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Parasitología Médica y/o Veterinaria: Revisión

Linking family farming to endoparasites implicated in public health: a review of current health discussions.

BRUNO FITTE [1*], CARINA BASSET [1*], MARÍA LAURA GOS [1],
MARÍA DEL ROSARIO ROBLES [2], JUAN MANUEL UNZAGA [1]

[1] Laboratorio de Inmunoparasitología (LAINPA), FCV-UNLP, La Plata, Argentina.
[2] Centro de Estudios Parasitológicos y de Vectores (CEPAVE-CONICET-UNLP- asociado a CICPBA), La Plata, Argentina.

*Due to their contributions, Bruno Fitte and Carina Basset should be considered as first authors.

*Corresponding autor:
Dr. Bruno Fitte. Laboratorio de Inmunoparasitología, Universidad Nacional de La Plata, Facultad de Ciencias Veterinarias, calle 60 y 118 (1900) La Plata, Argentina. Tel: + 54 221 4249621; fax: + 54 221 4257980.
Email address: brunofitte@cepave.edu.ar

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Summary

Family farming is essential in relation to food security, generation of employment, mitigation of poverty and conservation of biodiversity. Many governments have considered it a sector of indigence and degradation, adopting an agro-export model, which contributed to deepening inequality. Since 2000 decade, many countries started to include family farmers in their agenda. Only a few surveys have linked family farming to endoparasites, including zoonotic species. The aim of this paper was to review the records available of helminths, focusing on those with sanitary implication, and the protozoa *Toxoplasma gondii*, *Neospora caninum* and *Cryptosporidium* spp. Collection of data based upon literature available. Helminths with sanitary risk recorded were *Ascaris* spp., *Capillaria* spp., *Enterobius vermicularis*, *Fasciola* spp., *Hymenolepis* spp., *Schistosoma* spp., *Taenia* spp., *Toxocara* spp. and *Trichuris* spp., with prevalence values 0.1 to 95.8%. Three protozoa taxa were recorded, with prevalence values 1.4 to 70%. There is a common concern regarding the sanitary conditions that prevail in family farming system. It is necessary to create the conditions for family farmers to have access to information and education on safe food practices. Governments are called to correct this situation, promoting social integration and economic development, taking into account the particularities of each area.

Introduction

There is a broad agreement about the importance of family farming in food security, generation of agricultural employment, mitigation of poverty, conservation of biodiversity and cultural traditions(1). Nevertheless, at a global level, the establishment of an accurate definition of family farming has proven to be a complex affair, mostly due to the socio-economic and cultural heterogeneity that characterize each area considered(1). However, some aspects are common among certain regions of the world, particularly the reliance on family labor to perform agricultural work and the management of the farm, as well as the recognition of the linkages between the farm's agricultural functions with its economic, environmental, reproductive, social and cultural aspects(2). For this review, we will consider the definition made in 2014 by the Food and Agriculture Organization of the United Nations (FAO) during a General Assembly where the "International Year of Family Farming" was declared: family farming (including all agricultural activities based on the family) is defined as a way of organizing agriculture, livestock, forestry, fishing, aquaculture and grazing, which is managed and operated by a family and that depends predominantly on family work, both women and men. The family and farm are linked, co-evolve and combine socio-economic and cultural factors(3). In this context, it is important to point out that in Latin America the concept "family farming" had not been officially recognized until 2004, with the creation of the Family Farming Specialized Meeting (REAF). Before that, and especially during the 1980´s and 1990´s, many governments had considered family farming as a sector of poorness and degradation, adopting an agro-export model which excluded family farmers from politics and programs, taking to an increase of inequity and deepening of inequality in the area(4). However, since the 2000 decade, many countries started to propose policies which included family farmers in their agenda; therefore, it is necessary to carry out different studies to characterize the particularities of the system in our area(3, 5). Many studies have been carried out in Latin America and in other areas of the world where family farming is an essential production model. However, only a few surveys have been linked to a topic of utmost importance in productive systems: endoparasites. It is known that helminthes and protozoa are the cause of big economic losses in agricultural systems, and include zoonotic species that represent sanitary risk for humans(6, 7). Helminthiasis is one of the most important causes of mortality and morbidity in tropical and sub-tropical regions of the developing world, especially where adequate water and sanitation are lacking(8, 9). A high number of species have been recorded as the cause of disease in humans and other animals, for example *Echinococcus granulosus*, *Enterobius vermicularis*, *Fasciola hepatica*, *Trichinella spiralis* and *Trichuris suis*(10). Some of the signs associated with helminth infections are anemia, diarrhea, weight loss, edema, recumbency, destruction of liver parenchyma, dead liver tissue, splenomegaly, unthriftiness, emaciation and even death(11). Moreover, a high number of protozoa have sanitary implication for humans and other animals, for example *Toxoplasma gondii, Neospora caninum, Cryptosporidium* spp., *Giardia* spp., *Plasmodium* spp. *Eimeria* spp. and *Trypanosoma* spp. Among these, the taxa included in this review were *Toxoplasma gondii, Neospora caninum, Cryptosporidium* spp., due to their worldwide distribution, as well as their sanitary and production implication. Toxoplasmosis is one of the most common parasitic zoonosis(12), is associated with congenital infection and abortion, and can cause encephalitis or systemic infections in the immunocompromised patients(13). The transmission is generally due to ingestion of raw / undercooked meat or offals (viscera) infected with cysts, food or water contaminated with sporulated oocysts, unpasteurized milk or by transplacental transmission of tachyzoites(12). *Neospora caninum* is also a parasite with a wide host range, and dogs and related canids are the definitive hosts. Neosporosis is considered one of the main causes of abortion in cattle(14). Moreover, *T. gondii* and *N. caninum* are considered an important cause of abortion in small ruminants and neuromuscular disorders in dogs[15-17]. *Cryptosporidium* spp. can infect mammals, birds, reptiles and amphibians[18]. This parasite causes debilitating gastrointestinal illness in animals and humans, with diarrhea as the main clinical symptom[19]. In humans the disease affects all ages and, although generally self-limiting, it can be severe or life threatening in some immune-compromised patients. Cryptosporidiosis can cause significant neonatal morbidity and productive losses in farmed livestock[20]. *Cryptosporidium* is transmitted through the ingestion of oocysts by several routes: person-to-person contact, contact with companion and farm animals, and ingestion of contaminated food and drinking or recreational water[21]. In this context, the aim of this work was to review the records available of helminths, focusing mainly on those with sanitary implication, for family farming in different regions of the world. In addition, the protozoa *T. gondii*, *N. caninum* and *Cryptosporidium* spp. were also included, due to their high implication in human and other animal's health.

