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How globalization and climate change could affect foodborne parasites

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ABSTRACT

Foodborne parasites, most of which are zoonotic, represent an important human health hazard. These pathogens which include both protozoa (e.g., *Cryptosporidium* spp., *Cyclospora cayetanensis*, *Toxoplasma gondii*) and helminths (e.g., liver and intestinal flukes, *Fasciola* spp., *Paragonimus* spp., *Echinococcus* spp., *Taenia* spp., *Angiostrongylus* spp., *Anisakis* spp., *Ascaris* spp., *Capillaria* spp., *Toxocara* spp., *Trichinella* spp., *Trichostrongylus* spp.), have accompanied the human species since its origin and their spread has often increased due to their behavior. Since both domesticated and wild animals play an important role as reservoirs of these pathogens the increase/decrease of their biomasses, migration, and passive introduction by humans can change their epidemiological patterns. It follows that globalization and climate change will have a tremendous impact on these pathogens modifying their epidemiological patterns and ecosystems due to the changes of biotic and abiotic parameters. The consequences of these changes on foodborne parasites cannot be foreseen as a whole due to their complexity, but it is important that biologists, epidemiologists, physicians and veterinarians evaluate/address the problem within a one health approach. This opinion, based on the author's experience of over 40 years in the parasitology field, takes into consideration the direct and indirect effects on the transmission of foodborne parasites to humans.

1. Introduction

Foodborne parasites (FBPs) most of which are zoonotic, are distributed worldwide often due to their spread by humans (Dorny et al., 2009; Gajadhar, 2015; Robertson et al., 2014, 2018). The occurrence of some of these pathogens, such as liver and intestinal flukes, *Gnathostoma* spp. and *Paragonimus* spp., may be limited as a result of their complex cycles, which may include two intermediate and a final host (Chai, 2007; Keiser and Utzinger, 2009; Sithithaworn et al., 2007). Human infection with FBPs is directly linked with eating and cultural habits, livestock and wildlife management, environmental resources and population income.

In the last few decades, improvement in animal husbandry, hygiene conditions and detection and control methods, strongly reduced or eradicated the prevalence of FBPs in industrialized countries and in some developing countries. However, the reduction trend is not uniform for all FBPs and there are countries where the prevalence of these infections in humans is still high.

Globalization and climate change cause epochal migration of human populations (United Nations, 2017), a reduction in animal species and habitat variability and have variable impact on FBSs. The aim of this opinion, based on my experience of over 40 years in the parasitology field, was to highlight the impact of globalization and climate change on the epidemiology and transmission of FBPs. There are several human behaviors and physical factors related to climate change and their interactions are complex; consequently, it is difficult to define what the final impact would be. However, prevention and control programs, will need to consider how much these factors can increase/decrease the prevalence of FBPs in order to better address future control strategies.

2. Key factors favoring the perpetuation and transmission of human foodborne parasites

Most of FBPs are linked with old and poor farming practices and/or to wildlife. Subsistence agriculture occurs when farmers grow food crops and livestock to feed themselves and their families. In these situations, farm output is targeted to survival and is mostly for local requirements with little or no surplus trade. These farmers, through their inappropriate practices, can favor the transmission, among others, of liver and intestinal flukes, *Echinococcus granulosus sensu lato*, *Taenia* spp., *Angiostrongylus cantonensis*, *Capillaria philippinensis*, *Trichinella* spp., *Trichostrongylus* spp. and *Toxoplasma gondii* (Aguirre et al., 2019; Barratt et al., 2016; Chai and Jung, 2019; Pozio, 2014, 2015a; Saichua et al., 2008; Weka et al., 2019; Wen et al., 2019).

In a subsistence agriculture, there is a strict mingling between

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humans and animals, and most of the products of animal and human origin including scraps, offal, feces, and fur, are used by/for humans or animals. This has, over the millennia favored the spread of FBPs. For example, the highest incidence of cystic echinococcosis in humans, due to *E. granulosus sensu stricto*, occurs where there is a close association between man, sheep and dogs (Wen et al., 2019). A common source of infection for dogs is offal from infected sheep. The cohabitation with dogs and feeding of uncooked viscera is a known risk factor for human infection. In recent years, we are witnessing both the detection of high rates of echinococcosis in humans by ultrasound-based surveys (Tamarozzi et al., 2018) and a reduction of infection in young age groups, even in the presence of very high rates of ovine infections, suggesting that the improvement of hygiene practices (e.g., frequent hand washing, fewer contact with sheepdogs, greater attention to the washing of vegetables to be eaten raw) reduce the risk of parasite transmission to humans.

