

11. PHYSICAL AND CHEMICAL HAZARDS IN SEAFOOD

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Introduction

Seafood is a rich source of important nutrients has grown in consumption as it has become an important part of a diet. However seafood safety is a growing concern for human health. Seafood can contain harmful chemicals, biological agents and physical contaminants which can pose health risks to consumers. Fishes are harvested from waters that are contaminated by varying amounts of industrial chemicals, heavy metals, pesticides and antibiotics. These contaminants may accumulate in fish at levels that can cause human health problems (e.g. carcinogenic and mutagenic effects).The seafood may also get contaminated with various pathogenic bacteria due to unhygienic handling practices, cross contamination of raw foods with cooked or ready-to eat foods, and lack of proper temperature control. Physical hazards include foreign objects originate primarily from processing machinery, packaging or transportation/storage, and which also include objects that are intrinsic to the fish like bones or shell fragments in bivalve molluscs.Food can become contaminated at any point during production, distribution and preparation. Everyone along the production chain, from producer to consumer, has a role to ensure the safety of seafood.

Physical hazards

Physical hazards are any potentially harmful extraneous matter not normally found in food. Physical hazards can lead to adverse situations such as choking, injurieswith laceration and perforation of tissues in the mouth, throat, stomach and intestines. Broken teeth and damage to gums can also happen.The introduction of physical hazards should be controlled and the control measures should be monitored and verified. These are the hazards which are mostly recognized by the consumers and commonly reported by consumers.

Common physical hazards can be of natural objects (bone, hair, shell fragments etc) and objects added during processing (glass, plastic, metal etc). In addition to these extraneous objects like leaves, dirt, wooden splitter, jewellery, buttons, coins can also become physical hazards.

The common physical hazards in seafood are

Metal: It is one of the most common physical hazards in seafood. Metal-to-metal contact, especially in mechanical cutting or blending operations, other equipment with metal parts that can break loose (such as moving wire mesh belts, injection needles, screens, portion control equipment, metal ties, sawing devices and can openers) are the most likely sources of metal that may enter food during processing. This hazard can be controlled by subjecting the product to metal detection devices or by regular inspection of at-risk equipment for signs of damage. A calibrated metal detector can identify a food containing metal pieces more efficiently.

Glass: It is the other common physical hazard in seafood. Glass fragments can cause injury to the consumer. Glass inclusion can occur whenever processing involves the use of glass containers. Normal handling and packaging methods, especially mechanized methods, can result in breakage. Most products packed in glass containers are intended as a RTE commodity. Light bulbs, glass containers and glass food containers are common sources. Glass fragments originating from other sources must be addressed, where applicable, in a prerequisite sanitation program.

Bones: It is an intrinsic hazard in seafood. Only bones of certain dimensions in length and width can be found by mouth feel, but if chewed or swallowed can be a hazard and cause lesions. Bones exceeding these dimensions are called defect bones. A bone in a package designated as boneless is a defect if it is “greater or equal to 10 mm in length, or greater or equal to 1 mm in diameter; a bone less than or equal to 5 mm in length, is not considered a defect if its diameter is not more than 2 mm. The foot of a bone (where it has been attached to the vertebra) shall be disregarded if its width is less than or equal to 2 mm

Struvite: Struvite crystals are harmless crystals resembling glass observed in canned fishery products. They are magnesium ammonium phosphate hexahydrate. They are formed from natural, normal constituents of the flesh of all seafoods after they are sterilized in the can.

Struvite crystals are regularly shaped prisms, with the edges tending to form straight lines while glass particles are more likely to be irregular in shape.

Plastics: Material used for packaging, fragments of utensils used for cleaning equipment can become hazard. In addition to this gloves worn by food handlers and tools used to remove processed food from equipment can also come under hazard.

Stones: Stones incorporated in field crops, such as peas and beans, during harvesting can be hazardous. Structures in food processing facility can also act as source of small stones.

Wood: Splinters from wood structures and wooden pallets used to store or transport ingredients or food products can act as hazard.

Natural components of food: Hard or sharp parts of a food such as shells become hazardous if consumers do not expect them.

