

FOOD-BORNE PARASITIC INFECTIONS — A REVIEW

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ABSTRACT

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A review of food-borne parasitic infections is presented. Parasitic infections in conventional slaughtered animals and seafood (fish and shellfish) constituting a public health hazard are discussed. To the former category belong cysticercosis, echinococcosis and trichinellosis, and to the latter category belong various trematode, cestode and nematode infections. Examples of trematode infections are heterophyidiasis, transmitted to man by marine fish and *Paragonimus* spp. parasites, transmitted by crustaceans. Cestode infections include diphyllorhynchiasis transmitted by freshwater fish and fish from brackish waters. Special attention is drawn to the condition known as sparganosis. Of the nematode infections the eosinophilic granulomatous enteritis is mentioned. It is due to infections with members of the genera *Anisakis*, *Phocanema* and *Contracaecum* and is transmitted to man by either marine fish or crustaceans. Two other nematode infections *Angiostrongylus cantonensis* and *Capillaria philippinensis* can also be transmitted to man by marine fish.

Apart from a possible direct effect of these parasites, chemical alterations in seafood resulting from the presence of parasites may also be deleterious to the consumer.

Special attention is drawn to a newly developed serological detection method, the enzyme-linked immunosorbent assay, enabling not only detection of infection at the slaughter-house, but also in large herds at the farm.

Strategies to control parasitic infections both in conventional slaughtered animals and in seafood are discussed.

INTRODUCTION

Parasitic infections in conventional slaughtered animals may constitute a well-recognized public health hazard. Apart from this potential source of infection to man, which can be prevented by adequate meat inspection, hazards from parasites transmissible by seafood are of increasing importance. The use of marine fish as a protein source for human consumption has been limited, with some interesting exceptions. In Japan, the quantity of consumed animal protein per person is 50% in the form of fish and fish products, while in the United States of America this is only 5% (E.A. Huisman, inaugural address, Agricultural University, Wageningen, The Netherlands,

1977). The average consumption of fish per person of the world population is approximately 12 kg per year (consumption of meat is about 25 kg). Recent market analysis suggests that the demand for fish and fish products per individual will increase to approximately 16 kg by the year 2000 (Anonymous, 1973a,b). For the public health authorities this means an expansion of existing activities with regard to control of sanitation of fish meat. It is essential that parasites of food fish be identified and tested for their potential infectivity and pathogenicity to man (WHO, 1975). Apart from a possible direct pathogenic effect of these parasites, chemical alterations in seafoods resulting from the presence of parasites may also be deleterious to the consumer (Cheng, 1973).

In this review both categories of food products (meat and fish) will be discussed together with possible ways to improve the detection of the parasites to prevent public health hazards. Special attention will be drawn to a new serological detection method, the enzyme-linked immunosorbent assay (ELISA), enabling not only direct control at the slaughter-house, but also permitting a constant surveillance on the degree of infection in a certain area (WHO, 1976).

PARASITIC INFECTIONS IN SLAUGHTERED ANIMALS WITH A PUBLIC HEALTH HAZARD

Important parasitic infections in slaughtered animals include: cysticercosis in cattle, sheep and pig; hydatidosis in sheep, horse, cattle and camel; and trichinellosis in pigs.

Cysticercosis

The problem of cysticercosis was reviewed in 1972 by Pawlowski and Schultz. For our present discussion it is worthwhile to consider some of their statements. They stressed that the use of the term *Cysticercus bovis* should be abandoned since it is illogical to give separate generic and specific names to the larval stage of a parasite that already has a distinctive name (*Taenia saginata*). For the term '*Cysticercus bovis*' they use '*Taenia saginata* cysticercus', and for infection with '*Cysticercus bovis*' they use '*Taenia saginata* cysticercosis'. We would like to add that the same is applicable to '*Cysticercus cellulosae*' infections in pigs. In keeping with the nomenclature suggested above, for '*Cysticercus cellulosae*' the term '*Taenia solium* cysticercus' will be used in this presentation, and infections with '*Cysticercus cellulosae*' will be called '*Taenia solium* cysticercosis.'

T. saginata infection causes two types of losses:

- (a) losses due to the medical complications caused by the adult tape worm, which are difficult to assess; and
- (b) the evident economic losses due to cysticercosis in slaughtered animals.