Materials and Methods

The collection of data was based upon literature available. It included scientific publications, book sections and published theses. Literature research used the Google Academic and Dialnet, and Scopus databases, as well as available electronic data from surveillance systems all over the globe. Personal communications at congresses and conference reports were not included. Concerning the background and recognition of the concept "family farming" as we conceive it in this study, the time frame was restricted to studies between 1999 and 2020. The terms used for the search were "parasites-family farming", "helminths-family farming", "*Toxoplasma gondii*-family farming", "*Neospora caninum*-family farming", "*Cryptosporidium* spp-family farming", both in English and Spanish. The terms "samallholders" and/or "domestic" were also occasionally used for the search, because they are used as synonymous of family farming in some studies. Data collected was classified according to their geographical location, host species, parasite taxa and prevalence.

Results

Through this study, helminthes taxa with sanitary risk recorded were: *Ascaris* spp., *Capillaria* spp., *Enterobius vermicularis*, *Fasciola* spp., *Hymenolepis* spp., *Schistosoma* spp., *Taenia* spp., *Toxocara* spp. and *Trichuris* spp. All the taxa recorded are described in Table 1. In relation to Protozoa, the three species were recorded linked to family farming: *T. gondii*, *N. caninum* and *Criptosporidium* spp. (Table 1). *Toxoplasma gondii* was recorded in every continent with the exception of Oceania, where there was no data available. This species showed prevalence (P) values that ranged from 1.4 to 82.2%; *N. caninum* was recorded only in America, with prevalence values that ranged from 10.6 to 70%; and *Cryptosporidium* spp. was recorded in America and in Africa, with prevalence values that ranged from 10.2 to 32.2%.

Areas:

America: The data recorded belonged to Peru, Brazil and Argentina. Protozoa and helminths were registered in this region. With respect to helminths, different taxa were recorded in cattle, Creole goat, pigs, humans and Guinea pigs from Argentina, Brazil and Peru, with prevalence values that ranged from 0.1% to 95.6%. The most prevalent were of *Trichostrongylus* sp. (95.8%) in goats, *Paraspidodera uncinata* (83%) in Guinea pigs, *Blastocystis* sp. (58.9%) in humans and *Oesophagostomum* spp. (56.8%) in pigs. The helminths taxa with sanitary implication recorded were: *Trichuris* spp. in Argentina, Brazil and Peru; *Ascaris* spp. in Argentina and Brazil; *Blastocystis* sp., *Entamoeba coli*, *Enterobius vermicularis*, *Fasciola hepatica*, *Giardia lamblia* in Argentina; *Toxocara* spp. in Brazil; and *Capillaria* spp. in Peru (Table 2). The *T. gondii* records corresponded to studies conducted in chickens, dogs, goats, humans, pigs and turkeys from Argentina, Brazil and Peru, with prevalence values that ranged from 10.6% to 82.2%. *Neospora caninum* was reported in cattle from Brazil, with an overall prevalence of 10.6%, and in goats from Argentina with a prevalence of 70%. *Cryptosporidium* spp. was reported in cattle from Brazil, with prevalence values that ranged from 10.2% to 25.3%.

