Fish, Shellfish, and Human Health

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ABSTRACT

Foodborne illness may result in human beings from ingestion of fish food products containing bacterial or parasitic pathogens. The bacterial pathogens include Salmonella, Shigella, Streptococcus, Leptospira, Clostridium, Staphylococcus, Mycobacterium, Erysipelothrix, Francisella, and Vibrio species. Parasitic illness may result from Diphyllobothrium latum, Clonorchis sinensis, Opisthorchis felineus, Heterophyes heterophyes, and some species of Anisakis. Fishborne intoxication include ciguatera, scombroid, paralytic shellfish poison, and toxic hydrocarbons. Prevention of fish and shellfish-associated illnesses of man is possible by: (a) using only fish and shellfish from unpolluted waters, (b) use of proper refrigeration facilities, (c) practicing strict sanitation in processing plants and storage facilities, (d) assuring foodhandlers are free of carriers of human pathogens in water environments, and (e) cooking thoroughly all fish and shellfish before eating, and (f) not handling aquatic foods when one has wounds or abrasions.

This review has been divided into two parts: (a) fish and human health and (b) shellfish and human health. The reader is also referred to reviews of aquatic animal biology, production, and management (10, 17, 35), pathology (32), toxicology (16), hygiene (3, 24, 26), and aquatic food preservation (6, 7, 12, 28, 36). Fishborne and shellfishborne illnesses are also described in several monographs of zoonotic disease (5, 11, 13, 19, 31).

FISH AND HUMAN HEALTH

Fish and fish products have been associated with several human illnesses (20). It has long been known that fish may be a vehicle for foodborne bacterial and parasitic infections in human beings. Foodborne intoxications are another important group of fish-associated human illnesses. The third way fish can affect man’s health is by injury through physical attacks or accidents. A fourth miscellaneous category includes the human illnesses associated with envenomization, aflatoxicosis, food allergy reactions, and thiamine deficiency disease. Each of these four general categories of fish-associated illnesses will be presented in greater detail.

Fishborne infections and intoxicants (bacterial)

Most of the fish-related foodborne illnesses in the United States are due to Salmonella, Staphylococcus, Streptococcus, Clostridium botulinum, and fish toxins (2). Raw fish taken from waters not polluted by sewage rarely contain bacteria pathogenic for man, other than C. botulinum and Vibrio parahaemolyticus (18). Spoilage bacteria, however, normally abound in surface slime and in gut contents. Fish may also be passive carriers of human pathogens in water environments polluted by human sewage or diseased animals (20). A fish can retain its digestive tract or on its integument many human pathogens (e.g. Escherichia coli, Salmonella sp., Shigella sp., Staphylococcus sp., and C. botulinum) without becoming ill. Fish may also be carriers of waterborne pathogenic bacteria of several genera: Erysipelothrix, Leptospira, Pasteurella, Aeromonas, Pseudomonas, Vibrio, and Mycobacterium. Aeromonas, Pseudomonas, Vibrio, Mycobacterium, and Pasteurella species have been reported to cause active disease in fish. Salmonella, Shigella, Streptococcus, and Staphylococcus. In Salmonella and Shigella food poisoning, fish may be contaminated by polluted water or during processing. The reported Staphylococcus and Streptococcus foodborne illnesses are usually due to contamination of fish on a fishing vessel or in a processing plant.

Fish decompose rapidly enzymatically in comparison to red meat and poultry. Fish also deteriorate much faster than other food products. This has been attributed to the greater free amino acid content of fish tissue. Bacteria found on or in freshly caught fish do not usually present a human health hazard, if fish are promptly chilled on the boat and processed properly in the plant. If allowed to remain on the deck of the boat or if not

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referred to as “fish rose.”

Francisella. The causative agent of tularemia, Francisella tularensis, can infect fish. Contact with catfish has been reported as a cause of human infection. Punctures by the contaminated spines of the fish served to inoculate handlers with the organism.

Prevention

Prevention of bacterial fishborne illness in man is dependent upon the following: (a) fish in unpolluted waters, (b) use proper refrigeration facilities, (c) practice strict sanitation in processing plants and storage facilities, (d) foodhandlers should be disease-free, (e) always cook fish well and never consume raw fish, and (f) don’t handle fish if you have wounds or abrasions.

Fishborne infections (parasitic)

Fish, like other animals, are often parasitized. Internal parasites may be found in the gastrointestinal tract or their larva or cysts may be found in muscle tissue or subcutaneously just under the skin. The broad fish tapeworm, Diphyllobothrium latum, is the only fish parasite of public health importance in the U.S. However, a few other parasitic infections of fish have been reported in humans in this country who have eaten imported fish or who had recently visited a foreign country.

