 cases Several cases reported in Canada (Ontario and Alberta)	Yes [1, 2] Mostly tourists from Kenya and Tanzania.	Yes [1, 2] Raw frogs, fish, snakes, clams snails			
Fasciola hepatica	Yes [1] 1934-2008: 23 cases reported in the USA	Yes [1] Liver and bile ducts. Endemic in the USA in lymnaeid snails and herbivores. Most cases imported from a wide geographic range; only 4 locally acquired.	Yes [1, 4] Tainted aquatic vegetation (especially watercress) and water	Yes	Yes [4]	Yes [4] watercress
Giardia duodenalis (syn. *G. intestinalis*, *G. lamblia*)	Yes [7] Annual domestically acquired foodborne mean cases in USA: 76 840 (90% credible interval: 51 148 – 109 739)		Yes [8, 9] Outbreaks in USA attributed to prepared foods and fresh produce			

Parasite species	Regional Disease in humans	Disease severity/main populations at risk	Main food source and attribution	Global Disease in humans	Disease severity/ main populations at risk	Main food sources
Heterophyes heterophyes	Yes [1, 2] 43 cases (41 in Hawaii) A few cases reported in recent immigrants to Manitoba and Alberta (Canada)		Yes [1, 2] One USA case from sushi prepared from fishes imported from SE Asia			
Metagonimus spp.	Yes [1, 2] 10 cases 2 cases reported in recent immigrants to Alberta (Canada)	Yes [1, 2] Recurrent diarrhoea reported in 1 case in the US	Yes [1, 2] Fish (sushi) 1 case report suggested salad contaminated with metacercariae from a cutting surface			
Metorchis conjunctus	Yes [2, 6] Outbreak among a group of Korean nationals who consumed raw white sucker freshly caught in river near Montreal, Canada; 17 of 19 individuals became symptomatic	Yes [1] Abdominal pain, fever, headache, anorexia, diarrhea, nausea, backache.	Yes [1] Raw white sucker	No data	No data	
Nanophyetes spp.	Yes [1, 2] 21 cases, mostly Northwestern US	Yes [1, 2]	Yes [1, 2] Raw salmon, steelhead trout, trout eggs			

Parasite species	Regional			Global		
	Disease in humans	Disease severity/main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Main food sources
Opisthorchis viverrini and *Clonorchis sinensis*	Yes [1, 2] ca. 1270 cases 1890–2009, mostly individual case reports Commonly reported among immigrants from SE Asia to Canada	Yes [1, 2] Group 1 carcinogens; liver and bile duct cancer. Infections mainly imported into the USA. Through the 1970s most were imported in Chinese, Japanese and Korean immigrants or Caucasians who had resided in China. Beginning in 1979, SE Asians were a major source of imported cases, especially those from Thai refugee camps.	Yes [1, 2] Raw or under-cooked freshwater fish	Yes	Yes	Yes [1, 2] Freshwater fish, especially cyprinids
Paragonimus spp. *P. westermani* *P. kellicotti* *P. mexicanus*	Yes [1–3] 71 cases reported 1910–2009. *P. kellicotti*: 7 cases 1968–2008, 14 cases 2009–2010. A few cases reported in immigrants to Canada from Italy, Malaysia, Philippines. One domestic case in Quebec, who sold live snails and crustaceans from exotic food section of department store.	Yes [1, 3] Most cases in 1970s and 1980s imported by SE Asian refugees from Thai camps, immigrants from Korea and Philippines; some co-infections with other helminths.	Yes [1, 3] Raw or undercooked crayfish and crabs	Yes	Yes	Yes

Parasite species	Regional Disease in humans	Disease severity/main populations at risk	Main food source and attribution	Global Disease in humans	Disease severity/ main populations at risk	Main food sources
Pseudoterranova spp.	Yes [29] 1 case reported in Canada in 1973	Consumers of raw marine fishes	Raw marine fishes			
Toxoplasma gondii	Yes [7] Annual domestically acquired foodborne mean cases in USA: 86 686 (90% credible interval: 64–861 – 111 912)	Yes [9] Immunocompromised persons, pregnant women, consumers of raw meat (Inuit people)	Yes [8, 9] 1999–2008 USA: domestic meats 69.6%; game 20.4% produce 7.0% dairy 2.4% seafood 0.5% Outbreaks in USA attributed to rare hamburger, rare lamb, raw goat milk. Outbreak in Canada (northern Quebec) involved 4 pregnant Inuit women who had consumed raw or dried seal or caribou meat			
Trichinella spiralis	No data [23] Some of the 43 *Trichinella* spp. cases may be *T. spiralis*		Yes [23] Commercial swine in Canada are currently *Trichinella*-free			