Africa: The data recorded belonged to Benin, Egypt, Ethiopia, Ghana, Kenya, Nigeria, Somalia, South Africa and Zimbabwe. *Toxoplasma gondii*, *Cryptosporidium* spp., and helminths were reported in this region. In relation to helminths, different taxa were recorded in chickens and goats from Somalia, Ghana and Nigeria, and in cats from Kenya, with prevalence values that ranged from 1.5% to 81%. The most prevalent were *Raillietina echinobothrida* (81%) and *Hymenolepis* spp. (66%) in chickens, *Trichuris suis* (50.6%) and *Ascaris suum* (44.5%) in pigs and *Strongyloides stercoralis* (43.7%) in cats. The helminths taxa with sanitary implication recorded were *Capillaria* spp. and *Hymenolepis* spp. in Ghana; *Dipylidium caninum* and *Toxocara cati* in Kenya; and *Ascaris* spp., *Trichuris* spp., *Taenia* spp. and *Schistosoma* spp. in Nigeria (Table 3). *Toxoplasma gondii* was reported in cats, chickens, ducks, goats, pigs, sheep and turkeys from all the countries mentioned except Somalia, with prevalence values that ranged from 1.4% to 67.2%. *Cryptosporidium* spp. was recorded in ruminants from Egypt, with an overall prevalence of 32.2%, and in cats from Kenya (40.8%).

	America	Africa	Asia	Europe
	Toxoplasma gondii	*Toxoplasma gondii*	*Toxoplasma gondii*	*Toxoplasma gondii*
Protozoos	*Cryptosporidium* spp.	*Cryptosporidium* spp.		
	Neospora caninum			
	Ascaris lumbricoides	*Acantocephala* spp.	*Ascaridia galli*	*Ascaris lumbricoides*
	Ascaris suum	*Acuaria hamulosa*	*Amoebotaenia cuneata*	*Enterobius vermicularis*
	Ascaris spp.	*Allodapa suctoria*	*Amoebotaenia sphenoides*	*Hymenolepis nana*
	Capillaria sp.	*Ancylostoma* spp.	*Bunostomum* spp.	*Taenia saginata*
	Enterobius vermicularis	*Ascaridia galli*	*Capillaria* spp.	*Trichuris trichura*
	Fasciola hepatica	*Ascaris suum*	*Chabertia spp*	
	Fasciola sp.	*Ascaris* sp.	*Cheilospirura hamulosa*	
	Hymenolepis nana	*Avitellina* sp.	*Choanotaenia infundibulum*	
	Haemonchus sp.	*Bunostomium* sp.	*Cooperia* spp	
	Hyostrongylus Rubidus	*Capillaria* spp.	*Davaniea proglottina*	
	Metastrongylus spp.	*Choanotaenia infundibulum*	*Fasciola sp.*	
	Nematodirus sp.	*Cotugnia* sp.	*Haemonchus* spp.	
	Oesophagostomun sp.	*Dypilidium caninum*	*Heterakis gallinarum*	
	Ostertagia sp.	*Gaigeria* sp.	*Hymenolepis carioca*	
	Paraspidodera uncinata	*Gongylonema* sp.	*Moniezia* spp.	
	Strongyloides stercolaris	*Gongylonema ingluvicola*	*Oesophagostomum* spp.	
	Strongyloides spp.	*Haemonchus* sp.	*Paramphistomum* spp.	
	Teladorsagia	*Heterakis gallinarum*	*Raillietina cesticillus*	
	Trichostrongylus colubriformis	*Heterakis isolonche*	*Raillietina echinobothrida*	
	Trichostrongylus sp.	*Hymenolepis* spp.	*Raillietina tetragona*	
	Trichuris suis	*Mediorhynchus gallinarum*	*Raillietina* spp.	
Helminths	*Trichuris spp.*	*Oesophagustomum dentatum*	*Strongyloides* spp.	
		Oesophagustomum sp.	*Trichostrongylus* spp.	
		Ostertagia sp.		
		Raillietina (Raillietina) tetragona		
		Raillietina (R.) echinobothrida		
		Raillietina (S.) cesticillus		
		Raillietina (Paroniella) sp.		
		Raillietina (R.) sp.		
		Raillietina sp.		
		Schistosoma sp.		
		Strongyloides avium		
		Strongyloides stercoralis		
		Strongyloides sp.		
		Subulura suctoria		
		Subulura strongylina		
		Taenia spp.		
		Tetrameres fissispina		
		Toxocara cati		
		Trichostronygylus tenuis		
		Trichostrongylus spp.		
		Trichuris suis		
		Trichuris spp.		

Table 1: Protozoa and helminths taxa recorded in each continent (1999-2020).