The definitive host of D. latum is man. It may also infect dogs and cats. Proglottids containing operculated eggs, leave the body with the feces.

The first stage larvae, or coracidium, develop within the eggs. These larvae have dense cilia, and they are active swimmers when released from the eggs in the water. Each coracidium contains an oncosphere. They are eaten by a copepod in which the procercoid stage develops. Then pike, perch, turbot, salmon, trout, grayling, or eel eat the infected crustaceans. The procercoid migrates through the intestinal wall of the fish and matures into a pleurocercoid in the muscle. Man’s ingestion of raw or poorly cooked fresh-water fish completes the cycle. The tapeworm may cause severe anemia in man. D. latum presently occurs throughout much of the great Lakes Region of North America. Prevention of diphyllobothriasis is dependent upon abstinence from raw or poorly cooked fish. Researchers have shown that freezing or heating to an internal temperature of 56 °C will destroy the pleurocercoids.

In East Asia the cat liver fluke (Opisthorchis felineus) and the Chinese liver fluke (Clonorchis sinensis) are frequently diagnosed in humans. Heterophyes heterophyes, a fluke of fish, and Paragonimus westermani, a fluke of crab, are also transmissible to man.

Herring-worm disease has been reported in human beings in the Netherlands (37). The etiologic agent has been identified as the larva of Anisakis sp, which usually inhabits the viscera of small fish that serve as intermediate hosts. Human infections were contracted by eating raw or improperly cured herring. The syndrome in man was characterized by acute abdominal pain and peritoneal irritation. The parasite apparently penetrates the intestinal wall and migrates in the abdominal cavity.

In the midwest, black and white parasitic grubs, commonly referred to as “black spot” and “white spot,” are often found encysted in the muscle of freshwater bass and perch (34). They are the larval stage of flukes that have their adult stage in fisheating birds. Based on current knowledge, these larvae present no public health hazard, however, it should be recommended that fish be thoroughly cooked.
Other fishborne intoxications

As well as being carriers of bacterial pathogens, fish may contain other toxicants which have caused or have the potential for causing foodborne disease in man. These include Ciguatera, Scombroid, and Puffer ichthyosarco toxins; mercury; nitrites-nitrates; pesticides; radio nuclides; and the toxic substance causing Haff disease.

Ciguatera-Scombroid-Puffer. Ciguatera and Scombroid are two different types of fishborne intoxications in man. These fish muscle toxins, or ichthyosarco toxins, have been recognized for over 200 years.

Ciguatera toxin has been found in more than 300 species of marine fishes. Sea bass, jack, barracuda, snapper, wrasse, parrot fish, and surgeon fish are all renowned for carrying this toxin. Gastrointestinal and neurological disturbances, numbness around the lips, and muscle pains are common in poisoned humans. The case fatality rate is less than 10%. This fish species producing this form of poisoning may be toxic in some areas of the world, but safe in others. It is thought that the toxin is produced by blue green algae and transferred to fish through the food chain. The poison is generally not destroyed by cooking procedures.

When Scombroid fishes are kept at room temperature, bacterial spoilage can result in enzymatic decarboxylation of free histidine to produce histamine. Scombroid toxin is thought to be a combination of histamine and other toxic substances. Scombroid poisoning produces symptoms resembling those of severe allergy or histamine intoxication. Symptoms in man are headache, dizziness, abdominal pain, and gastrointestinal upset. Death due to suffocation and shock has been reported. Antihistamine agents may relieve the symptoms.

Puffer fish poisoning is another form of fish poisoning frequently diagnosed in Japan. Gastrointestinal upset may be present, but neurological disturbances are more common. Motor paralysis, convulsions, and death by respiratory failure within 24 h are common. The case fatality rate is approximately 60%. Puffer poisoning in Japan has accounted for as much as 44% of all fatal food intoxications.

Mercury. Fish were first recognized in Japan as being contaminated with and hence a source of mercury in the diet (27). Between 1953 and 1956, more than 100 people suffered severe central nervous system illness, and 12 people died after eating mercury-contaminated fish caught in Minamata Bay. A plastics factory on the bay was the source of inorganic mercury contamination in the bay. Chemical analysis of the fish showed 40 ppm of nearly pure organic methyl mercury which is much more toxic than inorganic mercury. In 1956, Japan banned fishing in Minamata Bay. It was later discovered that microorganisms in the bottom muck of the lake had the ability to convert inorganic mercury to methyl mercury. In view of the biological magnification of the mercury through the food chain in the bay and the 200-day half-life of mercury of fish, it is easy to see how fish concentrated mercury 1000 times the amount in water.

