Parasites

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Ill health related to food-borne infection transcends all geographical, political and cultural boundaries. The incidence of food-borne diseases continues to adversely affect the health and productivity of populations in most countries, especially non-industrialised ones. However, since the 1950s, the emphasis in the industrialised world had shifted away from addressing public health problems, to problems of chemical contaminants *etc.*, but recently food-borne infections have again become of increasing concern to governments and the food industry. Improvements in international transportation means food can be distributed throughout the world, but so can the parasitic pathogens which contaminate foods. Alternatively, tourists are being affected abroad and possibly transmitting the pathogen to others at home. Thus, an increasing number of food-related illnesses are international in scope. In this review parasitic contamination of foods of animal origin, particularly meat and fish, will be discussed together with potential problems associated with water and unwashed fruits and vegetables.

A predominant misconception is that parasites are a problem found only in tropical and third world countries, but nothing could be further from the truth. However, people who live in affluent modern society fail to appreciate the biological importance of parasites because they are so rarely encountered in everyday life. The World Health Organization (WHO) categorises parasites among the six most harmful infective diseases of man and parasitic infections outrank cancer as the number one killer in the world. Parasites can be contracted by eating contaminated under-cooked beef, pork, fish or other flesh foods, walking barefoot on infected soil, by being bitten by flies or mosquitoes, eating unclean raw fruits and vegetables or drinking infected water. There is an increased danger of contracting parasites when travelling to tropical and/or non-industrialised countries and the rise in immigration of people from areas of infection also contributes to the risk.

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Definition of a parasite

The definition of a parasite (literally *para* – beside, *sitos* – food) is any organism that derives benefit from living in or on another organism (the host) at a cost to the host. The cost may be anything from using small amounts of the host's food to causing a fatal illness. The highest costs are paid in the tropics and sub-tropics where parasites present a continual and unacceptable threat to the well-being of millions of people. The cost of harbouring parasites in terms of human misery and economic loss is incalculable. Parasites are also a major cause of mortality and reduced reproductive success among domesticated animals and crops and one of the main concerns in agriculture is the control of parasites that can wipe out crops and livestock.

Helminths

The vast majority of metazoan parasites of vertebrates are representatives of two phyla, the acoelomate Platyhelminthes and the pseudocoelomate Nematoda. The most commonly used term to describe these parasites, 'helminths' includes all the cestodes and digeneans of the former group and all members of the latter. Of the four classes of entirely parasitic platyhelminthes, only the cestodes and digeneans cause important diseases in man and his livestock. The monogeneans of fish can cause serious losses in stocks kept under high-density fish farming conditions. Helminths are common and ubiquitous parasites of man and the causative agents of a list of terrible debilitating, deforming and fatal diseases of humans and their domesticated animals. Table 1 provides an outline classification of the helminth groups and the important genera that infect man. There are about 20 species of helminths which are natural parasites of man, but many others cause zoonoses, *i.e.* infections of animals that also infect man[1].

Table 1 Brief outline classification of helminths parasitic in vertebrates

Phylum: Platyhelminthes (flatworms)		
	Class 1	Monogenea
	Class 2	Cestoda (tapeworms) (*Diphyllbothrium, Taenia, Echinococcus*)
	Class 3	Aspidogastrea
	Class 4	Digenea (flukes or trematodes) (*Fasciolopsis, Fasciola, Paragonimus*)
Phylum Nematoda (roundworms)		
	Order 1	Rhabditida (*Strongloides*)
	Order 2	Strongylida (*Necator, Ancylostoma, etc*)
	Order 3	Ascaridida (*Ascaris, Toxocara, etc*)
	Order 4	Oxyurida (*Enterobius*)
	Order 5	Spirurida (*Dracunculus, Wuchereria, Brugia, Loa, Onchocerca*)
	Order 6	Enoplida (*Trichinella, Trichuris*)

Examples of important genera that infect man are listed in brackets Adapted from Whitfield[1]