Parasite species	Regional			Global		
	Disease in humans	Disease severity/main populations at risk	Main food source and attribution	Disease in humans	Disease severity/ main populations at risk	Main food sources
Trichinella nativa	Yes [24, 25] 95 cases reported between 1982-2009 in Northern Canada	Yes [24, 25] Inuit and aboriginal people, hunters	Yes [24, 25] Black bear meat, grizzly bear meat, walruses			
Trichinella murrelli	Yes [18] In 2008, 30 of 38 attendees of an event US. No reported cases in Canada	Yes	Yes [18] Black bear raw meat	Yes [18] 431		Yes [18] Horse meat
Trichinella pseudo-spiralis	No reported cases in Canada					
Trichinella spp. [23]	Yes [18–23] 1997–2001: 72 cases reported. 2002–2007: 66 cases reported. 2008: 5 more cases 43 cases reported in Canada in 1999	Yes [18–23] Inuit and aboriginal people, hunters	Yes [18–23] Of the 72 cases, 31 eat wild game (31), bear (29), cougar (1),wild boar (1) and pork(12) meat. Of the 66 cases, bear, deer, walrus, seal pork, and beef meat			
Trichinella genotype T6	No reported cases in Canada					

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TABLE A8.6.2 Data availability for parasite prevalence or concentration in the main food categories

***Alaria* spp.**	
Seafood	Yes [1] Frogs.
***Anisakis* spp.**	
Seafood	Yes [13–15] Marine fish, squid.
***Blastocystis* spp.**	
Vegetables	Yes [9] Leafy vegetables.
Other	Water.
***Cryptosporidium* spp.** [7]	
Dairy	Yes [8] Un-pasteurized milk.
Seafood	Molluscan shellfish.
Fruits	Yes. Apple cider.
Vegetables	Yes. Green onions; produce.
Other	Water; prepared foods.
***Cyclospora* spp.** [7]	
Fruits	Yes. Raspberry.
Vegetables	Yes. Lettuce, basil, snow peas, watercress.
Other	Water.

***Diphyllobothrium* spp.**	
Seafood	Yes [10–12] Raw freshwater and anadromous fish.
Echinostomidae	
Seafood	Yes [1, 2] Frogs, snakes, fish, clams, snails.
Fasciola hepatica	
Vegetables	Yes [1] Aquatic vegetation: watercress.
***Giardia* spp.** [7]	
Seafood	Molluscan shellfish.
Vegetables	Yes; fresh produce.
Other	Water; prepared foods.
Heterophyes heterophyes	
Seafood	Yes [2] Sushi prepared from fish imported from SE Asia.
***Metagonimus* spp.**	
Seafood	Yes [2] Sushi; possibly salad contaminated with metacercariae.
***Nanophyetes* spp.**	
Seafood	Yes [1, 2] Raw salmon, steelhead trout, trout eggs.
Opisthorchis viverrini* and *Clonorchis sinensis	
Seafood	Yes [1, 2] Numerous species of freshwater fish.
Paragonimus kellicotti	
Seafood	Yes [3] Freshwater crustaceans (100%).
Paragonimus mexicanus	
Seafood	Freshwater crustaceans (100%).
Paragonimus westermani	
Seafood	Yes [1, 2] Freshwater crustaceans (100%): crayfish, crabs.
***Pseudoterranova* spp.**	
Seafood	Yes [16] Marine fish.
***Trichinella* spp.** [4–6]	
Pork	Yes. Pork meat
Game	Yes. Bear, walrus, wild boar, cougar.
***Toxoplasma* spp.** [7]	
Beef	Yes
Dairy	Yes
Pork	Yes
Poultry	Yes
Game	Yes; caribou, seal
Seafood	Molluscan shellfish

Fruits	No data, but oocyst contamination is feasible
Vegetables	No data, but oocyst contamination is feasible
Other	Water
Trypanosoma cruzi	
Very little substantive data available.	

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TABLE A8.6.3 Data availability for risk management options in North America for each parasite-commodity combination

NOTE: The authors were asked to consider all combinations of the particular parasite and the main food categories, namely Beef, Dairy, Pork, Poultry, Game, Seafood, Fruit, Vegetables and Other.