In developed countries, a combination of factors such as the rearing of the majority of pigs in closed pigsties, the use of controlled feed, veterinary controls at the slaughterhouses, and the use of latrines with efficient sewage systems, led to eradication of *Taenia solium*. The risk factors for human cysticercosis are closely associated with the characteristics of smallholder or backyard pig farming systems prevalent in poor world regions. Poverty and the lack of proper educational programs and of political incentive will continue to militate against successful eradication (Weka et al., 2019).

Although fasciolopsiasis and gastrodiscoidiasis can be controlled along with other FBPs, fasciolopsiasis still remains a public health problem in many endemic areas despite sustained WHO control programs. Fasciolopsiasis has become a re-emerging infection in recent years and gastrodiscoidiasis, initially considered to be restricted to Asian countries, has been reported from Africa (Mas-Coma et al., 2005).

The lack of appropriate educational programs for hunters and fishermen can favor transmission of meat and fishborne parasites. 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 of *Trichinella* spp. (Pozio and Murrell, 2006) and *T. gondii* (Guo et al., 2015). Fishermen frequently throw freshwater fish away on the shores of lakes and pools because of their low economic value or if they are too small (Pozio et al., 2013). Furthermore, restaurants in lake areas improperly dispose of leftovers. In both scenarios, the fish are eaten by stray cats and dogs favoring the spread of liver flukes (Pozio et al., 2013). The fishing industry and fishermen are responsible for the risk derived from the practices of waste elimination from fishing vessels (i.e. throwing the waste into the sea) favoring the transmission of Anisakidae and Raphidascarididae worms to fish (Pozio, 2013).

The increase in human population density in megacities results in a high level of both environmental and water contamination with protozoa such as *Cryptosporidium* spp., *Giardia duodenalis*, *Entamoeba* spp., and *Cyclospora cayetanensis* (Ahmed et al., 2018; Giangaspero and Gasser, 2019; Jones and Dubey, 2010). The increasing difficulties in water supply, especially for drinking water, will represent a major challenge for future generations. Wastewater reuse systems have often proven to be inefficient in preventing the passage of pathogenic protozoa in countries with no or inadequate water treatment plants (Cacciò et al., 2003).

3. Climate change and foodborne parasites

Climate change has a direct influence on FBP lifecycles increasing/decreasing the survival of parasite stages in the environment as well as affecting the biology of their hosts (Froeschke et al., 2010). Increased humidity favors the survival of parasite eggs, larvae and cysts/oocysts. Increased temperatures accelerate parasite development in the environment and in ectothermic hosts, but shorten the survival of parasite eggs, larvae, cysts and oocysts (Semenza et al., 2012; Knapp-Lawitzke et al., 2016; Mignatti et al., 2016) Increased temperature could favor the establishment in temperate regions of foodborne parasites currently prevalent in tropical areas such as *C. cayetanensis* (Semenza et al., 2012). Rainfall intensity increases the spread of eggs, oocysts and cysts through contaminated water (Jiménez et al., 2010). Increased drought periods reduce the survival of parasite eggs, larvae, oocysts and cysts, but increases their concentration in water. The reduction of good quality water resources increases the risk of outbreaks due to the consumption of low quality water.

Trichinella britovi larvae survive longer in carcasses beneath than in those above the snow. The stability of the environment beneath the snow favors the survival of *T. britovi* larvae in host muscles, increasing the probability of their transmission to other hosts; whereas, the environment above the snow, characterized by sudden temperature variations, results in strong environmental stress for larvae in host carrions thus causing their death (Rossi et al., 2019). During the past 60 years, there has been a significant reduction in *T. britovi* prevalence in red foxes from the Alps (from 20% to 35% in the fifties to 0.0%–0.01% in the last years) (Marazza, 1960; Rossi et al., 2019). At the same time, the snow depth and snow cover in the Alps showed a significant decrease (Marty, 2013; Scherrer et al., 2004).