Prevalence of helminths

It is estimated that 3.5 billion (3.5 x 10^9) people are infected with intestinal parasites of which 450 million are ill and the numbers of people infected is increasing in all WHO regions[2]. It is projected that by the year 2025, about 57% of the population in developing countries will be urbanised and, as a consequence, a large number of people will be living in shanty towns where parasites like *Ascaris lumbricoides* and *Trichuris trichuria* will find favourable conditions for transmission[2]. Helminths have been classified as a public health problem in Central and South America, Africa, Asia and the Middle Eastern Crescent and are reported as being transmitted in the US, Spain, Portugal, Greece, Italy, Australia, Turkey and Eastern Europe[3]. However, very little information has been published on current levels of infection in the former Soviet Union and Eastern Europe[4].

Unlike viruses, bacteria and protozoa (microparasites), which are small and possess the ability to multiply directly and rapidly within the host, helminths (macroparasites) are much larger and do not multiply within the human body, one notable exception being *Strongyloides stercoralis* in immunocompromised people. Because of the necessity to have an intermediate host, helminth diseases do not have a sudden acute crisis but tend to be chronic conditions, where the pathology of the disease is positively correlated with the burden of parasites harboured by the host[5].

THE GUERRILLA WORM

Helminths are unique among infectious agents – they do not, as a rule, multiply in the human body. Instead, they appear to follow the prospects of guerrilla warfare as outlined by Chairman Mao, repeatedly infiltrating host defences as individuals or as small groups and gradually building up into larger forces; warfare is usually by attrition and is often prolonged[6]

The individual parasite provides the basic unit of study and it is, therefore, desirable to measure the number of parasites within the host by direct (*e.g.* worm expulsion by chemotherapeutic agents) or indirect (*e.g.* egg or cyst output in the faeces of the host) methods. For most of the common human helminth infections there is a marked over-dispersion or aggregation within their host population, *i.e.* where many hosts harbour a few parasites and a few hosts harbour large numbers of parasites. Prevalence data indicate the proportion of individuals infected but do not give any idea of the number of worms harboured. The marked non-linearity of the relationship between prevalence and intensity is a statistical consequence of the over-dispersed pattern of intensity. For most helminth species, the initial rise in intensity with age mirrors that of prevalence but occurs at a slightly slower rate. For example, the maximum prevalence of *Ascaris lumbricoides* is usually reached before the age of 5 years, but the maximum worm burden is usually found in children aged 5–10 years.

Food safety

Food safety, regardless of the specific food product, should be of paramount concern to everyone. All countries need to ensure that national food supplies are safe, of good quality and available in adequate amounts at affordable prices to safeguard good nutrition and health for all population groups. Parasitic diseases represent one potential health risk from foods.

Tropical infectious diseases not only constitute the leading threat to health for the growing world population who live in tropical areas but also pose a threat to all areas of the world. Rapidly increasing globalisation of travel and trade means that tropical diseases that were once distant and unimportant are now on the doorstep of the industrialised countries. Tourism has now replaced agriculture as the biggest industry in the world with 50 million people travelling from Europe, US, Canada, Japan, Australia, and New Zealand to Asia, Africa, Latin America, the South Pacific islands and parts of Eastern Europe where food, water and vector-borne infections pose significant health risks. In addition, the food industry now sources fruit and vegetables increasingly in non-industrialised countries and many of these products are eaten with minimal processing/cooking in the home. To improve the health of the disadvantaged and protect the people of the industrialised countries, the best of modern medicine, research and public health must be applied to the understanding and control of tropical diseases that remain the leading causes of disability and mortality around the world[7].

Meat

The public health and economic impact of meat-borne parasitic zoonoses is considerable in terms of morbidity and even mortality in man. In addition, reduced productivity in animals and condemnation of parasitised meat is still a significant problem and in some countries the infection rates of cattle with *Cysticercus bovis* (the cysticercus of *Taenia saginata*) have increased. A European committee was recently set up to develop new tools for the diagnosis and control of the infection. Current techniques are unsatisfactory, as there is only a 30% detection rate in animals carrying low numbers of cysticerci. New recombinant antigens are becoming more sensitive for detecting antibodies against cysticerci in cattle, but problems still persist in detecting low level infections[8]. Scientists in Scotland believe that immunodiagnostic techniques could be used on a herd basis to determine whether the herd is free of cysticerci or not[8].