***Alaria* spp.** [1]	
Seafood	Rare
***Anisakis* spp., *Pseudoterranova* spp.**	
Seafood	Yes [3] Fish surveillance studies; candling of fillets at processing plants; use of pre-frozen fish for sushi; consumer education
***Blastocystis* spp.**	
Fruit	Good agricultural practices, e.g., water quality, worker hygiene, compost requirements; consumer and food handler education regarding fresh produce
Vegetables	Good agricultural practices; consumer and food handler education regarding fresh produce
***Cryptosporidium* spp.**	
Beef	Yes [1] Heat and freezing
Dairy	Yes [1] Pasteurization
Seafood	Yes [5] Shellfish sanitation programs
Fruit	Yes [5] Good agricultural practices, e.g., water quality, worker hygiene, compost requirements; consumer and food handler education regarding fresh produce; surveillance studies; disinfectants
Vegetables	Yes [5] Good agricultural practices; consumer and food handler education regarding fresh produce; surveillance studies; disinfectants
Other	Yes [1] Fruit juice pasteurization
Cyclospora cayetanensis	
Fruit	Yes [5] Good agricultural practices; import restrictions; surveillance studies; former "Model Plan of Excellence" program in Guatemala; disinfectants
Vegetables	Yes [5] Good agricultural practices; import restrictions; surveillance studies; disinfectants
***Diphyllobothrium* spp.**	
Seafood	Yes [5] Fish surveillance studies; wild-caught vs aquaculture (pelleted feed); consumer education
***Trichinella* spp.**	
Pork	Routine surveillance of commercial swine
Game	Surveillance of wildlife harvested for food; trichinellosis program in Arctic Canada (walrus testing); hunter education
Echinostomidae, *Heterophyes heterophyes*	
Seafood	Yes [1–3] Consumer education (cooking/freezing); good sanitation; import restrictions

Fasciola hepatica [1]		
Vegetables	Rare	
Other	Rare	
***Giardia duodenalis* (syn. *G. lamblia, G. intestinalis*)**		
Seafood	Yes [5]	Shellfish sanitation programmes
Fruit	Yes [5]	Good agricultural practices; surveillance studies
Vegetables	Yes [5]	Good agricultural practices; surveillance studies
***Metagonimus* spp.**		
Seafood	Yes [2, 3]	Consumer education (cooking/freezing); good sanitation; import restrictions
***Nanophyetes* spp.**		
Seafood	Yes [1–3]	Consumer education (cooking/freezing); good sanitation; import restrictions
Opisthorchis viverrini, Clonorchis sinensis* and *Paragonimus westermani		
Seafood	Yes [1–3]	Consumer education (cooking/freezing); good sanitation; import restrictions
Paragonimus kellicotti		
Seafood	Yes [6]	Consumer education: avoid eating raw crayfish
Paragonimus mexicanus		
Seafood	Rare	
Toxoplasma gondii		
Beef	Yes [5, 6]	Meat surveillance studies; consumer and food handler education (cooking and freezing)
Dairy	Yes [5, 6]	Milk pasteurization requirements
Pork	Yes [5, 6]	Meat surveillance studies; consumer and food handler education (cooking and freezing)
Poultry	Yes [5, 6]	Meat surveillance studies; consumer and food handler education (cooking and freezing)
Game	Yes [5, 6]	Meat surveillance studies; seroprevalence studies on wildlife; consumer and food handler education (cooking and freezing)
Seafood	Yes [5, 6]	Shellfish sanitation programs

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TABLE A8.6.4 Data availability for Central America

Parasite species	Disease in humans	Disease severity/ main populations at risk	Main food source and attribution
Alaria spp.			
Anisakis spp.			
Blastocystis spp.	Yes [8, 9] 30% of 456 children in day care centres in Cuba; 39% of local populations in Cuba		
Cyclospora cayetanensis	Yes [1–5] Endemic in Guatemala (2.3% prevalence). Among 182 raspberry farm workers and family members examined in Guatemala, 3.3% had *Cyclospora* infection; Another study failed to detect oocysts among raspberry farm workers in Guatemala		Yes [6, 16] Outbreak in Quebec, Canada, in 2005 associated with fresh basil from Mexico. Reported in lettuce from local markets in Costa Rica
Cryptosporidium spp.			
Diphyllobothrium spp. (*D. dendriticum*, *D. latum*, *D. ursi*, *D. nihonkaiense*)			

