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Economic Losses Caused by Foodborne Parasitic Diseases

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Abstract

Fragmentary data indicate that zoonotic parasites cause human illnesses with medical costs and productivity and disability losses totalling billions of dollars annually. Food is an important vehicle for some of these parasitic diseases. The cost to public health is not reflected in the priorities given to these parasitic diseases in either research or public health planning. In this article, Tanya Roberts, Darwin Murrell and Suzanne Marks discuss the cost of toxoplasmosis, taeniasis, cysticercosis, trichinellosis and other foodborne parasitic diseases.

Worldwide economic losses caused by foodborne parasitic zoonoses are difficult to assess. The prevalence of specific parasites in the food supply varies between countries and regions, and data on prevalence are fragmentary. Dietary preferences and food preparation practices affect the probability of eating contaminated food. For example, consuming raw or undercooked meat, poultry or seafood increases risk. There are few studies estimating the costs of parasitic foodborne disease. Generally, these studies estimate medical costs and productivity losses due to worker illness or death, but may include different cost categories or use different methodologies and assumptions. This review summarizes the available human illness cost estimates of the following foodborne parasitic zoonoses: toxoplasmosis, taeniasis/cysticercosis, trichinellosis and opisthorchiasis. The cost estimates are fragmentary and are primarily for developed countries because of the lack of suitable economic data from other countries.

Costs of congenital toxoplasmosis

USA

In the USA, the human illness losses due to congenital toxoplasmosis have been estimated at US\$0.4–8.8 billion annually (the wide range reflects uncertainty about the number of infected babies)^{1,2}. In this report, we are taking a middle estimate of one case per 1000 live births, or 4179 US cases annually. Costs are calculated using Roberts and Frenkel's methodology¹ and updated to 1992 prices. Three types of cost are estimated: (1) medical

costs, (2) income losses, and (3) costs incurred by special education or residential care required as a result of a handicap caused by congenital toxoplasmosis.

Medical costs are incurred by those ill as infants and those with consequent visual impairment. For the 2% of cases who die, three weeks of intensive care hospitalization were assumed, at a cost of US\$55442 per case. For the 11% of cases who survive severe illness, two weeks in intensive care and two weeks in a regular hospital room were assumed, plus fees for physician services and pharmaceuticals, resulting in a total cost of US\$53072 per case. Diagnostic tests for sequelae were estimated at US\$3183 for each surviving child. The total medical costs are estimated at US\$45 million (Table 1).

Consequences of fetal/newborn infection with *Toxoplasma gondii* were estimated to result in severe mental retardation in 33% of cases, moderate visual impairment (53%), cross-eyed vision (20%), slight mental retardation (23%), moderate hearing loss in one ear (10%) and moderate mental retardation (17%).

Income losses due to impairment include working in a lower-skilled job for lower pay (than would an unimpaired individual), unemployment or death. The largest component of income loss was the reduced earning of persons born severely or moderately retarded because of fetal acquisition of toxoplasmosis. Conley (cited in Ref. 1) found that slightly retarded adults (IQs between 50 and 70) were able to find US jobs at wages close to the average income of the general population, moderately retarded persons (IQs between 40 and 49) frequently found jobs at wages only 19% of the average, and few retardates with IQs below 40 were employed. Combining the income loss due to lower wages and the loss due to greater unemployment, the total income loss was estimated at 27% for the slightly retarded, 93% for the moderately retarded and 100% for severely retarded men and women. The income loss of persons with a severe visual impairment is estimated at 70% and the hearing impaired have a 56% income loss. Most of the total annual income loss of US\$2.8 billion (assuming a steady state of disease) is due to severe and moderate mental retardation (Table 2).

The costs of special education have also been estimated. Half of the severely retarded were assumed to be living in institutions and the other half to be living at home until the age of 18 years. The severely retarded dominated the estimates, largely because of the high costs of residential care. Special education costs are estimated at US\$2.4 billion (Table 3).

Of the three types of preventable cost estimated, the income loss is two-thirds that of the total cost. The largest contributors to the income loss are infected persons who are severely or moderately retarded. Next in importance are special education and residential care costs. Medical costs comprise a very small part of the estimated preventable losses.