What are the initial sources of infection? This question is problematic. The increase in foreign travel and becoming infected abroad are often blamed, but the maintenance of the life cycle depends on human sewage reaching pasture. Direct contamination from farm workers is one possibility, but proglottides can survive in sewage and eggs may pass into sewage sludge which is regularly spread as fertiliser. However, usually only a few cows in a herd become infected. Herring gulls feed widely and regularly around sewage farms eat the proglottides, which breakdown during digestion but the eggs survive and are deposited onto pasture in the gull's faeces in discontinuous and concentrated aggregations, which might explain scattered infections in herds[9].

Contamination of meat with tapeworms

The cosmopolitan distribution of *Taenia saginata*, the beef tapeworm, is due to the practice of eating beef which is raw or under-cooked and there are an estimated 45 million cases world-wide. In this way, infective cysticercus larvae (about 8 mm in length) found in the muscles of cows, are ingested. Once ingested, the larvae evert their hooked scoleces, attach and grow. The adult tapeworms are located in the ileum with their scolex (head end) embedded in the mucosa and the rest of the organism, up to 5 m in length, hanging free in the lumen. Posterior segments (proglottides) filled with eggs are passed out with the faeces. The eggs once ingested by cattle hatch to release hexacanth larvae in the duodenum. The larvae penetrate the gut wall and reach voluntary muscles via the blood stream and within 10–12 weeks transform into the infective cysticercus larvae in the muscle[1]. Once man ingests the under-cooked or raw beef muscle the whole life cycle begins again.

Taenia solium is the pork tapeworm and is less widely distributed than *T. saginata* with an estimated 3 million cases. *T. solium* is very similar in morphology and life-cycle characteristics to *T. saginata* and man is the only definitive host for both species. *T. solium* is found where pork and pork products are eaten raw or under-cooked.

Effective meat inspection should remove infected carcasses from the human food chain, but if the levels of infection are relatively low, the infection might be missed (see above). However, in many countries, none of these measures are in place and tapeworm infections are common. Even in Britain there has been an increase in *T. saginata* cases recently, although *T. solium* does not appear to be a problem. There is little risk if meat is thoroughly cooked or subject to prolonged deep freeze storage, at –10°C or below, which kills the cysticercus larvae of both tapeworms. In Europe, eating steak tartare or rare steak means tapeworm infection is an affliction of the affluent, as they are more likely to afford the raw material. In developing countries, it is the poor who cannot afford the cost of the fuel to cook their meat who are most at risk!

Contamination of meat with tissue nematodes

Trichinellosis, caused by *Trichinella spiralis,* is a cosmopolitan disease, which has a very low vertebrate host specificity. Short-lived adult infections in the small intestine of a wide range of carnivorous and omnivorous mammals give rise to a large number of invasive larvae (2000/female) which migrate via the blood stream to voluntary muscles throughout the bodies of the host animal. Once in the muscle they encyst. The cysts are the infective stages that can be transmitted to any new host when the flesh is eaten. Human infection is contracted by eating raw or under-cooked pork or pork products containing encysted larvae. Domestic pigs provide the main source of human infections in all areas except Africa where the wild boar, bears, bushpigs or warthogs transmit the disease and in the far north among the Eskimos where polar bears are most important. In the recent *International Commission on Trichinellosis Country Status Report (1995–97)*, 10,000 cases of trichinellosis were reported world-wide, of which 167 were in Western Europe and 7213 were in Eastern Europe. In addition, Switzerland and Norway revealed *Trichinella* infections in foxes (1.3% and 7.5%, respectively) but no infections in domestic pigs. Identification of *Trichinella* in wild animals is important as they may act as reservoir hosts[10].