Parasite species	Disease in humans	Disease severity/ main populations at risk	Main food source and attribution
Echinococcus granulosus, E. multilocularis			
Echinostomidae			
Entamoeba histolytica	Yes [11] In Mexico, *Entamoeba histolytica* antibodies found in 4.49%		
Fasciola hepatica			
Giardia duodenalis (syn. *G. intestinalis, G. lamblia*)	Yes [7–9] Nail biting and eating unwashed vegetables raw were significantly associated with infection in hospitalized children in Cuba; 54.6% of 456 children in day cares in Cuba; 25% of local populations in Cuba.		
Heterophyes heterophyes			
Metagonimus spp.			
Nanophyetes spp.			
Opisthorchis viverrini and *Clonorchis sinensis*			
Paragonimus spp.			
Pseudoterranova spp.			
Taenia solium	Yes [12–15] 4.9–10.8% tested positive for cysticercosis in villages in Mexico; *T. solium* taeniasis and cysticercosis are endemic in Guatemala; Clinical incidence of neuro-cysticercosis can reach 7% in Mexico. Honduras: cysticercosis annual incidence ca. 30.		

Parasite species	Disease in humans	Disease severity/ main populations at risk	Main food source and attribution
Toxoplasma gondii	Yes [10] Estimated incidence in Honduras 36 000/yr		
Trichinella spp.			

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ANNEX 8.7 – SOUTH AMERICA

A8.7.1 Report preparation

The Group members were: Jorge Enrique Bolpe, Argentina, and Jorge Enrique Gómez-Marín, Colombia. Their sources included systematic literature reviews, involving bibliographic database searches (Pubmed, Scopus, Scielo) and own data from unpublished reports (Dr Gómez-Marin). Additionally, literature reviews of bulletins, national reports, book articles and technical guidelines were used (Dr Bolpe).

A8.7.2 Data availability in humans and food attribution

Good evidence exists about *Toxoplasma* presence in meat for human consumption, although some countries have only limited data. Good quality reports exist of foodborne *Trypanosoma* infection. There is good information on the quantity and quality of regional data concerning trichinellosis and cystic echinococcosis in humans in Argentina and other countries in southern of South America, probably because these diseases are included in the national epidemiological surveillance systems in the affected countries. There is also valuable information regarding the identification of food infected with *Trichinella*, with the identification of the specific species (*T. spiralis*).

Data on the burden of disease and food attribution are summarized in Table A8.7.1, and data on parasite prevalence, incidence and concentration in the main food categories are covered in Table A8.7.2.

A8.7.3 Agri-food trade

All the countries in South America export fruits to many continents. Notably, during the last decade, Colombian fruit exports doubled to a total US$ 800 million and more than 1800 ton (Proexport data). Brazil and Argentina export significant volumes of horse and beef meat, while pork meat exportation is less important. At present there are no data indicating the presence of parasites in horses. However, in Argentina, because of trichinellosis endemicity, all horse and pork meat for exportation must be certified with a negative test of peptic digestion performed by the National Animal Health Service.

A8.7.4 Consumer perception

The recent free-trade agreement with the United States of America has raised important questions concerning sanitary security. In Colombia, for example, wide public consumer debates have developed regarding the origin and security of chicken imports from United States of America. A recent urban outbreak of foodborne trypanosomiasis in a school in Caracas, Venezuela, portends a new epidemiological situation for this disease in Brazil, Colombia and Venezuela. For trichinellosis consumer perception in Argentina, some parts of the population show a consumer willingness to accept risk in food consumption without sanitary control. In Argentina, many people are regular consumers of pork in the form of stuffed products, such as sausages produced by local butchers, and avoid foods processed under industrial conditions with sanitary control. This is enhanced by current cultural trends. In many family outbreaks, the consumers who have bred pigs using poor husbandry produced food without the detection of *Trichinella* infection in pig carcasses. Cystic echinococcosis from the ingestion of green vegetables contaminated with oncospheres is possible in rural areas the parasite is endemic, where cultural practice encourage the parasitic cycle through the slaughter of domestic sheep and the feeding of dogs with raw viscera.

A8.7.5 Social sensitivity

There have been increased foodborne outbreaks in most of countries in the region, reflecting cultural changes and increases in the frequency of eating outside the home. Theses outbreaks have been widely publicized, and public pressure developed to reinforce health authority controls.