Pawlowski and Schultz (1972) estimated the losses due to cysticercosis as

US\$ 25 per animal in developing countries and US\$ 75 per animal in industrialized countries. Apart from these direct losses, the high incidence of cysticercosis in certain regions in East Africa even inhibits the development of a profitable beef industry. It is therefore highly relevant that a joint FAO/WHO/UNEP effort be made to combat cysticercosis and taeniasis caused by *Taenia solium* and *T. saginata* more effectively. Promising results were reported by Richard and Adolph (1976). They found high resistance in calves against challenge infections after vaccinations with antigens collected during in vitro cultivation of the larval stages of *T. saginata*. Much will depend, however, on the promotion of adequate research in detecting *T. saginata* and *T. solium* cysticercosis in slaughtered animals. New serological methods are highly desirable. Recent studies by various groups including our own suggest a potential for the ELISA technique.

Echinococcosis

The problem of echinococcosis was reviewed by Euzeby (1974). Control of this infection might be envisaged by: (a) prevention of infection of definitive hosts, or (b) prevention of infection of intermediate hosts. Prevention of infection of the definitive hosts (dogs and other canines) is the most important measure since it eliminates the natural reservoir. Novel approaches to control include vaccination against *Echinococcus granulosus*. Gemmel (1962) found that extracts of adult worms injected subcutaneously enhanced resistance. Similar results were obtained by Movsesijan et al. (1967) using X-irradiated protoscolices given orally. Since a commercial vaccine is not available as yet, the most satisfactory control of rural and urban epidemiological cycles consists of treating dogs with taeniocidal drugs. The control of infection in wild carnivores is not solved by this method and therefore, the prevention of the infection of the intermediate host might not completely be achieved. An approach to prevent infection in the intermediate hosts (the food animals) could be the immunization of cattle, sheep and pigs against larval taeniids. Promising results were obtained by Gemmel and Soulsby (1968) by intramuscular inoculation of hatched activated embryos in sheep. Since this approach has not been used in practice, adequate monitoring with both macroscopic and serological methods could be very useful if such become available.

Trichinellosis

The parasite is a true cosmopolite and is found in most parts of the world. Infections in wild animals were reported in the Arctic, in tropical and in temperate regions. The pig remains the most important source of human infection. Tests for the detection of *Trichinella spiralis* infections make use of direct methods (trichinotomy, digestion method, by means of which the parasite itself can be demonstrated) (Ruitenbergh and Kampelmacher, 1970),

and of indirect methods (serology, by means of which serum antibodies against the parasite are demonstrated). Examples of the latter are the immunofluorescence test (Köhler and Ruitenbergh, 1974) and the newly developed enzyme-linked immunosorbent assay (ELISA) (Ruitenbergh et al., 1974; Ruitenbergh et al., 1976). ELISA is an immuno-enzyme method through which quantification of specific antibodies is obtained by enzyme-labelled anti-immunoglobulin in antigen-coated tubes. The enzyme remaining in the tubes after washing provides a measure of the amount of specific antibodies in the serum. ELISA fulfills the criteria required for routine use in a slaughter-house laboratory, viz. (1) simplicity of technique, (2) rapidity of operation, (3) ease of evaluation, (4) reliability and (5) possibility of its mechanization. Results from artificially and naturally infected pigs indicated the sensitivity of the assay (Van Knapen et al., 1976; Ruitenbergh and Van Knapen, 1977; Saunders and Clinard, 1976). As stated above, the assay can be readily mechanized. An on-line routing system (including dispensers, washing devices, spectrophotometer, carts, elevators and identification device) was developed, enabling processing of 4,000 sera daily by two persons (Ruitenbergh et al., 1977).

The use of serological techniques in the identification of infected slaughtered animals will be discussed later in this paper.

PARASITIC INFECTIONS IN FISH WITH POTENTIAL PUBLIC HEALTH HAZARD

Helminths (trematodes, cestodes and nematodes) may be transmitted to man in seafood causing symptoms directly related to the parasite. Apart from this direct effect, chemical alterations in seafood resulting from the presence of parasites might also induce pathological conditions in man.

Trematode infections

Marine fish can act as hosts for digenetic trematodes, both metacercariae and adults (Cheng, 1973). In Table I some examples are given of trematodes causing clinical disease in man. A number of species of heterophyid trematodes may be present in the cultured marine fish, the mullet, *Mugil cephalus*. Infective metacercariae of these trematodes are encysted in the musculature

TABLE I

Fish-borne parasitic infections: trematodes

Parasite	Fish		Man		
	Stage	Vector	Stage	Site	Effect
Heterophyids	Metacercariae	Fish	Adult Egg	Intestine Heart, brain	Malabsorption Inflammation
<i>Paragonimus</i>	Metacercariae	Crustacean	Adult	Lung (brain, heart)	Inflammation

(Lee and Cheng, 1970) and may be transmitted to man as the result of eating raw or inadequately cooked mullet. Human heterophyidiasis is characterized by malabsorption due to active destruction of the intestinal mucosa by the adult parasites. Furthermore, eggs deposited by adult worms can be transported by the circulation into such organs as the heart, brain and spinal cord where inflammatory reactions may occur (Africa et al., 1935a,b, 1936, 1937).