The adult *T. spiralis* is a small worm living partially embedded in the mucosa of the ileum, where it gives rise to some gut damage. However, important pathology occurs when the larvae migrate to and encyst in the muscles, when in heavy infections a diverse range of symptoms from vomiting and diarrhoea to high fever and muscle pain appear.

Water

Nematode contamination of water

Dracunculiasis, guinea worm disease, is confined to rural communities in East, Central and West Africa, India, Pakistan and the Arabian peninsula. Human infections occur when people drink water contaminated with copepods (crustaceans) containing infective larvae. Ingested larvae penetrate the intestinal wall and spend about 12 weeks in subcutaneous tissues. After mating, the female worm moves down the body reaching an ankle or foot about 8–10 months after the original infection. Here the female, containing up to 1 million eggs, induces a blister in the human host, which subsequently bursts enabling large numbers of actively swimming larvae to leave the lesion each time it is immersed in water[1].

Safe drinking water would eradicate the disease from the world and, in 1991, the 44th World Health Assembly declared the goal of eradicating dracunculiasis by the end of 1995. By 1996, there were less than 153,000 cases, 78% of which were notified in Sudan[10]. Transmission is easily interrupted by simple measures such as provision of safe water supplies and where it is not possible to provide safe water, control is by health education, by provision of filters (even an old T-shirt will do!) and by treatment of ponds with insecticides. Hopefully *Dracunculus medinensis* is an endangered species that will disappear without a whisper of protest!

Salad vegetables

Contamination of salad vegetables with roundworms

Ascaris lumbricoides, 'the large roundworm' of man, is one of the commonest and most wide-spread of human infections with an estimated 1300 million cases (24% prevalence) world-wide. It is found in all tropical, sub-tropical and temperate regions where standards of hygiene are low. The mortality rate from ascariosis is low, 2 per 100,000 people (total 60,000 deaths/year) but, due to the high prevalence rate, it is regarded as a serious public health problem[2]. Infection follows the ingestion of salad vegetables contaminated with embryonated eggs. Following ingestion, the hatched larvae penetrate the intestinal wall and are carried to the lungs where they may cause pneumonitis with numerous lesions and perhaps blood-stained sputum. The maturing larvae ascend the trachea and are swallowed to re-enter the ileum. Adult worms in the small intestine are long-lived (maximum survival 7 years) and in high density can cause obstruction. Worms can migrate out of the gut into the bile duct, pancreatic duct, oesophagus or mouth. However, in general, ascariosis probably causes little ill-health to the host except for the rare occasions when it does cause obstruction of the intestine or bile duct.

Trichuris trichuria is the causative agent of whipworm infection, an infection which is often found in the same areas as ascariosis. It is estimated that there are 902 million cases world-wide (17% prevalence). *Trichuris* spp. larvae do not migrate after hatching but moult and mature in the intestine. Adults are not as large as *A. lumbricoides*. Symptoms range from inapparent through vague digestive tract distress to emaciation and mucoid diarrhoea. Toxic and allergic symptoms may also appear.

The eggs of both *A. lumbricoides* and *T. trichuria* are found in insufficiently treated sewage-fertiliser and in soils where they may contaminate crops grown in soil or fertilised with sewage. Humans are infected when such produce is consumed raw. The eggs of these roundworms are 'sticky' and may be carried to the mouth by hands, inanimate objects or foods, transmission may also be caused by contamination of a wide variety of foods by infected food-handlers. Prevention of infection is by thorough washing of salad vegetables, improved hygiene practices of food-handlers and at the source of salad production by an improvement in standards of sanitation.

Eggs of *Ascaris* spp. have been detected on fresh vegetables in industrialised countries but no major outbreaks have occurred, although individual cases do occur.