4. Change of biomasses

From 1900 to 2016, the biomass of wild animals has been reduced by four times while the biomass of domestic animals has increased by about three and a half times and that of man by about four times (Fig. 1). The diversity of ecosystems is declining fast. Wild and domesticated plant and animal species, including domesticated breeds, are reducing or extinguishing. This loss is a direct result of human activity and constitutes a direct threat to human well-being worldwide (Smil, 2011).

Three-quarters of the land-based environment and about two-thirds of marine environment have been significantly altered by human actions (Di Marco et al., 2018). On average, these trends have been less severe or avoided in areas held or managed by indigenous peoples and local communities (Watson et al., 2018). More than a third of the world's land surface and nearly 75% of freshwater resources are now devoted to crop or livestock production (Di Marco et al., 2018). Urban areas have more than doubled since 1992 (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019).

5. The environmental impact of food animals

Raising animals for food requires massive amounts of land, food, energy and water. Globally, livestock is responsible for more CO_2 production than all the world's transportation systems combined (Poore and Nemecek, 2018). An enormous amount of water is needed to grow

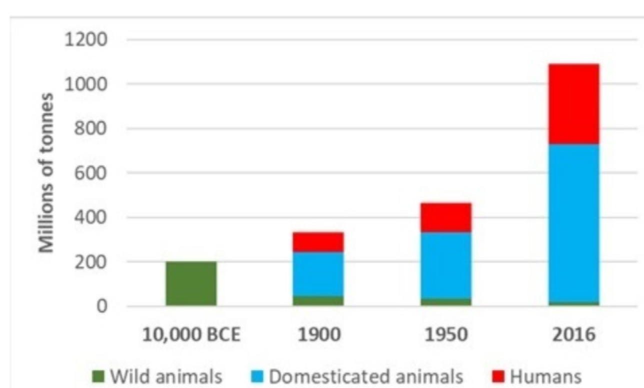

Fig. 1. Changes of terrestrial vertebrate biomass in the last 12,000 years according to Smil (2011).

Table 1
Influence of globalization and climate change on foodborne parasites. Most of the issues reported in this table refer more to developed than to undeveloped countries.

Foodborne Parasites	Globalization		Climate change	
	Issues favoring the increasing prevalence of human infections	Issues favoring the decreasing prevalence of human infections	Issues favoring the increasing prevalence of human infections	Issues favoring the decreasing prevalence of human infections
Cyclospora cayetanensis *Cryptosporidium* spp. *Giardia duodenalis*	• Increase number of travelers		• Reduction of drinking water resources • Increased use of waste water for watering vegetables	• Reduction of oocyst survival in the environment due to higher temperatures and longer dry periods
Toxoplasma gondii	• Introduction of atypical strains from endemic to non-endemic countries	• Increased knowledge of the problem • Increased consumption of industrial pigs	• Reduction of drinking water resources • Increased use of waste water for watering vegetables	• Reduction of oocyst survival in the environment due to higher temperatures and longer dry periods
Ascaris spp. *Trichiuris trichiura*		• Increased personal hygiene • Increased appropriate dispose of human feces	• Reduction of drinking water resources • Increased use of waste water for watering vegetables	• Reduction in the use of manure of human origin to fertilize vegetable gardens • Increasing use of latrines and WC
Trichinella spp.	• Illegal meat importation • Introduction of new eating habits • Introduction of alien host species	• Increase of pigs raised under high containment level	• Increase of wild boar populations	• Reduction of survival time of larvae in host carrions • Reduction of wild habitat
Echinococcus granulosus s.l.	• Immigration of shepherds from endemic to non-endemic countries	• Increased personal hygiene practices	• Washing away of pasture • Increasing use of wastewater • Reduction of drinking water	• Reduction of eggs survival in the environment due to higher temperatures and longer dry periods
Echinococcus multilocularis	• Introduction of infected dogs from endemic to non-endemic areas	• Increased personal hygiene practices	• Increase in rodent populations in urban and peri-urban areas	• Reduction of eggs survival in the environment due to higher temperatures and longer dry periods
Liver flukes	• Importation of infected fish • Introduction of new eating habits	• Increase consumption of freshwater fish from industrial farms • Reduction of consumption of wild freshwater fish	• Reduction of good water resources	
Fasciola spp.	• Importation of infected animals from endemic to non-endemic countries	• Increase control of the infection	• Increase of flooded areas due to increased torrential rains	• Reduction of the survival of cercariae due to longer dry periods
Taenia saginata	• Importation of infected cattle from endemic to non-endemic countries • Increase of persons defecating on cattle pasture	• Increased controls of cattle for international market	• Increase use of low quality water to water cattle	• Reduction of eggs survival in the environment due to higher temperatures and longer dry periods
Taenia solium	• Increase movement of persons from endemic to non-endemic countries	• Decrease production of backyard and free-ranging pigs • Increase use of latrines inaccessible to pigs		• Reduction of eggs survival in the environment due to higher temperatures and longer dry periods