Control measures for physical hazards

- Visual inspection
- Use of filters and sieves, metal detectors, magnets, x-rays, separation by density
- Personal precautions of the personnel
- Periodic checking of cutting or blending equipment or wire-mesh belts for damage or missing parts
- Visual examination of empty glass containers; cleaning (by water or compressed air) and inverting of empty glass containers; periodic monitoring of processing lines for evidence of glass breakage;
- Proper adjustment of capping equipment; visual examination of glass containers containing transparent liquid fishery products; and the passing of the product through x-ray equipment or other defect rejection

Chemical hazards

The number of chemical contaminants is increasing day by day, hence threats associated with chemical contamination of seafood is also increasing. Environmental contaminants mainly include ubiquitous pollutants such as heavy metals and dioxins. Even though they are naturally

present in the environment their level can be increased due to anthropogenic influences. Contaminants can also come as toxins produced by fungi (Eg. aflatoxins) and algae (Eg. ciguatera toxin). The different chemical contaminants in seafood can also include food additives that are intentionally added like preservatives, colour retention agents etc. The contaminants can also generate during processing or cooking which include acrylamide and heterocyclic amines. Residue of agricultural chemicals resulting from previous application of pesticides, and veterinary drugs during production and storage of food crops and animals, have been considered as human health hazards. But these types of contaminants have a great potential in control by proper conditions of usage and their presence. Also some natural components of food can also act as contaminant like allergic substances and phytohaemagglutinin.

Basically the chemical contaminants are classified into three main groups such as:

(i) Naturally occurring – allergens, Mycotoxins, Scomberotoxin (Histamine), Ciguatera poison, Puffer fish poison, Shellfish toxins (PSP, DSP, NSP, ASP)

(ii) Unintentionally or incidentally added chemicals – Pesticides, Fungicides, Fertilizers, Toxic compounds, Toxic metals

(iii) Intentionally added chemicals and food additives - Food preservatives, Food additives, Vitamins, Minerals, Antibiotics used in aquaculture, Sulfites used in shrimp to prevent melanosis, Nitrites as preservatives, Colouring agents, Detergents

Heavy metals

Heavy metals are toxic metals and above a normal level can affect the quality, safety and marketability of seafood. They are “Cumulative poisons” which can irreversibly accumulate in the body. They have atomic weight higher than 40.04 and specific density $> 5\text{g/cm}^3$. The main threats are Arsenic, Cadmium, Mercury and Lead. These metals have no beneficial effects in human and they have no homeostasis mechanism. These contaminants are highly dependent upon geographic location, species and fish size, feeding pattern, solubility of chemical and their persistence in the environment.

Lead is mostly deposited in bones and not in soft tissues. But, from food safety point of view lead accumulation in edible parts is important. Compared to fish lead content is higher in shellfishes as it is getting accumulated in hepatopancreas. The organic form of lead, tetra alkyl

lead is mostly found in fish. In fishes Cd is mostly deposited in kidney and liver and in muscles the level is quite low. In invertebrates like Cephalopods it can go as high as 30 ppm in digestive glands. Hence the digestive gland must be removed immediately after catch. Both Cd and Pb are carcinogenic in nature. Mercury is one of the most toxic heavy metal in the environment. Among metal contaminants methyl mercury has elicited the most concern among consumers. It is toxic to the nervous system especially the developing brain. Arsenic is a widely distributed metalloid and major contaminant in case of ground water. The major proportion of arsenic in seafood is in the organic form, e.g. as arsenobetain, arsenocholine or arsenosugars. A minor fraction is inorganic arsenic, which is the toxic form of this element. IARC has classified inorganic arsenic as a human carcinogen. The most widely used techniques for detection and quantification of heavy metals are Atomic Absorption Spectrometry, Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) and Inductively Coupled Plasma-Mass Spectrometry (ICP-MS).

Histamine in fish

Though all types of biogenic amines can be formed in fish, the most toxic amine detected in fish is histamine. Histamine poisoning is the most common form of toxicity caused by ingestion of fish and is generally due to the ingestion of foods containing unusually high levels of histamine. The commonly implicated incidents of histamine poisoning are associated with the fish families Scombridae and Scomberesocidae. It is also known as Scombroid poisoning. Histamine is a powerful biologically active chemical present in the mast cells and basophils in larger amounts. Histamine poisoning is often manifested by a wide variety of symptoms. Major symptoms affecting the cutaneous system include rashes, urticaria, edema and localized inflammation etc. gastrointestinal effects include nausea, vomiting, diarrhoea and abdominal cramps. Also include symptoms like hypotension, headache, palpitation, tingling and flushing. Severe suffocation and respiratory distress have been reported in severe cases of histamine poisoning. The onset of histamine poisoning can extend from 10 minutes to 1 hour following consumption of contaminated fish and can last from 12 hour to a few days. Histamine concentration required to produce poisoning varies with respect to the susceptibility of each individual. In case of susceptible individuals concentration between 5 and 10 mg/100g can cause symptoms. Many foods contain small amounts of histamine which can be tolerated easily.