Heterophyid trematodes are most abundant in the Far East and Near East, but several species are also known to occur in Hawaii (Glover and Alicata, 1957). Shellfish may act as vector for certain trematodes. A human infection with metacercariae of *Himasthla muelhensi* present in clams eaten raw and resulting in gastro-intestinal disturbances was described (Vogel, 1933). Members of the genus *Himasthla* were found along the Atlantic coast of North America. In Japan, infections with the oriental fluke, belonging to the genus *Paragonimus* were reported. The species *P. ohirai* and *P. iloktsuenensis* are transmitted by estuarine crabs. Man is infected by eating raw or poorly cooked crabs harboring metacercariae. So far, human paragonimiasis is limited to the Orient. Export of pickled crabs from endemic areas might represent a public health hazard elsewhere as well (Cheng, 1973).

Cestode infections

Cestodes have two types of intermediate hosts, fish and copepods, which might be consumed and thus lead to infection in man (Table II). Well-known is the human infection due to the so-called broad fish tapeworm *Diphyllbothrium latum*. Man becomes infected after eating infective plerocercoids in freshwater fish. However, infective larvae were also found in fish (such as salmon) in brackish waters of the Baltic Sea and in Washington State (Wikgren and Muroma, 1956; Becker and Brunson, 1967). Symptoms in man include megaloblastic anemia due to vitamin B12 consumption by the parasite. Plerocercoids of species other than *Diphyllbothrium* cannot mature into adult tapeworms in man, but remain in the plerocercoid stage. Thus larvae of *Spirometra* sp., present in invertebrate crustaceans (*Cyclops* spp.), may in-

TABLE II

Fish-borne parasitic infections: cestodes

Parasite	Fish		Man		
	Stage	Vector	Stage	Site	Effect
<i>Diphyllbothrium latum</i>	Plerocercoid	Fish	Adult	Intestine	Anaemia
<i>Spirometra</i> sp. (sparganosis)	Procercoid	Crustacean (copepod)	Plerocercoid	Skin and other tissues	Minor pathology

fect man, migrate into the skin or subcutaneous tissues and may cause generally a mild pathological condition known as sparganosis (Mueller, 1974).

Distribution of human sparganosis is worldwide with cases reported from all continents including East Africa (Widmer, 1974), Taiwan (Chen and Cross, 1975) and the United States (Daly et al., 1975). Normally man is a dead-end, accidental host. However, Nelson et al. (1965) proposed a possible connection between the adult *Spirometra* infections in hyenas and sparganosis in the African Masai. Transmission to man may occur by drinking water containing *Cyclops* infected with proceroid larvae. Since the Masai still practise the custom of carrying their dead into the bush, hyenas may become infected by ingestion of encysted spargana in the human flesh.

Nematode infections

Migrant larvae of several nematode genera may reach man by ingestion of infected fish, molluscs or crustaceans, when these are consumed raw or are not adequately salted, marinated, smoked or cooked (Table III). Of importance are the infections by the related parasites *Anisakis*, *Phocanema* and *Contracaecum* (for reviews see Ruitenbergh, 1970 and Margolis, 1977). Larvae of nematodes occurring in crustaceans or fish (herring, cod) may accidentally infect man.

TABLE III

Fish-borne parasitic infections: nematodes

Parasite	Fish		Man		
	Stage	Vector	Stage	Site	Effect
<i>Anisakis</i> <i>Phocanema</i> <i>Contracaecum</i>	Larva	Crustacean Fish (e.g., herring)	Larva	Intestine	Granuloma
<i>Angiostrongylus cantonensis</i>	Larva	Crustacean	Larva	Brain	Meningitis
<i>Capillaria philippinensis</i>	Egg	Fish	All stages (autoinfection?)	Intestine	Malabsorption

In most cases the larvae will die in the lumen of the gastro-intestinal tract. Sometimes, however, they penetrate the mucosa and elicit mild inflammatory reactions which, in a few cases, might become severe eosinophilic granulomas causing clinical symptoms, including violent abdominal colics. The disease was first diagnosed in The Netherlands in 1955 in association with a history of consuming 'green' (i.e., lightly salted) herring.

The question whether or not an acquired or natural allergic predisposition of the patient is required, is still unanswered. Recent clinical evidence from Japan supports the allergic nature of the illness (T. Oshima, personal communication, 1974).