Study	Country / area	Host species	Parasite taxa	Parasite species / genus	Prevalence (%)	Methods
Silva Filho et al., 2012 (69)	Brazil	Dogs	Protozoa	*T. gondii*	79.1	Indirect Immunofluorescence Assay (IFA)
		Humans	Protozoa	*T. gondii*	82.2	
Cuervo et al., 2013 (33)	Argentina	Goats	Helminths	*F. hepatica*	32.9	Sheater's flotation technique, Ritchie's formol-ether concentration technique and Lumbreras technique
				Egg of Strongyloidea and Trichostrongyloidea	9	
				Nematodirus sp.	40.6	
				Trichuris ovis	2.3	
				Trichostrongylus sp.	95.8	
				Haemonchus sp.	3.1	
				Oesophagostomum sp.	0.9	
				Ostertagia sp.	0.1	
Garcia et al., 2013 (29)	Perú	Cuyes	Helminths	*Paraspidodera uncinata*	83	Stereoscopic microscope
				Trichuris spp	31	
				Capillaria spp	18	
				Trichostrongylus colubriformis	2	
Barboza et al., 2015 (53)	Brazil	Swine	Helminths	*Ascaris suum*	4.5	Sedimentation techniques Ritchie modified by Young et al. (88), centrifugal flotation Faust et al. (89); Centrifugal flotation Sheather modified by Huber et al. (90)
				Egg of Strongyloidea and Trichostrongyloidea	46.6	
				Trichuris suis	9	
Vilas Boas et al., 2015 (39)	Brazil	Cattle	Protozoa	*N. caninum*	10.6	Indirect fluorescent antibody test (IFAT) in accordance with Dubey et al. (91)
Suarez et al., 2015 (70)	Argentina	Goats	Protozoa	*T. gondii*	oct-20	IELISA
			Helminths	*Haemonchus sp.*	55.7	Counts of helminths eggs and oocysts per gram of fecal samples (hpg)
				Trichostrongylus sp.	43	
				Oesophagostomum sp	1.3	
Sá et al., 2016 (71)	Brazil	Turkeys	Protozoa	*T. gondii*	11	MAT
		Chickens	Protozoa	*T. gondii*	25.8	IFA
dos Santo Toledo et al., 2017 (49)	Brazil	Cattle	Protozoa	*Cryptosporidium parvum*	64	modified Ziehl-Neelsen staining method PCR/nPCR
				Cryptosporidium ryanae	12.5	
				Cryptosporidium bovis	6.3	
				Cryptosporidium andersoni	7.8	
Luyo et al., 2017 (52)	Peru	Swine	Protozoa	*T. gondii*	33.6	IELISA
Rodrigues Chaves, 2017 (72)	Brazil	Goats	Protozoa	*T. gondii*	31	Indirect hemagglutination (HAI)
Dodero et al., 2019 (73)	Argentina	Goats	Protozoa	*T. gondii*	16.2	ELISA - IFAT
Gómes de Araújo, 2019 (74)	Brazil	Swine	Helminths	Strongyloidea	15.5	Counts of Eggs Per Grass (EPG) and Oocyst Per Grass (OoPG) feces.
				Trichuris sp.	6.9	
				Ascaris sp.	0.6	
				Oesophagostomum sp.	56.8	
				Strongyloides sp.	43.1	
				Hyostrongylus sp.	18.1	
Gos, 2019 (75)	Argentina	Goats	Protozoa	*T. gondii*	39	IFAT
Principi, 2019 (76)	Argentina	Swine	Helminths	*Ascaris sp.*	49/29 farms	Observacion directa de huevos
				Trichuris sp.	6/5 farms	
				Oesophagostum Dentatum	13 farms	
				Hyostrongylus Rubidus	5 farms	
de Mattos et al., 2020 (54)	Brazil	Swine	Helminths	*Trichuris spp.*	3.7	Willis-Mollay Method
				Strongyloidea	2.8	
				Metastrongylus spp.	0.9	
				Strongyloides spp.	0.9	
				Ascaris spp.	43.2	
Falcone et al., 2020 (77)	Argentina	Humans	Protozoa	*Cryptosporidium* spp.	2.6	Modified Ritchie and Sheater
			Helminths	*E. vermicularis*	26	
				H. nana	1.1	
				A. lumbricoides	0.6	
				S. stercolaris	0.3	
Suarez et al., 2020 (27)	Argentina	Goats	Protozoa	*T. gondii*	48.2	IFI
				N. caninum	100	
			Helminths	*Fasciola* sp.	0.8-10.5	Eggs counts per gram of feaces (epg) and identifying genera by coproculture

Table 2: America: Protozoa (*Cryptosporidium* spp., *Neospora caninum* and *Toxoplasma gondii*) and helmiths recorded in family farming. Prevalence values and applied methods (1999-2020).