Contamination of salad products with liver flukes

The sheep and cattle fluke, *Fasciola hepatica,* is endemic in many parts of the world and causes some human infections in South America, Cuba, North Africa and Western Europe including the UK and France. Most human infections come from the ingestion of watercress, lettuce or radishes in salads contaminated with metacercarial cysts. Following ingestion, the young worms penetrate the gut wall then eat their way to the bile ducts causing necrosis and inflammatory reactions *en route*. Early symptoms consist of abdominal pain, nausea, fever and hepatomegaly.

Human liver flukes are discussed later (fish and shellfish).

Fish and shellfish

A multitude of parasites has been reported in aquatic food products but only a few are capable of infecting humans. A total of 50 species of helminth parasites have been implicated as producing zoonotic infections resulting from eating raw or under-cooked aquatic foods such as fish, crabs, crayfish, snails and bivalves[12]. Fish or crustacean-borne trematodes infect about 39 million people and another 550 million are at risk[8]. Examples of common raw seafood dishes known to transmit parasitic zoonoses are Japanese sushi, sashimi, and salad (contains raw fish), Hawaiian lomi lomi salmon, tako poki (Cephalopod dish), palu (meat from a fish head and visceral organs allowed to ripen in a closed container), Dutch green herring, Scandinavian gravalax, Latin American ceviche (fillets marinated in lime juice), Philippine bagoong (uncooked fish viscera) and Pacific island poisson cru (fish fillets marinated in coconut juice)[12].

Contamination of fish with nematodes and liver flukes

The increasing exploitation of the marine environment by humans, changes in dietary habits incorporating 'natural' seafood dishes, tendencies to reduce cooking times when preparing seafood products all increase the chances of becoming infected with helminth parasites. Most helminth zoonoses are rare and cause little damage; however, some are more prevalent and pose serious potential health hazards. For example, in Japan in 1987, there were 4882 reported cases of anisakiasis (a severe gastric upset), caused by larvae in sushi or sashimi. The nematodes attach to or penetrate the intestinal lining but as humans are not a suitable host, the larvae will not live longer than 7–10 days in the human digestive tract[13]. A more serious problem is caused by the human liver flukes, *Clonorchis sinensi* and *Opisthorchis viverrini,* in South–East Asia. *O. viverrini* is the leading cause of food-borne parasitic disease in Thailand, Laos and Vietnam where it affects more than 8 million people. In Thailand, data from a liver fluke control operation in 1996 showed the country-wide prevalence of opisthorchiasis to be 21.5%. Opisthorchiasis is transmitted as a result of consuming raw or insufficiently cooked freshwater cyprinoid fish (carp). Economically, the estimated wage loss in Thailand may be as high as Baht 1620 million (~£27 million, if Baht 59 = £1) and the direct cost of medical care may be as high as Baht 495 million (~£8 million) per year[14].

Contamination of fish with tapeworms

Diphyllobothrium latum, the broad fish tapeworm, found in Northern Europe, is transmitted when raw, undercooked or lightly smoked fish (*e.g.* pike or salmon) containing viable plerocercoids are eaten. In many cases, human infections largely go unnoticed because of the non-specific symptoms such as intestinal discomfort, nausea and diarrhoea. However, in some *D. latum* infections, the parasite cleaves and selectively takes up vitamin B_{12} competing with the host for the vitamin, so that, in heavy infections, the parasite might take all available dietary vitamin B_{12} and in more susceptible people this can lead to megablastic anaemia[15].

In regions with poor sanitation where untreated sewage is released directly into rivers or lakes, infected fish with high prevalence and intensity rates are common. Effective control measures include cooking fish properly or freezing fish below –12°C for a minimum of 24 h. In addition, properly treated and managed sewage is also important.