In the spring of 1970, fish in Lake St. Clair, a small lake adjacent to Detroit, Michigan, had mercury levels as high as 7 ppm almost 14 times that of the FDA’s guideline of 0.5 ppm. Ontario and Michigan subsequently closed the lake to commercial fishing. In December 1970, the FDA recalled from grocers' shelves one million cans of tuna that had mercury levels above FDA guidelines of 0.5 ppm. Danger of mercury poisoning in fish generally increases with the size of the fish; swordfish are usually larger than 100 lb. In May, 1971, FDA issued a notice recommending that the public not eat swordfish. By September 1970, 18 states had closed either a major river or lake to fishing because of the mercury hazard present in the fish. In 1972, the mercury level in the muscle of pike was found to be as high as 20 ppm when the fish came from rivers downstream from sites of pulp or paper industries where phenyl mercury acetate was used as a slimicide. In uncontaminated areas, a level of 0.1 ppm in pike is regarded as natural.

It was later determined that use of mercury fungicides on golf course greens in the U.S. caused high mercury levels in fish located in golf course lakes and ponds (25). Some of these impoundments were closed to fishing.

Nitrite and nitrate. When nitrites and nitrates are added to meat that has begun to decompose, the meat becomes more red in color thus appearing fresh. This practice of "camouflage" is obviously dangerous because the consumer can not recognize spoiled meat and because excessive amounts of nitrates or nitrates added to food can result in human illness associated with hemoglobinemia, cyanosis, vomiting, and possibly death.

Another possible risk from using nitrites and nitrates as "camouflage" or as curing salts in fish processing is the production of the carcinogen N-nitrosamine; Reducing bacteria on fish convert nitrates to nitrates; these nitrates can interact with secondary amines in gastric fluids to form N-nitrosamine. Whether this occurs when people eat nitrite-containing fish products has not been definitely proven.

Pesticides. DDT, a chlortated hydrocarbon insecticide, has been reported as the etiologic agent in cases of non foodborne acute and chronic toxicity in man (33). Seafood was not involved in any of these cases. Chronic toxicity from seafood has not been reported in man, but the potential hazard is present in food fish because of: (a) the phenomenon of biological magnification or concentration of DDT in the food chain, and (b) DDT storage in human fat and its slow excretion.

The DDT threat in fish is well illustrated by studies of Coho salmon in the Great Lakes. These salmon were found to contain much more than the permissible 5 ppm. The Cohos rapid weight gain, before migration up tributaries, may be the primary reason the fish accumulated large amounts of pesticide.

In just 2 h, endrin concentration in blood of catfish can reach 1,000 or more times the amount present in
surrounding water. This is a major problem in catfish farming on converted cotton land where pesticides was used as a cotton spray. Consumption of fish containing DDT in concentrations of 5 ppm or less is permitted by FDA provided the menu does not contain fish items for days or weeks at a time. Variety in the diet is recommended.

Radioactivity. Another potential threat seafood presents to man is radiation. Oceans covering large portions of the earth are major recipients of man-induced (military and industry) radionuclides. Today most foods have more radioactivity than present before 1945. Studies have shown that aquatic organisms can accumulate considerable quantities of nuclides. Researchers at White Oak Lake and the Columbia River near Hanford, Washington, where plutonium production reactors are located, found that minnows could accumulate $^{32}$P to levels 150,000 times greater than that of surrounding water. They also found that the total radioactivity of plankton was about 2,000 times that of surrounding water. Clams and oysters collected off the Marshall Islands after the Bikini Atomic Tests had radioactivity 2,000 times greater than that of sea water. The concentrating of radioactivity by clams probably involved their ability to filter large volumes of water. In fish, most radioactive elements are absorbed from water via the gills and not via ingestion and intestinal absorption.

In summary, nuclides with longer half-lifes, ($^{137}$Cs and $^{90}$Sr) present a potential health hazard (1). However, nuclides with a short half-life or extreme insolubility are of relatively little public health concern.