UK

Congenital human toxoplasmosis illness costs for clinical cases (excluding subclinical cases) in the UK have been estimated at US\$1.2–12 million (updated to 1992) (Ref. 3). The greatest loss was due to income loss and residential care for the moderately mentally retarded. Income loss is more narrowly defined than in the US study. Also, a lower percentage of mental retardation and other sequelae were estimated in the UK. Based on the

estimates of the effects of mental retardation on income from the UK and the US studies, the severely retarded will not be employable and have a 100% income loss. For the moderately retarded group, a 67% income loss is assumed in the UK and greater than 90% income loss in the USA. For the slightly retarded, women's reduced income is comparable for both studies, but the US men have only an 18% income loss compared with 33% in the UK.

The estimation method of Henderson and colleagues³ is similar to that of Roberts and Frenkel¹, although the productivity/income loss is more narrowly defined and a higher discount rate (5% rather than 3%) is used³. Neither study estimated psychological costs caused by family disruption and the stress of having a mentally retarded child, nor did they place a value on the fact that the mentally retarded have fewer friends and are less likely to marry than are persons with an average IQ.

Worldwide

In Europe, the rate of congenital toxoplasmosis may be greater than in the US. Lamb and mutton may be a greater source of dietary risk due to a greater preference for undercooked or raw meat, especially in France⁴. The estimated occurrence of congenital toxoplasmosis in live births and the total number of cases in the US, the UK, Australia and a selection of European countries are given in Table 4.

Toxoplasmosis in AIDS patients

Toxoplasmic encephalitis, marked by dementia and seizures, is the most commonly recognized cause of central nervous system opportunistic infection in AIDS patients⁷. Between 15% and 68% of all adults in the USA have antibodies to *T. gondii*, and 30% of AIDS patients seropositive for *T. gondii* will develop toxoplasmic encephalitis^{8,9}. Multiplying these percentages times by approximately 50000 (new US AIDS cases in 1992), there were an estimated 2250–10200 new cases of toxoplasmic encephalitis in 1992. Hay *et al.*¹⁰ calculated the cost of a treatment protocol for toxoplasmic encephalitis to be US\$10379 per case (1992), and the total cost for treatment was US\$23–106 million (1992 dollars) using Hay's analysis^{8–11}. These costs are probably an underestimate of the real costs of toxoplasmosis in immunocompromised patients because of the well-documented difficulties in diagnosis¹².

Corroborating this estimate are 1360 annual hospitalizations for toxoplasmic encephalitis recorded in the US National Hospital Discharge Survey between 1987 and 1990 (Ref. 13). Toxoplasmosis hospitalizations for infections at locations other than the central nervous system averaged an additional 3630 cases annually, and were concentrated in the 25–44 age group¹³.

This problem is obviously not confined to the US. In Germany, between 40 and 70% of the population is estimated to have antibodies to *T. gondii*; in France, 80%; in Indonesia, 1–60%; in Hong Kong, 9.8%; and in Africa, 15–60%¹⁴. These high levels of antibodies indicate significant risk of toxoplasmic encephalitis to AIDS patients.

Taeniasis/cysticercosis

Taeniasis, a tapeworm infection of the human intestinal tract, results from the ingestion of the cysticercus (larval stage) in raw or undercooked infected pork (*Taenia solium* infection) or beef (*T. saginata*). In the USA, diagnostic laboratories have diagnosed *Taenia* tapeworms in 0.056% of stool specimens, over half of which were reported from western states⁷. Many cases of taeniasis are asymptomatic (*T. solium* and *T. saginata*). An annual average of 1104 tapeworm cases were documented by the Centers for Disease Control and Prevention (CDC) between 1978 and 1981 (Ref. 7). Medical treatment to eliminate the tapeworm generally requires two visits to a physician, at least one lab test and drug therapy (T. Roberts and K.D. Murrell, abstract*). The medical costs plus the wage losses for these mild cases are estimated at US\$238 per case; annual costs for 1104 cases in the USA total US\$263228.

Forty-five million people have been estimated to harbor *T. saginata*: 11 million in Europe, 15 million in Asia, 18 million in Africa, and one million in South America (J.T.R. Robinson, MSc Thesis, University of Pretoria, South Africa). Estimates are especially high in the former Yugoslavia¹⁵. In Laos, 12% are infected with either *T. saginata* or *T. solium*¹⁵. *Taenia solium* remains a major public health problem in Latin America: infection rates range from 0.3% in Chile to 1.13% in Guatemala¹⁶.