Contamination of crustaceans with parasites

Over 20 million people are infected with the lung fluke, *Paragonimus*, the treatment of which is currently unsatisfactory. Eggs from the adults are passed out in human faeces and once in fresh water, the larvae burst out of the eggs and enter a suitable snail host. A free-living stage, the cercaria, emerges from the snail and penetrates a freshwater crustacean (crab or crayfish). When the crustaceans are eaten uncooked, the metacercarial larvae excyst and reach the lungs after passing through the intestinal wall and diaphragm. The developing worms in the lungs provoke inflammatory and granulomatous reactions, forming a cyst with an opening into a bronchiole. The majority of infections are asymptomatic; but, in heavier infections, there is a dry cough, chest pain, dyspnoea and haemoptysis. Control of the parasite can be achieved by cooking the crustaceans before consumption, alternatively, the sanitary disposal of human faeces will reduce transmission.

Seafood safety

World-wide, the majority of seafood zoonoses used to occur along coastal regions where seafood products were commonly consumed but continual improvements in transportation, technology and food handling allow fresh seafood to be shipped throughout the world and further inland. In 1993, the UK imported 684,000 tons of fish for direct human consumption and 1,381,000 tons for animal feed and other purposes[16]. Reports of imported seafood contaminated with viable parasites are known; therefore, marine foods on a global scale must be considered by government regulatory agencies to ensure a safe seafood supply.

Health authorities in the past focused on the safety of their own fisheries and seafood products and problems associated with marine products imported from other countries were of little concern. However, this approach to seafood safety was not prudent because parasites do not honour national borders. The strengthening of national food control infrastructures, in particular in non-industrialised countries, the need for harmonisation of food control at international levels, the need for collection and exchange of data on food control and contamination issues are essential elements to ensure food safety in the world.

Potential problems

Aquaculture is important to the world's fishery system. Both import and export markets for aquaculture products will expand and increase, as over-fishing of wild stock will necessitate supplementation and replenishment through aquaculture. However, future aquaculture development will require an integrated public health approach to ensure that it does not cause unacceptable risks to public or environmental health and negate its potential economic and nutritional benefits[17].

A common practice in many developing countries is the creation of numerous small fishponds. This approach greatly increases the overall aggregate shoreline causing higher densities of mosquito larvae and cercaria. Centralised planning for new freshwater and marine aquaculture sites should include discussions about optimal conditions on issues such as disease transmission (*e.g.* from fish-to-fish and fish-to-man), water supply, irrigation and power generation. Ignorance of the hazards associated with the use of untreated animal or human waste in aquaculture ponds to increase production also has tremendous health implications, for example, in China, where the two liver flukes, *Clonorchis sinensi* and *Opisthorchis viverrini*, are common, human faeces were commonly used to enrich ponds containing the host fish, but in recent years the faeces have been stored or treated before use. In addition, food growers have traditionally used cultured species in waste water fed ponds and grown secondary vegetable crops in waste water and sediment material in integrated aquaculture operations. The potential for transmission of human pathogens to the cultured species and secondary vegetable crops was rarely considered.

Disease control in aquaculture

Procedures to help protect humans from aquaculture-associated risks include better education and training of aquaculture staff and FAO and WHO recommend that the hazard analysis and critical control points (HACCP) concept be applied to fresh water aquaculture programmes to control food-borne digenetic trematode infections in humans. A study in Vietnam used 2 ponds, one in which fish were cultured according to HACCP principles and one used conventional local aquaculture practices. Water supply, fish fry, fish feed and pond conditions were identified as critical control points. Results showed 45% of control pond fish were infected with *Clonorchis sinensis* metacercaria while the fish monitored according to HACCP principles were free of trematode infection. Similarly, the application of the HACCP principles to freshwater aquaculture ponds in Thailand and Laos to control *Opisthorchis viverrini* infection were also successful[17].