Haff disease. In countries bordering the Eastern Baltic Sea, a condition known locally as Haff Disease is caused by consumption of fish containing a factor that inactivates thiamine (Vitamin B$_1$) (30). "Haff" means an inland sea. Patients complain of muscular pain in arms, legs, and back. The skin is extremely sensitive to touch and their urine is brown to black. Haff disease has been associated with Swedish and Russian lakes after luxuriant blooms of blue-green algae. The etiology has been proposed as being either a Ciguatera-like poison or a thiamine-inactivating compound.

Physical injury. Piranha and sharks have remarkable teeth. These are well known examples of species which can inflict physical injury on human beings.

Miscellaneous. Envenomization of fish stings may be caused by a wide variety of fish species. Over 100 different fish species are known to possess toxin spines. The venoms vary greatly in toxicity; most are merely painful while others are lethal. Stonefish off the coast of East Africa and Australia are the most venomous fish known (16). These fish have excellent camouflage; they erect their spines and remain perfectly still when being approached. Most exposures occur when a person steps directly on top of the fish. Several deaths have been reported, usually within 6 h after exposure.

Allergy. Fish and shellfish may cause food allergies in certain humans. Fish proteins act as allergens and subsequent meals may initiate anaphylactoid or cutaneous hypersensitivity reactions. Allergic individuals are believed to have inherited a predisposition or capacity to become sensitized. In man, symptoms of allergic reactions are urticaria, angio-neurotic edema, gastro-intestinal disturbances, and migraine headache. Allergy is usually confined to one general class or species of fish. Sensitized people usually react more frequently to sardine and salmon than to cod and halibut.

Thiamine deficiency. A number of distinct nutritional problems are related to consumption of fish by animals. The first important nutritional disease of fur-bearing animals was noted on the fox ranch of J. S. Chastek of Glencoe, Minn. in 1932 (14). Foxes given a ration of 18% uncooked carp developed paralysis within a few weeks and died. Researchers reported...that an enzyme was involved and it seemed to be confined to fresh water fish, with the exception of ocean herring species. Later mink ranchers found they could use fish in their mink diet if fish was cooked at 82-93 C for 15 min to destroy the enzyme.

Fish also contain a high level of unsaturated fatty acids. It has been shown that low dietary level of Vitamin E and a high dietary level of unsaturated fatty acids stimulate development of steatitis in young mink and cats (23).

Human beings eating a diet of primarily raw fish might develop thiamine deficiency. A diet of semi-cooked or raw fish would be contraindicated for persons on a low thiamine diet.

Aflatoxin. In the early 1960s liver tumors called hepatomas were found in epizootic proportions in rainbow trout in the United States (38). California researchers found that a diet containing cotton seed meal was responsible. It was later shown that aflatoxins produced by the mold, Aspergillus flavus, were contaminants in the cottonseed meal. This disease is rapidly becoming rare in the U.S. as feed manufacturers improve their feeds and as hatcherymen store their feed under better conditions. Fish farmers and veterinary consultants should develop management procedures that will avoid mold growth in feed for trout, pompano, and catfish commercial operations. Tolerances for aflatoxins in food products have been set at 15-30 ppb. Aflatoxins are partially detoxified by normal cooking temperatures, but even high temperatures over long periods often do not achieve total destruction.

FISH, SHELLFISH, AND HUMAN HEALTH

Shellfish, like fish, have been reported to cause a variety of disease conditions in man. Shellfish have been the source of such human infections, as typoid, *Vibrio* food poisoning, and infectious hepatitis. Shellfish can also be responsible for an intoxication such as paralytic shellfish poisoning. Mercury, pesticides, and toxic hydrocarbons are other toxicants which shellfish may concentrate and pass on to higher trophic levels.
Shellfishborne infections

Vibrio. A picnic was held in Maryland which was attended by 550 guests (15). It was a feast of Chesapeake Bay steamed crabs, a regional delicacy that has been esteemed by Marylanders since colonial days. Approximately 16 h later, 320 of the picnickers became ill with symptoms such as diarrhea, severe abdominal cramps, nausea, vomiting, fever, headache, and chills. A number of the affected people were hospitalized. An organism known as V. parahaemolyticus was isolated. This organism has been recognized to be an important cause of foodborne disease in Japan for the last 20 years, but it had never been isolated in the United States before 1968 and never identified with outbreaks until 1971.

V. parahaemolyticus is a gram-negative, rod-shaped bacterium; the most favorable condition for its growth is in a medium containing 2 to 4% salt. It particularly favors alkaline conditions and multiplies rapidly at 37 C. It appears to be able to live in marine waters without an animal host. It has been found in coastal and estuarine waters and sediments and on marine fish, crustaceans, and shellfish in many areas of the world, including all coastal waters of the United States. It thrives better in warm weather than in cold and the illness it causes is usually associated with warm weather (22).