Trichinellosis

The economic impact of trichinellosis is apparent in the control system for detecting this infection in potential *Trichinella* carriers, mainly in slaughterhouses, and the occurrence of the disease in human and animals. The economic loss due to the destruction of infected carcases is a significant economic loss in Argentina. The cost for human treatment has been estimated at US$ 6000 in the United Staes of America, and at US$ 3000 in Europe.

Cystic echinococcosis

In a Regional Socio-economic Impact of Cystic Echinococcosis (CE) in Argentina, Brazil, Chile and Uruguay, DALYs calculated for the region as a measure of damage caused by CE were 1551.83 due to premature death and 1766.93 due to different degrees of disability, both values adjusted for reported cases. The overall monetary cost of CE in the countries—collating human cases, the lost income due to relapse and morbidity, and livestock losses associated with the condemnation of the liver, reduced carcass weight, loss of milk production, decreased fertility and wool yield—was estimated in the range of at least US$ 75 million to a maximum of US$ 97 million (See ref. [83] in Table A8.7.1).

For Global Socio-economic Impact, when no underreporting is assumed, the estimated human burden of disease is 285 407 DALYs or an annual loss of US$ 193 530 000.

A8.7.6 Risk management

Data are summarized in Table A8.7.3.

TABLE A8.7.1 Data availability on the burden of disease and food attribution for South America at the regional and global levels

Species	Regional level			Global level		
	Disease in humans	Disease severity/ main population at risk	Main food source and attribution	Disease in humans	Disease severity/main population at risk	Main food sources and attributions
Balantidium coli	Yes [53, 76] Low prevalence: Bolivia 1–5.5%; Colombia 1.8%	Yes [53] Low prevalence; infrequent cases of diarrhoea	Yes, but no data reported	Yes [77]	Yes [78] Low prevalence	Yes [77] Pigs
Blastocystis spp.	Yes [29–32, 43] 36–49% in Colombia in pre-school children; 16%–38% Venezuela; 22% Argentina; 26% Parana, Brazil; 57% Mapuera community, Brazil; 41.3–62.3% Chile. *B. hominis* Argentina: B. Aires Province – prevalence in 119 children age 1 to 14 years old (urban: 26.9%; peri-urban: 46.2%; rural: 31.7%)	Yes [33, 34] Unconfirmed, some genotypes. Pre-school children, some adults with irritable bowel syndrome	Yes [36] Eggs, plants	Yes [37] *Blastocystis* has a worldwide distribution and is often the most commonly isolated organism in parasitological surveys (up to 50% in some cohorts). Extrapolating from available prevalence data, the parasite colonizes the intestine of more than 1×10^9 people worldwide	Yes [38–40] Unconfirmed, some genotypes associated to diarrhoea, some studies indicates association with irritable bowel syndrome	Yes [39, 41, 42] Plants, food handlers, pigs, chicken
Cyclospora cayetanensis	Yes [44–47] 18–6% Perú; 2% Guatemala 11.9% Venezuela	Yes [48] Outbreaks diarrhoeal disease	Yes [49] Raspberry, plants (lettuce)	Yes [50]	Yes [51]	Yes [49]

Species	Regional level Disease in humans	Disease severity/ main population at risk	Main food source and attribution	Global level Disease in humans	Disease severity/main population at risk	Main food sources and attributions
Echinococcus granulosus	Yes [12, 79–85] Over 2000 new human cases are reported every year in the region of South America. Incidence from 41 per 100 000 in the Patagonian region in southern Argentina, 80 per 100 000 in the XI Region of Chile; up to 100 per 100 000 in the Flores Department of Uruguay. Infection rates of 5.5% in 1986 in Black River, Argentina; 14.2% in 1988 in Loncopué, Neuquén, Tacuarembo, Uruguay; 1.6% in 1997 in Florida, Uruguay; 3.6% in 1998 in Peach, Uruguay; 5.1% in 1999 in Vichaycocha, Peru. 1418 cases have also been reported by ultrasound screening on asymptomatic human population. Argentina: Morbidity in 1987–1996: 5248 human cases, 1997–2005: 4079 human cases Argentina: between 2006 and 2010 1883 suspected Hydatidosis cases were reported. Argentina, Brazil, Chile and Uruguay: DALYs 1551.83 to 1766.93 adjusted for reported cases. Chile: 2004 estimates an incidence of 10 per 100 000, with mortality 0.3–0.4 per 100 000. Brazil: see [85] for data on Rio Grande do Sul	Yes [12, 79–85] 3.8 ×10^6 rural inhabitants live in risk area.	Yes [12, 79–85] Ingestion of vegetables or polluted water with infected canine faeces.	Yes [12, 79–85] The most conservative estimate of global DALYs lost is 285,407, with no consideration for disease under-reporting.		