Study	Country / area	Host species	Parasite taxa	Parasite species / genus	Prevalence (%)	Methods
Terregino et al., 1999 (78)	Somalia	Chickens	Helminths	*Ascaridia galli*	26	Lactophenol clarification technique Carmine staining
				Subulura suctoria	45	
				Raillietina (Raillietina) tetragona	15	
				Raillietina (R.) echinobothrida	8.5	
				Raillietina (S.) cesticillus	2	
				Raillietina (Paroniella) sp.	25.5	
				Raillietina (R.) sp.	2	
				Raillietina sp.	8.5	
				Cotugnia sp.	2	
				Hymenolepididae	8.5	
				Mediorhynchus gallinarum	10.5	
El-Massry et al., 2000 (79)	Egypt	Turkeys	Protozoa	*T. gondii*	59.5	modified agglutination test (MAT)
		Chickens		*T. gondii*	47.2	
		Ducks		*T. gondii*	50	
Poulsen et al., 2000 (30)	Ghana	Chickens	Helminths	*Acuaria hamulosa*	25	Stereoscopic microscope
				Allodapa suctoria	20	
				Ascaridia galli	24	
				Capillaria spp	60	
				Gongylonema ingluvicola	62	
				Heterakis gallinarum	31	
				H. isolonche	16	
				Strongyloides avium	2	
				Subulura strongylina	10	
				Tetrameres fissispina	58	
				Trichostronygylus tenuis	2	
				Choanotaenia infundibulum	13	
				Hymenolepis spp	66	
				Raillietina cesticillus	12	
				R. echinobothrida	81	
				R. tetragona	59	
Van der puije et al., 2000 (80)	Ghana	Goats	Protozoa	*T. gondii*	26.8	ELISA - IFAT
		Sheeps		*T. gondii*	33.2	
Hove et al., 2005 (51)	Zimbabwe	Swine	Protozoa	*T. gondii*	35.7	ELISA - IFAT
Helmy et al., 2013 (46)	Egypt	Ruminants	Protozoa	*Cryptosporidium* spp	32.2	PCR-RFLP
		Humans		*Cryptosporidium* spp	49.1	
Gebremedhin and Gizaw, 2014 (38)	Ethiopia	Goats	Protozoa	*T. gondii*	15	IELISA
		Sheeps			31.4	
Nwoke et al., 2015 (11)	Nigeria	Goats	Helminths	*Ascaris sp.*	19	Simple floatation. Sedimentation method
				Trichuris sp.	12	
				Strongyloides sp.	39	
				Trichostrongylus sp	17	
				Oesophagustomum sp	24	
				Haemonchus sp	7	
				Bunostomium sp	3	
				Gaigeria sp	21	
				Gongylonema sp	23	
				Ostertagia sp	85.4	
				Avitellina sp	8	
				Taenia sp	13.1	
				Schistosoma sp	1.5	
Tonouhewa et al., 2018 (81)	Benin	Sheeps	Protozoa	*T. gondii*	1.4	IELISA
		Goats			53.6	
Tagwireyi et al., 2019 (82)	South Africa	Cats	Protozoa	*T. gondii*	31.6	Latex agglutination test
		Chickens		*T. gondii*	33.2	Latex agglutination test
		Goats		*T. gondii*	55.6	
		Sheeps		*T. gondii*	67.3	
		Swine		*T. gondii*	33.7	
Nwafor et al., 2019 (55)	South Africa	Swine	Helminths	*Ascaris suum*	44.5	McMaster technique. Baermann technique (92)
				Trichuris suis	50.6	
				Oesophagustomum dentatum	26	
Nyambura Njuguna et al., 2017 (83)	Kenya	Cats	Protozoa	*T. gondii*	7.8	PCR
				Cryptosporidium spp.	40.8	Kinyoun's carbol fuchsin and methylene blue stains
			Helminths	*Strongyloides stercoralis*	43.7	McMaster method. Sedimentation technique
				Toxocara cati	23.3	
				Ancylostoma spp.	1.9	
				Dypilidium caninum	8.7	
				Acantocephala spp.	1.9	

Table 3: Africa: Protozoa (*Cryptosporidium* spp., *Neospora caninum* and *Toxoplasma gondii*) and helmiths recorded in family farming. Prevalence values and applied methods (1999-2020).

Asia: The data recorded belonged to Bangladesh, India, Pakistan and Thailand. *Toxoplasma gondii* and helminths were reported in this region. In relation to helminths, different taxa were recorded in Bengal goats and chickens from Bangladesh and India, with prevalence values that ranged from 1.5% to 51.7%. The most prevalent helminthes were *Ascaridia galli* (29.6%) and *Raillietina cesticillus* (19.2%) in chickens, *Strongyloides* spp. (51.7%) and *Haemonchus* spp. (41.8%) in goats. The helminths taxa with sanitary implication recorded were: *Capillaria* spp. in both Bangladesh and India; and *Fasciola* spp. in Bangladesh (Table 4). *Toxoplasma gondii* was reported in goats and sheep from Pakistan and Thailand, with prevalence values that ranged from 27.9% to 44.1%.