Cysticercosis

Cysticercosis, which typically affects the brain or other parts of the central nervous system, can result when humans infected with *T. solium* (acquired from consuming inadequately cooked infected pork) handle food and contaminate it with tapeworm eggs. Cysticercosis is an indirect foodborne disease, but it is discussed here because of the seriousness of the disease and the extent of human infection in Latin America and among US immigrants.

In Los Angeles, Sorvillo found the brain to be the cyst infection site in 86% of cases (the eye was the infection site in 7%). Six percent of the cases were fatal¹⁶. Neurocysticercosis (cysticercosis of the central nervous system) may lead to other serious illness, as shown in a recent study in Mexico, which documented neurocysticercosis as the most common cause of late onset epilepsy¹⁷. The number of neurocysticercosis cases in the USA have been increasing. An annual average of 1133 cysticercosis cases were diagnosed at US hospitals between 1987 and 1990 (Ref. 13). Part of the recent increase in cases is due to improved diagnostic capabilities by either computer tomography (CT) or magnetic resonance imaging (MRI)⁷. Another reason for the increase may be increased numbers of infected immigrant farm workers arriving from Latin America, where the problem is endemic⁷.

A case of human cysticercosis in the USA would involve visits to a physician, diagnosis by serology, confirmation by CT or MRI scan (and possibly a biopsy), treatment with praziquantel and sometimes corticosteroids and hospitalization. Surgery is sometimes necessary to relieve certain symptoms, and survivors often are unable to work. A rough calculation of the hospitalization costs and wage losses follows. One day at a community

*Symposium on Cost-Benefit Aspects of Food Irradiation (1993) IAEA/FAO/WHO, Aix-en-Provence, France

hospital averages US\$817 (Ref. 18). A case of cysticercosis requires approximately eight days in hospital¹³, for a total of US\$6536 per person per stay. This amount excludes the extra costs of CT or MRI scans and drug therapy. Assuming approximately 1100 cases of cysticercosis annually, the minimum total amount for hospitalization is US\$7 million. Assuming it takes 19 days (off work) to recuperate, the wage losses per case would be US\$1416, totaling US\$1.6 million for all cases. Thus, a minimum estimate of the hospitalization and wage losses due to cysticercosis is US\$8.8 million annually (Table 5). This total also excludes the value of the 66 lives lost (6% of 1100) and that of human suffering because of this illness.

Human cysticercosis is widely endemic in rural areas of Latin America, Asia and Africa¹⁹ (Table 6). Neurocysticercosis has been observed in 17 Latin American countries^{16,20}. In Mexico, 1% of all deaths in general hospitals and 25% of intracranial tumors are estimated to be due to cysticercosis¹⁶. Velasco-Suarez estimated that 1% of the population of Mexico has neurological illness and that 6% of outpatients at the Neurological Institute in Mexico City had neurocysticercosis (42000 neurocysticercosis cases in 1982)²¹. The number of cases in 1992 (using the Velasco-Suarez methodology) is 52620. In Brazil in 1973, the incidence of cysticercosis was estimated at 1.5% from diagnoses at neurology and neurosurgery centers²⁰. If 1% of the total population has neurological problems, as in Mexico, this implies almost 23000 cases of human cysticercosis in Brazil. Reported estimates in Latin America generally reflect data gathered in the major cities. In rural areas, rates can vary widely. A study in a Mexican village found 10.8% positive for cysticercosis by immunoassay in over 1500 blood samples²².

Updating Velasco-Suarez²¹ estimates from 1982 to account for inflation and population increases, it is estimated that Mexican medical treatment costs in 1992 for neurocysticercosis were US\$89 million and wage losses were US\$107 million for an annual total of US\$195 million. Applying the approximate cost per case in Mexico (about US\$3700) to Brazil, total costs for 23000 cases would be approximately US\$85 million.