The organic food revolution in industrialized countries – the hidden menace

In parallel with increasing public anxiety over the emergence of genetically-modified foods in industrialised countries has been a trend towards ever increasing public demand for organically-grown produce. In commercial response, most, if not all, of the major food retailers in the UK have now a stated policy of removal of genetically-modified foods from their shelves with an increase in capacity for organic produce. While such trends may appear to be eco-friendly on face value, there are potential hidden dangers for consumers. Over the past 20 years, the use of artificial fertilisers on farmland to facilitate an intensive agriculture focused on the rapid production of uniform products for mass consumption has led to a massive reduction in the use of organic manures on the land. During the same time period, intensive usage of anthelmintics in domestic livestock for the same purpose of maximising productivity has led to massive reductions in parasite burdens. Taking both factors into account, one can see the reason for the virtual elimination of parasitic disease as a major clinical problem in industrialised countries. However, changing practices for economic or social reasons can provide parasites with new opportunities for transmission which they will exploit with gusto. After all, this is what evolution has gifted parasites to do. While little evidence exists of the nutritive benefits of organic produce, the change from the relative sterility of inorganic farming to an organic culture system may turn back the pages of history to the time when parasitic disease in the population was the norm. After all, it is a fact that under natural conditions, all vertebrates (including man) are probably universally infected with at least one helminth parasite – is this really to where we wish to return? How many of us who live in the countryside or who drive through such *en route* to our places of employment have not been subjected to mighty olfactory attack as farmers spread 'muck' on their fields? Such spreadings usually have large flocks of attendant gulls, many of which defecate over a wide area including in our parks, playing fields and reservoirs. The factors are thus already in place for the resurgence of helminth parasitic disease – one can be sure that it remains a matter of when, rather than if, this will occur.

Anthelmintic resistance

The picture of impending doom which has been painted would be somewhat moderated if society had in its possession a broad and effective arsenal of chemotherapeutic agents (anthelmintics) for the treatment of parasitic infection. It is a sobering thought that virtually all anthelmintic discovery programmes in multinational pharmaceutical companies are directed towards finding drugs of efficacy, not in man, but rather in his domestic pets and livestock. The curious reason for this is market driven. Put simply, industrialised countries can afford to spend vast sums on anthelmintics for veterinary purposes with little need for human clinical application. Non-industrialised countries, while having a greater veterinary problem but more importantly, a crippling human clinical problem, cannot afford the costs of new pharmaceuticals which have to be priced to cover development costs as well as procure profits. The economic reasons for this state of affairs undoubtedly presents the parasites with yet another potential avenue of exploitation. In common with antibiotics, whose wide-spread usage has led to virtual universal resistance acquisition in bacteria, anthelmintics used with equal abandon in domestic livestock have initiated resistance in many highly pathogenic helminths. Levamisole-resistant strains of *Strongyloides* and *Haemonchus* are now widespread in Australian and New Zealand sheep and praziquantal and oxamniquine resistant schistosomes are now found in humans in Africa and Brazil, respectively. First generation anthelmintics, such as the benzimidazoles, are now all but useless due to selection of allelic variants of the β-tubulin gene which confer resistance. The picture painted, as with antibiotic resistant bacteria, is one of impending defeat by the enemy in the absence of effective defensive weaponry. For this reason, industrialised countries should reflect much more carefully on the potential effects of radical change in farming practice and food production in the light of current and developing knowledge of the biological threat from parasitic helminths. Recently, in response to the lack of concern in the West to the rapidly developing drug-resistant tuberculosis epidemic in the former Soviet Union, a WHO spokesperson put it like this: 'We all live in what could be described as one large forest. A fire is raging at one side and those of us at the other side are unconcerned as we cannot see it or smell it. But sooner or later it will become our problem if we do not take steps to douse the flames'. I think that this accurately reflects our attitudes to parasitic disease – but we in industrialised countries take it one stage further – we are building fire-lighter factories.

Food irradiation

The incidence of food-borne diseases continues to adversely affect the health and productivity of populations in most countries, especially non-industrialised ones. The report of the joint FAO/WHO Expert

Committee on Food Safety stated that: 'illness due to contaminated food is perhaps the most widespread health problem in the contemporary world and an important cause of reduced economic productivity'. Contamination of foods especially those of animal origin with micro-organisms, particularly pathogenic non-sporing bacteria, parasitic helminths and protozoa is among the most important health problem and the most important cause of human suffering world-wide. In addition, many dry ingredients particularly herbs and spices, the major proportion of which are produced in non-industrialised countries giving an important source of their foreign exchange, may be highly contaminated with spoilage organisms.