Study	Country / area	Host species	Parasite taxa	Parasite species / genus	Prevalence (%)	Methods
Jittapalapong et al., 2005 (84)	Thailand	Goats	Protozoa	*T. gondii*	27.9	Latex agglutination test kits
Hassan et al., 2011 (36)	Bangladesh	Bengal goats	Helminths	*Strongyloides* spp.	51.7	Direct smear and flotation methods.Modified McMaster Counting technique
				Haemonchus spp.	41.8	
				Paramphistomum spp.	39.3	
				Trichostrongylus spp.	36.3	
				Oesophagostomum spp.	10.9 - 12.9	
				Bunostomum spp.	10.9 - 12.9	
				Fasciola sp.	10.9 - 12.9	
				Cooperia spp	10.9 - 12.9	
				Capillaria spp.	1.5 - 2	
				Moniezia spp.	1.5 - 2	
				Chabertia spp	1.5 - 2	
Katoch et al., 2012 (57)	India	Chickens	Helmints	*Ascaridia galli*	29.6	Necropsy of gastrointestinal tract. The helminth species were identified according to the description given by Soulsby (93)
				Heterakis gallinarum	24	
				Capillaria spp.	2.4	
				Cheilospirura hamulosa	1.6	
				Raillietina cesticillus	19.2	
				R. echinobothrida	13.6	
				R. tetragona	9.6	
				Amoebotaenia cuneata	4	
Shah et al., 2013 (85)	Pakistan	Goats	Protozoa	*T. gondii*	42.3	Indirect Haemagglutination Test (IHA)
		Sheeps			44.1	
Abdullah and Mohamedd, 2013 (86)	Irak	Chickens	Helminths	*Heterakis gallinarum*	81	Necropsy of gastrointestinal tract. The helminth species were identified according to the description given by Soulsby (93)
				Ascaridia galli	31	
				Cheilospirura hamulosa	8.62	
				Capillaria spp.	55.17	
				Raillietina spp.	1.72	
				Choanotaenia infundibulum	31	
				Amoebotaenia sphenoides	10.34	
				Hymenolepis carioca	6.9	
				Davaniea proglottina	3.45	

Table 4: Asia: Protozoa (*Cryptosporidium* spp., *Neospora caninum* and *Toxoplasma gondii*) and helmiths recorded in family farming. Prevalence values and applied methods (1999-2020).

Europe: The data recorded belonged to Czech Republic/Slovakia, Romania, Serbia and Turkey. *Toxoplasma gondii* and helminths were reported in this region. In relation to helminths, different taxa were recorded in humans from Czech Republic / Slovakia, with prevalence values that ranged from 1.2% to 11.6%. The helminths taxa with sanitary implication recorded were: *Ascaris lumbricoides, Enterobius vermicularis*, *Hymenolepis nana*, *Taenia saginata* and *Trichuris trichiura,* all of them in Turkey (Table 5). *Toxoplasma gondii* was reported in goats and rabbits from Romania, Serbia and Turkey, with prevalence values that ranged from 35.4% to 79.5%.

No data was recorded in Oceania.

Parasites

With respect to helminths, a high number of taxa were recorded. Many of these taxa correspond to endemic parasites from the different areas or to specific parasites from the different host species (Table 1). In this way, and according to the objective of the study, we focused on those taxa that represent sanitary risk. The taxa recorded with this implication were *Ascaris* spp., *Capillaria* spp., *Enterobius vermicularis*, *Fasciola* spp., *Hymenolepis* spp., *Schistosoma* spp., *Taenia* spp., *Toxocara* spp. and *Trichuris* spp.

The geohelminths *Ascaris* spp. and *Trichuris* spp. were recorded in America, Africa and Europe. The species *Ascaris suum* was recorded in America and

Study	Country / area	Host species	Parasite taxa	Parasite species / genus	Prevalence (%)	Methods
Koruk et al., 2010 (28)	Turkey	Children	Helmints	T. saginata	11.6	Saline and iodine preparations; formal-ethyl acetate concentrationunder 10x and 40x magnification
				H. nana	9.1	
				E. vermicularis	7.9	
				A. lumbricoides	6.7	
				T. trichura	1.2	
Iovu et al., 2012 (87)	Romania	Goats	Protozoa	T. gondii	79.5	ELISA
Djokic et al., 2014 (59)	Serbia	Goats	Protozoa	T. gondii	73.3	Modified agglutination test (94)
Numayerova et al., 2014 (88)	Czech Republic - Slovakia	Rabbits	Protozoa	T. gondii	35.4	ELISA

Table 5: Europe: Protozoa (*Cryptosporidium spp, Neospora caninum* and *Toxoplasma gondii*) and helminths recorded in family farming. Prevalenve values and applied methods (1999-2020).

Africa while *Ascaris lumbricoides* was recorded in Europe. However, according to Alves et al.[22] and Leles et al.[23], both cases seem to refer to the same species. *Ascaris* sp. is one of the most studied geohelminths in the world, and can produce massive infestations invading organs, ducts, and cavities[24, 25]. The environmental fecalism is the most important factor in acquiring this parasite and the diseases associated. It is hard to determine if the practices around family farming promote the development and circulation of this parasite.