Species	Regional level			Global level		
	Disease in humans	Disease severity/ main population at risk	Main food source and attribution	Disease in humans	Disease severity/main population at risk	Main food sources and attributions
Entamoeba histolytica	Yes [69, 70] Colombia: 0.6–1.4%	Yes [71] Low prevalence when studies differentiated pathogenic from non-pathogenic.	Yes, but no data reported.	Yes [72]	Yes [73]	Yes [74, 75] but little data Only one report differentiated pathogenic from non-pathogenic. Only *E. dispar* was found in food handlers
Fasciola hepatica	Yes [1–3, 86] Argentina – 619 autochthonous cases from 13 Provinces, in 58 reports of different kinds analysed up to 2010.	Yes [1–3, 86] Case spread, by gender, province, diagnostic method, treatment, etc.	Yes [1–3, 86] Ingestion of freshwater plants carrying infective metacercaria, watercress			
Giardia spp.	Yes [34, 43, 52, 53] Mexico 50%; Colombia 15,0% Argentina: prevalence of *Giardia duodenalis* (syn. *G. lamblia, G. intestinalis*) in 119 children age 1 to 14 years old – urban 9.6%; peri-urban 34.6%; rural 7.3% Argentina: in multicentre studies using data from different provinces – prevalence of *Giardia duodenalis* (syn. *G. lamblia, G. intestinalis*) (13.17%) in 1 to 3 year-old children in the country 2004–05.	Yes [54] Retard in cognition development	Yes [55,56]	Yes [57] In developing countries around 20% (4–43%) and in developed countries 5% (3–7%)	Yes [54]	Yes [56] Canned salmon, sandwiches, noodle salad, fruit salad, raw vegetables, ice

Species	Regional level Disease in humans	Disease severity/ main population at risk	Main food source and attribution	Global level Disease in humans	Disease severity/main population at risk	Main food sources and attributions
Hymenolepis nana	Yes [59–61] Children: 1%-6.6% Peru; 1% -14% Venezuela: 31% in aborigines in Salta in Argentina; 1% Ecuador; 7% Minas gerais, Brazil;	Yes [34, 61] No, rare cases of diarrhoea Low prevalence.	Not reported	Yes [62] Low prevalences	Yes [63–65] Infrequent Only one significant report in India. One report in immuno-suppressed patient	Yes [66–68] Food handlers
Taenia solium, cysticercosis	Yes [14] Human prevalence in Latin America: Colombia (1.8-2.2%), Brazil (3.0-5.6%), Honduras (15.6-17%), Ecuador (2.6-14.3%), Guatemala (10-17%), Bolivia (22%), Venezuela (4-36.5%).	Yes	No data	Yes [13] DALY: $2–5 \times 10^6$	No data	No data
Toxoplasma gondii	Yes [16–18] Human prevalence: Colombia 47% general population; 60% pregnant women; Perú 58% in pregnant women; Brazil 50% to 76%, Chile 36,9%; Argentina: Human prevalence Ciudad de Buenos Aires, Pregnant women 47.3%. Provincia de Buenos Aires 51.7%, Provincia de Jujuy 39.7%, Provincia de Santa Fe 42.2%, Ciudad de Resistencia 28.5%, Provincia de Chaco 23.8%.	Yes [19, 20] Newborn: 0.2% to 2% Immunosuppressed people; main cause of cerebral disease in HIV infected patients	Yes [23] Meat (see Table in Ref. 23)	Yes [21, 24] One third of human population infected	Yes [22]	Yes [23] Meat (between 20% to 50% of cases)