Table 2
Water consumption for the production of 1 kg meat of the most common type of meat and their future production.

Animal species	Water consumption (L) for 1 kg meat production	The future of meat
Chicken	1,000	Increased production
Pig	6,000	Increased production
Beef	16,000	Decreased production in proportion of the total meat production at the global level

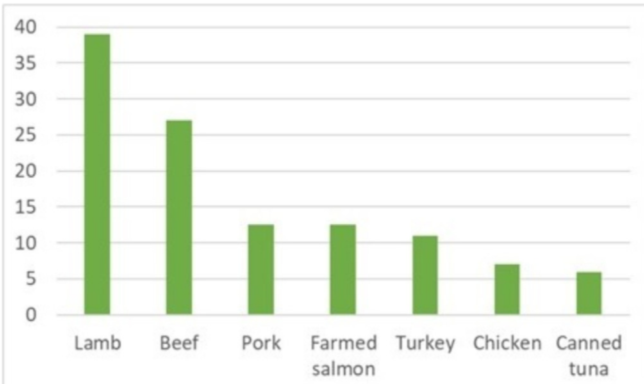

Fig. 2. Carbon dioxide production (kg) per kg of produced meat.

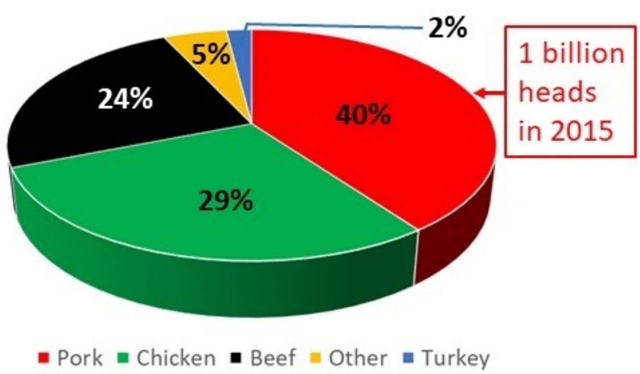

Fig. 3. Most widely eaten meat in the world.

crops for animals to eat, clean factory farms, and give animals water to drink (Gerbens-Leenes et al., 2013). A single cow used for milk can drink more than 200 L of water per day, or twice that amount in hot weather, and it takes about 600 L of water to produce just 1 L of milk. It takes about 16,000 L of water to produce 1 kg of beef. Since the production of chicken and pig meat requires much less water and produces much less carbon dioxide than beef (Table 2; Fig. 2), in the future, there will be a strong increase in chicken and pig production; consequently, beef production will decrease in terms of percentage of the total meat produced worldwide (Fig. 3).