Trichuris spp. infects around 465 million people worldwide, being especially prevalent where hygiene and sanitation are poor. The species *Trichuris bovis* is also associated with significant economic losses[26]. The records in America corresponded to *T. bovis* in Brazil, *T. ovis* in Argentina and *Trichuris* sp. in Argentina, Brazil and Peru (Table 2), while in Africa the records corresponded to *Trichuris* spp. in Nigeria. In both continents values of prevalence were low, relating the presence of the parasite mostly to environmental conditions[11, 27]. In Europe, *Trichuris trichiura* was recorded in migrant children from Turkey, relating the results to overcrowding households and to the lack of formal education of the parents[28], which is not a situation that represents other areas of the globe in the context of family farming, and more related in many cases with big urban centers.

Capillaria spp. was also recorded in three continents: America, Africa and Asia. In America the record corresponded to guinea pigs (*Cavia porcellus*) from Peru, with a significant prevalence of 18%, mostly taking into account that guinea pigs are one of the main hosts of *Capillaria* spp., a species with high sanitary implication[29]. In Africa *Capillaria* spp. was recorded in scavenging chickens from Ghana, registering one of the highest prevalence of the study (60%). Although the possible species in this case do not represent a sanitary implication for humans, they reflect an issue that needs attention in terms of the production system of the area[30]. In Asia, both in Bengal goats from Bangladesh and chickens from India, the prevalence was very low, concluding in these studies that the presence of the taxa might be related to environmental conditions.

Hymenolepis spp. was recorded in Africa, Asia and Europe, while *Taenia* spp. was recorded in Africa and Europe. With respect to *Hymenolepis* spp., the records from Africa and Asia would not represent sanitary implications for humans, mostly because in all cases the records belonged to chickens. The high prevalence of the taxa in Ghana (66%), as the study mentions, should be considered on strategies for pathology prevention in the production system[30]. In Europe the study was carried out in humans, and the species recorded was *H. nana* (P=9.1%)[28]. This is one of the species that causes hymenolepiasis, a widespread zoonosis, endemic in Asia, Southern and Eastern Europe, Central and South America, and Africa[31]. The study carried out in Europe, specifically in the Anatolia region, involved migrant children (similar situation to *T. trichiura*), and the presence of *H. nana* was related to living conditions and the lack of physical follow-up[28,32]. The same situation was presented for the cases of *T. saginata* (P=11.6%), and the nematode *E. vermicularis* (P=7.9%). In Africa, the records belonged to *Taenia* spp. from goats in Nigeria, where the parasite was found with prevalence of 13.1%. This was related to poor management and the climate conditions of the region[11].

Fasciola spp. was recorded in America and Asia. Concerning America, the species *F. hepatica* was recorded in goats from Argentina (P=33%), alerting about the role goats play in the transmission and dissemination of this zoonotic trematode[33]. The presence of this parasite represents a serious challenge to the health, welfare, productivity and of livestock throughout the world[34]. It is also considered a re-emerging neglected tropical disease associated with endemic and epidemic outbreaks of disease in human populations[35]. In Asia, the record of *Fasciola* spp. corresponded to goats from Bangladesh, with prevalence values of 10.9 - 12.9%. In this study the possibility of the record of *Fasciola hepatica* is raised, due to the fact that *F. hepatica* is an important parasitic infestation in goats from the ame area[36].

Regarding protozoa, it is important to highlight the record of *T. gondii* in every continent and in different host species, with prevalence values that ranged from 1.4 to 82.2%. This reflects the ability of *T. gondii* to reproduce and adapt to different kind of environments, and evidences the need of increasing control measures of this parasite that, although having such an adverse health effect for human and other animal species, is still neglected and underreported[37,38].

In the case of *N. caninum,* we registered only one study in Brazil[39] and one in Argentina[27] related to family farming, evidencing of the lack of information related to family farming and parasites. Most of the data available belongs to the presence of *N. caninum* in animals from agro-industrial systems and in wild animals, even in the same or close areas to the ones involved in the mentioned studies. For example, we found studies in wild animals from Kenya[40], cattle from Senegal[41], cattle and sheep from Tunisia[42], cattle from Paraguay[43], llamas from Peru[44], and stray dogs from Iran[45].

A similar situation was found regarding *Cryptosporidium* spp. Only one study from Brazil and one from Egypt were available. In both studies the taxa were identified in calves, and in Egypt it was also recorded in humans (species *C. hominis* and *C. parvum),* with higher levels of infection in children[46]. Again, taking into account that these taxa represent important implications in human and animal health, it is remarkable the lack of data published comparing to the same parasite in other contexts[47-49].