Species	Regional level			Global level		
	Disease in humans	Disease severity/ main population at risk	Main food source and attribution	Disease in humans	Disease severity/main population at risk	Main food sources and attributions
Trichinella spiralis	Yes [4–11] Argentina, Buenos Aires Province: Total human cases and 65 outbreaks reported from 01/2000 to 09/2004 were analysed. No. of human cases increased from 908 between 1971 and 1981, to 6919 between 1990 and 2002 Chile: Total cases 2012 and previous incidence description Argentina: Serological survey in blood donors prevalence 8.0%	Yes [4] Description of clinical symptoms and/or signs, epidemiological data and laboratory aspects of human trichinellosis	Yes [1–5, 7, 9] Meat Eating pork and pork products not sanitary inspected and not properly cooked.	Yes [1–4, 12] DALYs: The most conservative estimate of number of global DALYs lost is 285 407, with no consideration for disease under-reporting.	Yes [1–3]	Yes [1–3] Domestic pigs, wild boars, raw horse meat 100% foodborne transmission
Trichuris trichiura	No data	Yes [15]	No data	No data	Yes [15] For 2010, global population at risk: 5.023 billion.	No data
Trypanosoma cruzi	Yes [25] More than 7 ×10^6 people infected in the Americas	Yes [25, 26] 10% mortality in acute cases; 41 200 new cases per year – rate of 7.7 per 100 000 inhabitants –14 385 cases of congenital Chagas	Yes [27, 28] Açai palm juice Guava juice	No data	No data	No data

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TABLE A8.7.2 Data availability for parasite prevalence or concentration in the main food categories for South America

Balantidium coli No substantive data.	
Blastocystis **spp.**	
Vegetables	Yes [22] Colombia: 44% tomatoes; 37% carrot; 28% cabbage; 25% onion.
Other	Yes [22] Colombia: 34% of eggs.
Cyclospora cayetanensis	
Fruits	Yes [23–25]
Vegetables	Yes [23–25]

Entamoeba histolytica No substantive data.		
***Giardia* spp.** No substantive data.		
Hymenolepis nana No substantive data.		
Toxoplasma gondii [9–21]		
Beef	Colombia: 48% by PCR Colombia: seroprevalence 35% Brazil: 49.4% seropositive (38/77) in cattle in Rio Janeiro; For comparison: 0% by bioassay in USA	
Pork	Colombia: 29–70% by PCR Erechim, Brazil: 17/50 (34%) samples from the diaphragm and 33/50 (66%) samples from the tongue demonstrated a positive PCR reaction. Colombia: seroprevalence 9–15%. Rio Janeiro, Brazil: seroprevalence 7.64% (31/406) in pigs; 11.5% (7/61) in pigs. Londrina, Brazil: bioassay in mice, 13 (8.7%) sausage samples were positive, in one of them *T. gondii* was isolated and in the other 12 the mice seroconverted) 1% USA; USA 24–92% by bioassay	
Poultry	40% by PCR (Colombia); Seroprevalence 16% (Colombia); 40% seroprevalence in free range chicken in Espirito Santo, Brazil.	
Game	Deer: 21%-27% by bioassay (USA)	
Other	Sheep: 4-77% (bioassay, USA); Brasil seroprevalence 1980–2011: 18.6% São Paulo to 61% Minas Gerais	
Trichinella spiralis [1–8]		
Pork	Argentina: in 11.7% of 1128 human cases the suspected food was pork meat and derivatives 1–150 larvae per gram. Argentina: pigs in Buenos Aires Province studied by DAR had 2.07% prevalence, with worm burdens 8.4–105.6 larvae per gram of muscle. ELISA serology prevalence 20–21% Argentina: Muscle larvae of Trichinella from infected animals were identified at the species level by PCR in 38 of 56 pork products. Argentina: 300 pigs slaughtered in Rio Negro province 2000–2002 had prevalence (DAR) of 4.8–7.3%. ELISA serology prevalence in 181 animals 19.9%.	
Game	Argentina: *Trichinella* spp. from a sylvatic cycle caused human outbreaks due to eating meat from puma, armadillo and wild boar. Chile: human trichinosis from eating roast wild boar (*Sus scrofa*)	
Trypanosoma cruzi		
Fruits	Yes [7, 8] Experimental infection. In outbreak oral transmission by juice fruits considered the most important origin.	

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TABLE A8.7.3 Data availability for risk management options for each parasite-commodity combination for South America

NOTE: The authors were asked to consider all combinations of the particular parasite and the main food categories, namely Beef, Dairy, Pork, Poultry, Game, Seafood, Fruit, Vegetables and Other.

Echinococcus granulosus (See refs 13–14)	
Beef	In endemic areas of Argentina, Chile, Uruguay, Brazil and Peru: Control programmes with systematic de-worming of rural dogs, improvement of family slaughter of sheep and pigs for human consumption, avoiding feeding dogs with raw viscera, and health education of rural inhabitants.
Pork	In endemic areas of Argentina, Chile, Uruguay, Brazil and Peru: Control programmes with systematic de-worming of rural dogs, improvement of family slaughter of sheep and pigs for human consumption, avoiding feeding dogs with raw viscera, and health education of rural inhabitants.
Vegetables	In endemic areas of Argentina, Chile, Uruguay, Brazil and Peru: Control programmes with systematic de-worming of rural dogs, improvement of family slaughter of sheep and pigs for human consumption, avoiding feeding dogs with raw viscera, and health education of rural inhabitants.