6. Introduction of alien host species

In the last century, 44 alien mammalian species reached Europe, including several carnivores, such as the American mink (*Neovison vison*), the raccoon (*Procyon lotor*), the raccoon dog (*Nyctereutes procyonoides*), and the jackal (*Canis aureus*), all of which are good hosts of *Trichinella* spp. and *T. gondii* (Cybulska et al., 2018; Kärssin et al., 2017; Pozio, 2015b; Shamsian et al., 2018; Széll et al., 2013). Although the introduction of alien species in Europe has mainly occurred during Neolithic times, a marked increase in the rate of invasions has been noted since the beginning of the 20th century (Genovesi et al., 2012). There is a need to consider not only species introduced from one to another continent, but also the species that have colonized new areas of the same continent. The introduction of central European wild boar (*Sus scrofa*) breed to southern Europe by hunting associations, due to its greater reproductive rate and larger size, is a good example. This introduction created considerable damage to the environment and favored the transmission of pathogens such as *Trichinella* spp. and *T. gondii*. In addition, mild winters, reforestation, intensification of crop production, supplementary feeding and a stable or declined number of hunters, since hunting is the main cause of mortality for this species, have contributed to increase the biomass of this ungulate throughout Europe (Massei et al., 2015).Table 1.

7. Changes of animal behavior and population growth

Species of mammals and birds with a more versatile behavior and a wider trophic spectrum are colonizing peri-urban and urban areas where they find abundant trophic resources than those present in the wild environment. The adaptation to anthropized environments influences the diet and the feeding behavior of these vertebrates preventing *Trichinella* spp. transmission or reducing that of *T. gondii* (Pozio and Murrell, 2006).

In Europe, during the last decades, the protection of large carnivore mammals such as the lynx (*Lynx lynx*), bear (*Ursus arctos*), wolf (*Canis lupus*) and wolverine (*Gulo gulo*), resulted in an increase in their populations. Since these carnivores are at the top of the food chain, *Trichinella* spp. biomass in these animal species has consequently increased. In Europe, the reduction of agricultural areas, the increase in environmental temperature with mild winters, the increase in trophic availability linked to the human environment and the increase of wild boar populations across Europe (Massei et al., 2015), have all favored the occurrence of outbreaks of trichinellosis caused by the consumption of wild boar meat (European Food Safety Agency, 2018). In developed countries, the huge increase of pet animals, especially dogs and cats, can be a source of FBPs if they are not properly reared. In fact, dogs and cats of peri-urban and residential outskirts wandering and feeding on garbage and rodents can favor the transmission of *Echinococcus multilocularis*, *Toxocara* spp. and *T. gondii* to humans.

In Western countries, the seroprevalence of *Toxocara* spp. infections varies between 2% and 5% in urban areas, between 15% and 20% in semi-rural zones such as residential outskirts of large cities and peaks at 35%–42% in rural areas. Factors that have been associated with an increased rate include low socioeconomic status and poor environmental hygiene (Macpherson, 2013). These factors could possibly be exacerbated by warm climates, i.e. those favored by global warming.

8. Impact of globalization on meat and fish borne parasites

Most of meat and freshwater fish borne human parasitic infections occur in poor and disadvantaged areas of the world. Industrial livestock and fish farms appear to be exempt from foodborne zoonotic parasites. These scenarios explain why the impact of globalization on meat and fish borne parasites can be considered relatively low. However, several examples explain why there is a need to remain vigilant and implement both prevention and control methods. The movement of people from one to another continent can represent the way of introduction of FBPs by personal baggage. Meat and meat derived products of pig origin and bush meat have been detected in personal baggage of persons from Africa and Asia at France, Swiss and German airports (Chaber et al., 2010; Falk et al., 2013; Beutlich et al., 2015).

In recent years, atypical *T. gondii* strains from South America were detected in humans in Europe (Elbez-Rubinstein et al., 2009). These strains can infect individuals already carrying the three known European genotypes. It therefore follows that a pregnant woman who is IgG-positive for *T. gondii* cannot be considered risk-free of being reinfected by the atypical *T. gondii* strains from South America. These atypical strains may have been introduced through the importation of horsemeat from South America into France, where people frequently eat this meat raw (Elbez-Rubinstein et al., 2009).

8.1. *Trichinella*

Since nematodes of the genus *Trichinella* are mainly circulating among wildlife and backyard or free ranging pigs, these pathogens do not represent a great concern for the international meat trade. From the fifties to today, according to the international literature, there are only 43 reports describing the importation of *Trichinella* spp. infected animals or meat by the international trade to Europe. Most (60%) of these reports refers to live horses or their meat, 18.6% to pigs, 4.7% to wild boars and 14.3% to bears. In contrast, the scientific literature is reach of reports on meat from pigs, wild boar and bears, illegally introduced in personal baggage causing trichinellosis outbreaks in several European countries (Pozio, 2015a,b).