Trichinellosis

Trichinellosis (infection by *Trichinella spiralis*) is caused by the ingestion of raw or undercooked pork contaminated with the organism. As physicians are required to notify the state or local health departments, who in turn notify CDC of trichinellosis cases, the CDC reports on the disease frequency. The latest CDC report for 1987–1990 indicated an annual average of 52 cases²³. This average includes two large outbreaks that occurred in 1990. The number of cases have steadily decreased since the peak in the 1940s when the Public Health Service began collecting statistics. While three deaths were reported during 1982–1986, no deaths occurred from 1987 to 1990 (Ref. 7). However, this system sometimes results in underreporting. Approximately 131 cases were diagnosed and treated annually from 1987 to 1990 (T. Roberts and K.D. Murrell, abstract^{*}). The authors assume the latter number (131 cases) more accurately portrays the extent of trichinellosis in the USA.

Assuming that all cases are hospitalized for an average of six days (T. Roberts and K.D. Murrell, abstract^{*}) at US\$817 per day for a total of US\$4905 per case, hospitalization costs

US\$642499. Wage losses of six days in the hospital plus nine days to recuperate, at an average wage of US\$73 per day, adds up to approximately US\$1062 per case. The total wage loss is US\$158000. Total costs (both hospitalization costs and wages lost) due to trichinellosis amount to US\$781578.

Trichinellosis varies in importance as a human disease around the world. It has been cited as a continuing problem in China, Thailand, Germany, Yugoslavia, Poland and most of Eastern Europe²⁴. The extent of the problem is unknown, since few incidence statistics are available. Poland has an estimated incidence of 0.015% (Ref. 25).

Liver fluke infections

Human infection with the liver fluke *Opisthorchis viverrini* (associated with consumption of undercooked fish) is an important problem in Laos and is the leading cause of foodborne parasitic disease in Thailand²⁶. Sixty percent of the work force in Northeast Thailand are infected and their wage losses, estimated by Loaharanu and Sornmani²⁶, and updated to 1992 prices, are US\$76.5 million annually²⁶. Hospitalization costs are US\$10.6 million and drug costs US\$12.8 million, for a total cost of US\$99.9 million per year (Ref. 27).

Other parasitic infections

In the USA, 5108 annual cases of giardiasis, a water- or foodborne disease caused by *Giardia lamblia*, were diagnosed through a hospital discharge survey from 1987 to 1990 (Ref. 13). While most cases are water-borne, there have been documented cases of giardiasis that were foodborne. In a study of patients tested for giardiasis, five diagnostic tests cost US \$338 per patient²⁸.

In Japan, anisakiasis (caused by consumption of raw or undercooked fish) is the major foodborne disease. In the USA, it is less common, but anisakiasis is still the greatest threat to public health associated with US seafood^{29,30}.

Summary

The fragmentary evidence of human disease caused by foodborne parasites indicates both an increasing ability to detect these public health problems and changing demographic, cultural and environmental practices that result in greater public health risk³¹. For example, both Thailand and the Philippines have a 'plethora of foodborne parasitic zoonoses' due to eating undercooked meat and seafood, poverty, illiteracy and poor hygiene and sanitation²⁴. In China, improved living standards are resulting in an increase in the consumption of meat and seafood, with consequent rises in toxoplasmosis, clonorchiasis, cysticercosis and trichinellosis.

Foodborne disease is a worldwide problem of great magnitude, both in terms of the extent of human illness and the economic costs due to medical expenses and lost wages. Farm-level interventions are probably the most effective control strategy for parasites that originate on the farm, since they (unlike bacteria) do not multiply in food. In the USA, three management practices have been most effective in controlling *T. spiralis* in hogs: keeping rodents out of

barns, restricting access to dead animals (including pigs), and cooking all feed that contains meat scraps or other animal by-products. We recognize that, in some countries, the climate and cost of housing may make it difficult to limit access of rodents to hogs, but the importance of this risk factor cannot be ignored. For fishborne parasites, control is inherently more difficult when cultural preferences for raw or undercooked fish are strong. However, the potential public health benefits that would result from more successful control of these particular zoonoses warrant greater research on practical means to reduce their incidence.