Discussion

The aim of this study was to review literature matching the concepts of family farming and different parasite taxa, which include helminthes and the protozoa *Cryptosporidium* spp., *N. caninum,* and *T. gondii*. During the search, we found that there is scarce literature published available, with most of the studies belonging to areas of the world considered since the end of XIX century to nowadays as underdeveloped. For example, the low number of studies related to *Cryptosporidium* spp. and *N. caninum* is a reflection of the lack of data published in comparison with studies of these parasites in other productive models. The same situation is represented in the case of helminth species that represent high implication in health and production, for example *F. hepatica* and *Taenia* spp. It is important to remark that this is far from being a coincidence, since developed countries have oriented food production to an agro-industrial system, with small family farms tending to disappear[50]. In the same way, underdeveloped countries gradually adopted (or were imposed) these strategies. Consequently, the family farming system became practically invisible regarding political programs and economical support[3]. Since the beginning of the 21st century family farming has recovered some attention, however there is still a lack of politics that tends to protect it. On the other hand, because family farming has been defined relatively recently, and its definition is still controversial, it is possible that some surveys may not have been included in this review.

Across the literature analyzed, there seems to be a common concern about the sanitary conditions that prevail in family farming, especially when considering parasitosis[11,38,51,52]. These conditions are mostly linked to poor sanitary and biosecurity measures[11, 53-55]. Some examples recorded are water contamination by feces of domestic and/or wild animals or by human sewage, poor hygiene, poor nutrition, low efficiency use of natural resources and poor agricultural management[56], low infrastructure, presence of other animals, feed crop residues, household waste[51,52,57], use of non-potable water for animal consumption and for cleaning the facilities[49,51,52], little or no sanitary management, as lack of veterinary care and anti-parasite limited control treatments[27,53,58,59]. All factors indicate characteristics that represent, in some way and from a hegemonic view, the underdeveloped side of the world, suggesting in most cases that the survival of the majority of family farms will depend on transformation rather than preservation[60]. As detailed in the bibliography recorded, it has been shown that these factors contribute to the transmission of microorganisms that can be responsible for human and other domestic and/or breeding animal diseases, and can cause heavy economical losses to farmers due to reduced productivity attributable to loss of appetite, poor growth rate in the infected animal, high cost of treatment, and even death[11,34,57]. However, others argue that these sanitary issues associated to family farming are not the main source of health dangers that we face nowadays. In this way, and accompanied by the current global situation, it is becoming apparent that the transmission of parasites and pathogens highly implicated in production losses and possible epidemics are linked mostly to modern farming practices and intensified systems, which, in most of the cases, under the excuse of higher food demands, pursue the goal of increasing the earnings of a very small sector of societies[61].

Thereby, studies support that agricultural intensification and habitat alteration play an essential role in the emergence and reemergence of infectious diseases by affecting ecological systems at landscape and community levels, as well as host and pathogen population dynamics(62). For example, intensification of livestock production facilitates disease transmission by increasing population size and density(62-65).

Although the intensity of the interface between wildlife, humans, and domestic animal species has always been dynamic, and all biological systems have an inherent capacity for both resilience and adaptation(66), the current pace of anthropogenic change and intensity of production systems could be too strong to allow system adaptation and overwhelm resilience(62).

Beyond the different existing points of view, oversimplification and general explanations for zoonosis emergence are not possible. Instead, the geographical diversity and complexity of systems requires local interdisciplinary studies to be conducted to generate locally relevant solutions(62). A priority for research therefore should be a holistic perspective on pathogen dynamics at the wildlife–livestock–human interface, based on an interdisciplinary approach to the examination of biological, ecological, economic, and social drivers of pathogen emergence. Investigations are required on the frequency and risks of pathogen flow between species, the mechanisms of amplification and persistence, the influence of different livestock production systems, and the socioeconomic context, to identify possible interventions to reduce pathogen emergence, as well as more effective strategies for responding to such events.

Moreover, nowadays food production and consumption are disconnected from ecological and social systems. In order to meet the needs of present and future generations, it is essential to protect sustainable food and agriculture systems that can simultaneously provide economic and social opportunities, while protecting the ecosystems upon which agriculture depends and respecting the cultural and social diversity of territories(67). In this context, questioning the current dominant production model, and taking into account climate change and environmental disasters, family farming is presented as a possible way to produce safe and sustainable food.

Therefore, it is necessary to create the conditions for family farmers to have access to information, education and communication on safe food practices, also to improve sanitation and veterinary public health measures to decrease transmission rates and reduce risk of infection, and to help extension agencies for the implementation of these programs.

Thus, government institutions are called to provide solutions for situations of inequity that have been growing dramatically, designing and implementing actions aimed at promoting the social integration and economic development of this sector taking into account the particularities of each area.

This necessarily implies having an institutional framework aimed at development and inclusion of family farming, which systematically addresses the main obstacles to its development(68). For example, notions such as self-reliance and local equivalents of Local Economic Development (LED) appear to be options available to these vulnerable sectors, who seem to have been almost abandoned by the western - dominated global economy.

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