V. parahaemolyticus in food products is associated almost exclusively with seafood, and it has been found in practically all seafood products — fish, shellfish, crustaceans, and others. Fish samples are prepared for bacteriological examination by blending and diluting the sample with saline. The sample is then inoculated into enrichment media and incubated. A plate is then streaked with a portion of the incubated food sample, incubated, and then examined for colonies of V. parahaemolyticus.

Some Japanese scientists believe that the Wagatsuma agar plate containing human erythrocytes, can determine the virulence of a strain of V. parahaemolyticus (15). This hemolytic test, referred to as the Kanagawa phenomenon, is based on the ability of an organism to hemolyze blood cells within 24 h. Cleared zones around colonies is due to hemolysis of the erythrocytes, thus indicating pathogenicity.

Infectious Hepatitis. Contamination of shellfish harvested or held in waters polluted with sewage is an important route of transmission of viral agents (4). Epidemics of infectious hepatitis in Texas and Georgia were traced to a single Louisiana oyster supplier. Approximately 265 clinical cases of hepatitis A resulted from consumption of raw oysters (9). Enteroviruses have also been isolated from oysters taken as far as 4 miles from the nearest outlet of raw sewage into estuary waters.

Typhoid. Marine and fresh water vertebrates, crustaceans, and shellfish living in waters not polluted by discharge of crude sewage or effluent are normally free of salmonellae. Oysters and mussels, which feed by filtering organic matter from 20 to 40 liters of sea water hourly from beds in sewage-polluted waters, form a well recognized source of infection with S. typhi.

By the process of depuration, placing shellfish in enormous shallow trays and allowing clean estuarine water to flow over them for several days, shellfish cleanse themselves of harmful viruses. In addition to microbiological testing of waters, obviously contaminated areas are designated as "off limits" for shellfish cultivation.

Shellfishborne intoxications

Paralytic shellfish poisoning. Severe and often fatal human intoxications following ingestion of bivalve mollusks occur sporadically in widely scattered areas throughout the world (29). This illness is referred to clinically as paralytic shellfish poisoning (PSP) and is caused by small phytoplankton. This disease in shellfish is similar to Ciguatera poison in fish. Filter-feeding mollusks, mussels, clams, oysters, and scallops accumulate toxin without harm to themselves by ingesting toxic dinoflagellates. PSP in man is manifested by either paralysis or neurotoxic symptoms. Numbness and ataxia usually begin within 30 min after eating toxic shellfish. Patients surviving the first 12 h generally recover. No antitoxin is known for this toxin. The toxin is not completely destroyed by cooking, but toxicity is reduced by approximately 70%.

PSP does not constitute a major public health concern in the United States, although outbreaks do occur occasionally. In recent years there have been three confirmed outbreaks of PSP on the west coast. The outbreaks were small and no fatalities resulted. The northern coast of California annually quarantines mussels from May 1 to October 21 because of the PSP threat during the summer months. Most victims of PSP in North America are tourists and picknickers who harvest shellfish for personal consumption on outings to beaches and estuaries. Visitors and new residents in an endemic area are often unaware of the regions of shellfish toxicity or they may disregard posted warnings against poisonous shellfish.

The greatest number of human PSP poisonings have been traced to various species of mussels, hence the common term, "mussel poisoning." Fortunately, except for butter clams and scallops which may remain toxic throughout the year, most mollusks lose the toxin rapidly as winter approaches.

Prevention and control lies in surveillance of edible mollusks for toxicity during potential danger periods. The mouse bio-assay is the standard method for monitoring safety of shellfish. Growing areas are quarantined when toxicity is known to reach 400 mouse units/100 g of shellfish.

Extensive blooms of dinoflagellates, “Red Tides,” are often accompanied by spectacular displays of luminescence or phosphorescence at night. This feature is reported to have been used by Indians along the Pacific Coast of North America as a warning of shellfish toxicity.

Mercury. Some lots of frozen, breaded oysters have been found to contain large mercury residues (4). State officials had sampled and analyzed several lots. They
found mercury in one lot in a range of 0.5 to 3.4 ppm while the second lot contained from 3.6 to 10.2 ppm. The amounts were considerably greater than the guidelines of 0.5 ppm.

Toxic hydrocarbons. One of the more current problems of concern is the effect of toxic hydrocarbons on the health of shellfish consumers. An estimated 600 oil spills per month have been reported in coastal waters of the United States.

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