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Table 1

Congenital toxoplasmosis US medical costs 1992

Clinical illness or procedure	% of cases	Loss per case ^a (US\$)	Cases (No.)	Total loss (US\$ million)
Severe neonatal illness				
Deaths	2	55442	84	4.6
Survivors	11	53072	460	24.4
Diagnostic tests (average)	100	3183	4179	13.3
Yearly eye exam	48	1257	2006	2.5
Strabismus ^b	8	483	341	0.2
				45.0

^aRounded to nearest US\$ 100.^bDeviation of the eye (includes cost to correct).

Table 2Congenital toxoplasmosis US annual productivity losses^a

Disability or death	Income loss (%)	Loss per case (US\$)	Total loss (US\$ million)
Fetal/perinatal deaths	40 ^b	433922	36.3
Severely retarded	100	1084804	1496.0
Moderately retarded	93	1008868	716.7
Slightly retarded	27	292897	281.5
Blind	70	759363	253.9
Deaf	56	607490	50.8
			2835.2

^a1992 US\$ values.^bThis is an understatement of income loss. The income loss for fetal deaths is assumed to be 40% because these are not likely to be replaced by another infant³².

Table 3

Congenital toxoplasmosis US special education and residential care costs 1992

Disability	Cases affected (%)	Loss per case ^a (US\$)	Cases (No.)	Total loss (US\$ million)
Severely retarded				
Lifetime residential care (40 years)	16.5	2049231	690	1413
Live-in at home for 18 years ^b	16.5	160276	690	111
	–	16028 ^c	–	11
Residential care after age 18	–	829919	–	572
Moderately retarded	17.0	125690	710	89
Slightly retarded	23.0	69828	961	67
Blind	8.0	–	334	–
Special education for 15 years	–	261048	–	87
Additional expense	–	26105	–	9
Deaf	2.0	–	84	–
Special education for 15 years	–	184238	–	15
Additional expense	–	187424	–	<u>2</u>
				2376

^aCosts are discounted by a 3% annual interest rate to arrive at a present value assuming a 40-year life span.

^bThe cost of schooling for the first 18 years at home.

^c10% of the cost of schooling for the family's additional expenses.

Table 4

Congenital toxoplasmosis incidence in selected countries

Country	Estimated % of live births	Live births (millions) (1992)	Estimated cases (No.)	Ref.
USA	0.01–0.026	4.2	420–10920	1
Europe	0.03–0.6	6.1	18396–36792	5
UK	0.03–0.3	0.8	243–2428	3
France	0.2–0.3	0.7	1479–2219	4
Switzerland	0.1	0.1	90	4
Belgium	0.2	0.1	260	4
Former Czechoslovakia	0.2	0.2	440	4
Australia	0.2	0.3	534	4
Worldwide	0.1–0.8	140.9	140900–1127200	6

Table 5

Cysticercosis US annual costs 1992

	Cases ^a (No.)	Days ^b (No.)	Cost per day (US\$)	Cost per case ^c (US\$)	Costs (US\$)
Hospitalized	1100	8	817	6539	7193368
Wages lost ^d	1100	19	73	1416	1557122
					8750490

^aPreliminary data from Steahr's analysis of NHDS data¹².

^bIt is arbitrarily assumed that there would be two days recuperation for each day of hospitalization.

^cExcluding cost of computer tomography and magnetic resonance imaging. Number of hospital days of income lost = [no. of hospital days + (2 × no. of hospital days) × 5/7].

^dUsing the average private sector weekly wage (US\$364.30) for 1991, Statistical Abstract of the US 1992 (Ref. 18).

Table 6

Cysticercosis: incidence in selected countries

Country	Estimated % of population infected	1992 population (millions)	Estimated cases (No.)	Ref.
USA	0.0004	255.6	1100	13
Mexico	0.0600	87.7	52620	20
Brazil	0.0150	150.8	22620	20
Chile	0.0900	13.6	12240	21
Colombia	0.4500	34.3	154350	20
Costa Rica	0.5000	3.2	16000	20
Ecuador	0.4700	10.0	47000	33
El Salvador	0.4000	5.6	22400	20
Honduras	0.0200	5.5	1100	20
Venezuela	0.4900	18.9	92610	<i>a</i>
Cameroon	15.0000	12.7	1905000	24
		598	2327040	

^aR. Arroyo, *Teniasis: Cisticercosis en Costa Rica Asociacion Guatemalteca de Parasitology y Medicina Tropical*, 1990.