8.2. *Opisthorchis*

An outbreak of acute opisthorchiasis occurred in a family in Israel, a non-endemic area, after eating raw carp illegally imported from Siberia (Russia) where *Opisthorchis felineus* is widespread in several species of freshwater fish. With the growing numbers of immigrants from endemic to non-endemic countries, physicians need to be alert regarding *Opisthorchis*-associated pathology in these populations (Yossepowitch et al., 2004). In Thailand, regional origin and raw-fish eating habits are the variables affecting the prevalence of *Opisthorchis viverrini* infections (Pumidonming et al., 2018).

9. Introduction of new food habits

Opisthorchis felineus was first described in Italy at the end of the 19th century. However, no human cases were documented until 2003, when the consumption of raw tench fillets began to be popular. More than 200 human infections were described in 9 years (2003–2011) among Italians and foreign tourists, who acquired the infection in Italy and developed the disease when they went back home to Austria and The Netherlands (Pozio et al., 2013). Opisthorchiasis is a serious disease; indeed, chronic and untreated infections can result in the development of cholangiocarcinoma (Sripa et al., 2018).

In Romania, the prevalence of trichinellosis in humans and the prevalence of *Trichinella* spp. infections in pigs are inversely correlated. In Transylvania in the north of the country, the prevalence of this zoonotic agents in pigs is lower than the prevalence in pigs of the southern part of Romania. However, people from Transylvania, most of which are of German origin, consume larger amount of raw pork and raw pork derived products than people of the rest of the country (Blaga et al., 2007).

From 1975 to 2005, trichinellosis outbreaks involving hundreds of individuals and caused through horsemeat consumption were documented only in France and Italy, where horsemeat is usually eaten raw. In Italy, raw horsemeat is consumed mainly in Lombardy and Emilia-Romagna regions in the north and Apulia region in the south, where this food habit was introduced by French colonists (Pozio, 2015a,b).

10. Impact of globalization on the international trade of vegetables and fruits

Fruits and vegetables can be contaminated with *Cryprosporidium* spp., *C. cayetanensis* and *T. gondii* oocysts, *G. duodenalis* and *Entamoeba* spp. cysts, and worm eggs. Today, the ecological context of food encompasses the planet, as food commodities are traded across the globe. Among FBPs, *Cryptosporidium* spp. and *C. cayetanensis* were the cause of important outbreaks in North America due to the importation of contaminated vegetables (e.g., mesclun, salad, coriander, basil, garlic, watercress, leafy herbs, sugar snap peas, and lettuce) and fruits (e.g., raspberries, berry juice, berry desserts) from tropical areas. In these regions, hygienic conditions are unfavorable, contaminated wastewater is used to water vegetables and fruits and the personal hygiene of pickers is low (Dawson, 2005; Giangaspero and Gasser, 2019; Robertson and Chalmers, 2013).

11. Urbanization

Today, 55% of the world's population lives in urban areas with the highest percentage (83%) in North America and the lowest percentage (43%) in Africa (United Nations, 2018. Department of Economic and Social Affairs. www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html). In urban areas of megalopolises of not industrialized countries, the higher concentration of humans, the dissolution of social structure, lack of sanitation, controlled water supply and sewerage system, increased the risk of foodborne protozoa transmission (e.g., *Cryptosporidium* spp., *C. cayetanensis*, *G. duodenalis*, *Entamoeba* spp., *T. gondii*).

People with chronic FBP infections (e.g. echinococcosis, opisthorchiasis) acquired when they lived in rural areas of endemic regions years before, who emigrated to urban areas, may not be properly diagnosed and treated due to the poor knowledge of these diseases by physicians.