Toxoplasma gondii (See refs 10–12)	
Beef	Pre harvest: remove cat from farm; reduce or prevent oocyst shedding contamination; sterilize feed and bedding; no outdoor access; reduce exposure to oocysts. *Toxoplasma*-infected rodents: rodent control programme; reduce transmission of *Toxoplasma* to omnivorous meat animals. Tissue cysts in meat: post-harverst. Irradiation at 0.4–0.7 kGy or high-pressure processing at 300–400 MPa can inactivate *T. gondii* tissue cysts in meat. However, the effects of irradiation on colour and of high pressure treatment on colour and texture have limited consumer acceptance. Freezing meat to an internal temperature of -12°C kills *T. gondii* tissue cysts. Salting, curing, smoking, and the addition of solutions to meat to enhance colour and taste can reduce the viability of *T. gondii* in meat. However, there is too much variability in these procedures to make a safety recommendation.
Pork	Pre harvest: remove cat from farm; reduce or prevent oocyst shedding contamination; sterilize feed and bedding; no outdoor access; reduce exposure to oocysts. *Toxoplasma*-infected rodents: rodent control programme; reduce transmission of *Toxoplasma* to omnivorous meat animals. Tissue cysts in meat: post-harverst. Irradiation at 0.4–0.7 kGy or high-pressure processing at 300–400 MPa can inactivate *T. gondii* tissue cysts in meat. However, the effects of irradiation on colour and of high pressure treatment on colour and texture have limited consumer acceptance. Freezing meat to an internal temperature of -12°C kills *T. gondii* tissue cysts. Salting, curing, smoking, and the addition of solutions to meat to enhance colour and taste can reduce the viability of *T. gondii* in meat. However, there is too much variability in these procedures to make a safety recommendation.
Poultry	Pre harvest: remove cat from farm; reduce or prevent oocyst shedding contamination; sterilize feed and bedding; no outdoor access; reduce exposure to oocysts. *Toxoplasma*-infected rodents: rodent control programme; reduce transmission of *Toxoplasma* to omnivorous meat animals. Tissue cysts in meat: post-harverst. Irradiation at 0.4–0.7 kGy or high-pressure processing at 300–400 MPa can inactivate *T. gondii* tissue cysts in meat. However, the effects of irradiation on colour and of high pressure treatment on colour and texture have limited consumer acceptance. Freezing meat to an internal temperature of -12°C kills *T. gondii* tissue cysts. Salting, curing, smoking, and the addition of solutions to meat to enhance colour and taste can reduce the viability of *T. gondii* in meat. However, there is too much variability in these procedures to make a safety recommendation.

Trichinella spiralis (See refs 1–9)		
Pork		Recommended methods for monitoring *Trichinella* in domestic and wild animals for human consumption *Trichinella* control at all levels (farm, slaughterhouse and processed meats) Breeding improvement
Game		Recommended methods for monitoring *Trichinella* in domestic and wild animals for human consumption *Trichinella* control at all levels (farm, slaughterhouse and processed meats) Breeding improvement

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Infectious diseases caused by food-borne parasites have not received the same level of attention as other food-borne biological and chemical hazards. Nevertheless, they cause a high burden of disease in humans, may have prolonged, severe, and sometimes fatal outcomes, and result in considerable hardship in terms of food safety, security, quality of life, and negative impacts on livelihoods. The transmission routes for food-borne parasites are diverse. They can be transmitted by ingesting fresh or processed foods that have been contaminated via the environment, by animals or people. Additionally, notification to public health authorities is not compulsory for most parasitic diseases, so official reports do not capture the true prevalence or incidence of the diseases, as much underreporting occurs.

This report presents the results of a global ranking of food-borne parasites from a food safety perspective. It also provides an overview of the current status of knowledge of the ranked parasites in food and their public health and trade impact, and provides advice and guidance on the parasite-commodity combinations of particular concern, the issues that need to be addressed by risk managers, and the risk management options available to them. It documents the ranking process used to facilitate its adoption at regional, national, or local levels.

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