Considerable data and commercial experience exist which demonstrate that irradiation of foods could play an important role in solving food-borne diseases. At a meeting on the *Use of irradiation to ensure hygienic quality of food* in 1986, it was concluded that no technology was available to produce safe raw foods of animal origin; a situation which poses significant threats to public health. However, where such foods are important in the epidemiology of food-borne diseases, irradiation decontamination/disinfection must be seriously considered[17]. The most apparent health benefit from the use of food irradiation would be: (i) in the treatment of chilled or frozen poultry to destroy Salmonella; (ii) in the treatment of pork, to inactivate *Trichinella* larvae; and (iii) for the decontamination of spices and other dry food ingredients. Very low doses of 0.5–0.6 kGy (1 Gray [Gy] = the energy of 1 Joule absorbed by 1 kg of matter) are sufficient for inactivation of *Taenia saginata* and *Taenia solium* cysticerci in beef and pork, and in the US, irradiation has been approved for raw poultry and meat. However, as the regulations for irradiation of beef products are still being determined, the products are not available in the shops yet. High public awareness of problems caused by pathogens in raw meat means the prospect for the introduction of irradiated meat is favourable in the US. However, in Europe, public acceptance of this technique will be more difficult[18]. An example of successful commercial irradiation has been carried out in Belgium and The Netherlands, where frozen shrimp and frogs' legs for export are dosed with 2–7 kGy. The dose was considered adequate to destroy pathogenic micro-organisms and parasites without causing an adverse effect on the organoleptic properties of the food.

Street-vended food

Street-vended food has an important role in feeding urban populations, particularly the socially disadvantaged. Street food is varied, inexpensive and often nutritious, but has some risk due to inadequate sanitation and waste management. However, authorities charged with the responsibility for food safety have to match risk management action to the level of assessed risk, hence the rigorous codes of practice enforced on larger permanent food service establishments are unlikely to be justifiable for street food vendors. If such rigorous codes of practice were enforced, it would result in the disappearance of the street vendors and result in hunger and malnutrition in those who rely on them for a cheap supply of food. However, WHO encourages the development of regulations that empower vendors to take greater responsibility for the preparation of safe food and codes of practice based on the HACCP system[19].

Conclusions

Food-borne diseases are much more of a concern to governments and the food industry than a few years ago. Some factors which have led to this conclusion are: increasing world trade and travel, migrant populations demanding traditional foods in their country of settlement, the ease of world-wide shipment of fresh and frozen food and the development of new food industries including aquaculture. However, to monitor increases and decreases in food-borne diseases requires an effective surveillance system for which resources have not been available. Initiatives in the US and UK are underway to monitor food-borne diseases. These initiatives should stimulate other countries to conduct similar programmes so the real burden of food-borne disease can be determined. If food-borne disease is recognised as a major concern in industrialised countries, how much more of a problem is it in countries where the urban growth is faster than the public health infrastructure can support and in rural areas where drinking water is frequently contaminated? This issue is becoming increasingly important now that immigration from non-industrialised countries is becoming more frequent, international travel is commonplace and trade barriers between blocks of countries are coming down[20]. Food-borne diseases are for the most part preventable, but food use by Western populations is a dynamic phenomenon responding to fashions, social structure, cultural influences of foreign travel, *etc.*, not to mention the more traditional criteria of suppliers or manufacturers, to provide food with the greatest cost:benefit ratio to their organisation. The risk of parasites entering the food-chain is an ever present threat and public health authorities must be constantly vigilant to meet that threat. Advice to the tourist on reducing the risk of HIV is widely advertised. Vaccination or prophylaxis to prevent infection by the major tropical diseases is often mandatory, but advice on food use and simple hygienic measures to reduce the risk of food poisoning or parasite infection is rarely seen. More attention by public health authorities to educating the public on how to prevent such organisms entering the food-chain is needed now.

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