12. Carnivore populations from wild to urban areas

Wild populations are strongly limited by environmental factors such as increased urban areas and climate change. Urban and periurban areas are characterized by an abundance of roads, habitat fragmentation and altered climate (e.g. temperature, light, rainfall and water runoff). As a result of these factors, several carnivores, e.g. the red fox, coyote, jackal, badger, stone marten, raccoon and raccoon dog, have become established in many cities of the world feeding on anthropogenic food sources and achieving higher population densities than are found in the wild environment (Parsons et al., 2018). Others, like bobcat and mountain lion, are negatively affected by urbanization (Ordenãna et al., 2010). Other larger carnivore species such as bears, hyenas and wolves, exploit the food sources arising from the urban environment (Carter and Linnell, 2016). The populations of these wild carnivores that have colonized the urban and periurban environment, are increasing due to abundant feed resources, lack of hunting pressure and of predators (Bateman and Fleming, 2012). In the urban environment, some FBPs such as *E. multilocularis*, *Baylisascaris procyonis* and *Toxocara* spp. can be easily transmitted representing a serious health problem for the human population (Deplazes et al., 2004; Otranto and Deplazes, 2019).

13. Foodborne parasites and immigrants

The burden of FBPs due to immigrants moving from developing to industrialized countries can be considered quite low, since most of the immigrants belong to a fairly medium social class in their countries of origin. The intestinal parasite burden (e.g., that of *Ascaris lumbricoides*, *Trichuris trichiura*, *Entamoeba* spp.) reduces in a few months due to the lack of reinfection, immune response and appropriate treatment.

However chronic infections such as cystic echinococcosis, opisthorchiasis and fascioliasis, although rare, can represent a problem for physicians, since most of them are not aware of the epidemiology, clinical patterns, diagnosis and treatment of these infections.

Cultural practices of immigrants can favor the transmission of FBPs. Slaughtering sheep in the field and feeding dogs their infected offal is practiced across the world and can increase the transmission of *E. granulosus sensu lato*.

In addition, in developed countries, there is a decrease in the availability of anti-parasitic drugs on the EU market due to the lack of economic interest of pharmaceutical companies. For example, in Italy, triclabendazole, praziquantel and ivermectin for humans are not on the market and niclosamide is available only upon request.

14. Prevention and control of foodborne parasites in the globalization and climate change era

At the global level, there are millions of people living in industrialized countries who have access to food with a low FBP risk. At the same time, there are millions of people who still survive by a subsistence agriculture at high risk for FBP. Therefore, international food and health organizations need to provide consolidated safety guidelines for important foodborne parasites to populations living in poor and disadvantaged areas. The integration of veterinary, environmental and public health efforts, i.e. the one health concept, must be encouraged and supported (Trevisan et al., 2019). Physicians, biologists and veterinarians must be appropriately trained on FBPs. Native and immigrant populations of consumers, farmers, hunters, and fishermen must be educated and policy makers must be appropriately informed. Wastes of animal origin, control of drinking water resources and improvement of terrestrial and sea/freshwater animal husbandry, should be improved and adequate financial resources must be allocated.

In recent decades in industrialized countries, we are witnessing a sharp reduction in skills in morphological identification of macroscopic and microscopic FBPs at the university level, research institutes and dedicated funding (Bruschi, 2009). This represents a further problem that will add to the ecosystem alterations caused by globalization and climate change.

15. Conclusions

The interaction of human and environmental factors influence the epidemiology of FBPs both favoring and reducing their prevalence. In general, it can be considered that all FBPs for which wild animals represent the most important reservoir, e.g. *Trichinella* spp., will suffer a reduction due to the reduction of wild animals and to their changed feed behavior as reported above. In contrast, the prevalence of protozoa transmitted mainly by environmental contamination or food including water, will greatly increase creating health problems especially in the poorest regions of the planet.

Presently, no new drugs to treat FBPs in humans are available. There is no known effective drug against cryptosporidiosis. Anti-*Toxoplasma* drugs are not active against tissue cysts. The drugs used today for the treatment of alveolar and cystic echinococcosis are only parasitostatic and not parasitocidal. Translational medicine shows that there is a 17-year innovation adoption curve from discovery into accepted standards of practice and the lack of innovation adoption planning in the discovery process (Morris et al., 2011). Even if an innovation is accepted as a standard of practice, patients have a 50/50 chance of receiving appropriate care. It follows that there is an urgent need to invest funds for the development of new drugs.

There is also the urgency to develop new diagnostic tools to identify animals with active tissue cysts of *T. gondii*, to unequivocally diagnose cystic and alveolar echinococcosis and to trace FBPs from fork to farm.

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