Angiostrongylus cantonensis is a common parasite of the lungs of rats in the Pacific Islands and South East Asia (Mackerras and Sandars, 1955). The parasite can be passed through a series of paratenic hosts, including the fresh water prawn, *Macrobrachium lar* (Alicata and Brown, 1962) and the land crab, *Cardisoma hirtipes* (Alicata, 1965), which prey on infected molluscan intermediate hosts. Man may acquire the infection by ingesting infected prawns or raw or inadequately marinated or cooked land crabs. The parasite gives rise to an eosinophilic meningoencephalitis in man (Alicata and Jindrak, 1970). Intestinal capillariasis is a relatively new nematode-caused disease in man, recognized from the early nineteen-sixties, and due to infection with *Capillaria philippinensis* (Chitwood et al., 1968). The syndrome in man is characterized by diarrhea and malabsorption due to atrophic changes in the intestinal mucosa. The parasite may be present in fish along the west coast of the Philippines. Infection is believed to be caused by eating raw fish harboring eggs of the parasite (WHO, 1975).

CHEMICAL CHANGES IN SEAFOOD FROM PARASITE INFECTIONS

Lee and Cheng (1970) reported some alterations in the chemical composition of the musculature of the mullet, *Mugil cephalus*, surrounding the encysted metacercariae of the heterophyid trematode, *Stellantchasmus falcatus*. Furthermore, Cheng (1965) found an accumulation of toxic fatty acids in the tissues of the clam surrounding metacercariae of *Himasthla* sp. The short-chain fatty acids were mainly butyric acid. It was suggested that short-term gastroenteritis (24–36 h), characterized by vomiting and diarrhea, might be the result of ingesting sufficiently large quantities of these toxic fatty acids. Further epidemiological studies are necessary to evaluate the public health hazard of these observations.

APPROACH TO CONTROL OF FOOD-BORNE PARASITIC INFECTIONS

In the control of food-borne parasitic infections a distinction should be made between control of parasitic infections with recognized public health hazard in conventional slaughtered animals and that of fish-borne parasitic infections.

In slaughtered animals the conventional detection methods rely on the direct visualization of the parasite (e.g., trichinoscopy, gross inspection for *T. saginata* and *T. solium* cystercosis). With the availability of reliable indirect techniques (e.g., serology and, theoretically, skin tests) and especially with the development of the highly sensitive ELISA an alternative approach might be suggested. With a negative serological result the animal is directly

released. A positive serological finding means that the animal has been exposed to the parasite. No conclusion, however, can be drawn on the stage of infection, i.e., past exposure or present infection. Therefore, a re-examination with a direct method should be carried out. A negative result with the latter method would then indicate that no parasites are present in the carcass at slaughter and that the meat is safe for the consumer. This procedure might be adopted at the slaughter-house in the framework of preventive control. As interesting is the potential of ELISA for screening animals at the farm or in herds for the presence of specific disease agents. Sero-epidemiological surveys can be carried out, permitting a constant surveillance on the degree of infection in a certain area. Furthermore, serological results from individual animals can be used for preventive control purposes. A positive result in an animal on the farm or in a herd would mean re-examination with a direct method at the slaughter-house. With a negative result, however, the farmer could receive a certificate for slaughter without further examination of the animal at the slaughter-house.

In contrast to the detection procedures used in slaughtered animals, individual examination of fish or shellfish is not practical. Therefore, if a public health hazard is suspected, mass treatment (e.g., freezing) is a more feasible approach. This procedure was adopted in The Netherlands after it was established that virtually all herring from the North Sea was infected with *Anisakis* sp. (Ruitenbergh, 1970). Because of the introduction of various legislative regulations in 1968 and 1969, no cases of human anisakiasis have been reported since 1971. The actual control is carried out by examining the product by random sampling. Herring and herring products are checked for the presence and viability of *Anisakis* larvae.

DISCUSSION AND CONCLUSIONS

Food-borne parasitic infections remain an important public health hazard. The continued interest in meat products from conventional food animals and the increasing interest in seafood, including both fish and shellfish, should prompt an alert attitude of the food hygienist for problems related to food inspection especially of the latter category. Since fish are not confined to certain areas they are capable of carrying parasites to many parts of the world. Therefore, it is felt necessary to develop a global strategy for the control of parasites from seafood.

The availability of a new serological technique, the ELISA method, suggests a reorientation of the conventional approach to slaughter-house control. Effective control of infections at the farm or in large herds is a challenge to any worker in this field. The possibility of applying such techniques in developing countries and effectively improving current control methods is not only relevant for combatting infections in man and cattle, but may also help to stimulate animal industry.

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