As per USFDA guideline the toxicity and defect action level established are 50 mg/100g and 5 mg/100g respectively. According to EU regulation No 2073/2005 mean value all samples (nine) must not exceed 10 mg/100g, two samples may be > 10 mg/100g but < 20 mg/100g and no sample may exceed 20 mg/ 100g. According to USFDA guideline for the control of histamine production a core temperature of 4.4 °C or less should be achieved and maintained throughout handling, processing and distribution of susceptible species. A wide variety of procedure for the determination of histamine and biogenic amines is available. Include both semi quantitative and quantitative methods. Methods based on colorimetry, fluorometry and enzyme-linked immunosorbent assay (ELISA) are available. Mostly biogenic amines including histamine is analysed by High Performance Liquid Chromatography (HPLC) methods with pre and post column derivatisation and UV–visible or fluorescence detection. LC with tandem mass spectrometry (MS/MS) can also be a useful approach for an unequivocal confirmation of the studied analytes.

Biotoxins

Marine biotoxins are responsible for many seafood borne diseases. It includes both shellfish toxins and ichthyotoxins (fishtoxins). Shellfish toxins include Paralytic shellfish toxins, Diarrhetic shellfish toxins, Azaspiracid shellfish toxins, Neurotoxic shellfish toxin and Amnesic shellfish toxins. Ichthyotoxins include Ciguatera toxin and Tetrodotoxin. Fish poisoning is caused by consuming fish containing poisonous tissues and shellfish poisoning results from ingestion of shellfish that have accumulated toxins from the plankton they have consumed.

- (i) Tetrodotoxin (Puffer fish poison): It is the most lethal of all fish poisons. Toxin production is due to the activity of symbiotic bacteria. Toxin will be accumulated in liver, ovaries and intestine as a defence mechanism. But the muscle is free of toxin. It is also called as Tetradon poisoning or Fugu poisoning. It is 275 times more toxic than cyanide. On an average a dose of 1-2mg of purified tetrodotoxin can be lethal to humans.
- (ii) Ciguatera - Ciguatera is a clinical syndrome caused by eating the flesh of toxic fish caught in tropical reef and island waters. Most common fish poisoning and the fish becomes toxic due to feeding of toxic algae – dinoflagellates, *Gambierdiscus toxicus*. Red snapper (*Lutjanus bohar*), Grouper (*Variola louti*) and Moray eel are recorded as ciguateric. More than 400 species have been implicated in ciguatera poisoning.

- (iii) Paralytic shell fish poisoning (PSP) –This is associated with dinoflagellate blooms (*Alexandriumcatenella*, *Gonyaulaxtamerensis*). Heat stable saxitoxin will be accumulated in mussels, clams, oysters, scallops etc. grown in algal bloom areas. Greater number of human deaths is reported due to consumption of contaminated shellfish. The current regulatory level for fresh bivalve molluscs in most countries is 80 µg/100 g.
- (iv) Diarrhetic shellfish poisoning (DSP) - Dinoflagellate *Dinophysisfortiis* the algae which produces okadaic acid, the causative of DSP. Primary symptom is acute diarrhoea. Regulatory level in fresh bivalve molluscs in most countries is 0-60 µg /100 g.

Mouse bioassay and analysis by HPLC are the important methods for monitoring biotoxins. Reliable sampling plans are required for effective monitoring.

Pesticides

Pesticides are substances used for preventing, destroying or controlling any pest. The major chemical types of pesticides include (i) Organochlorine pesticides – mostly banned because of its lipophilic nature. Have properties of bioaccumulation and high persistence (Eg: DDT and its derivatives, BHC, Endosulfan, aldrin, dieldrin etc). (ii) Carbamates – widely used insecticides (Eg: carbaryl, carbofuran, carbosulfan). (iii) Organophosphates – have rapid action at lower concentration, easy biodegradable in nature (Eg: malathion, Monocrotophos). (iv) Pyrethroids – have low mammalian toxicity and knock down effect against insects (Eg: Deltamethrin, Cypermethrin, Cyhalothrin, Fenvalerate etc.). Pesticide contamination in fish mainly comes through agricultural runoff and municipal sewage effluent. Persistent organic pollutants (POPs) are organic chemicals that remain intact in the environment for long periods, become widely distributed, bio accumulate in food chain and are toxic to humans, wild life and environment. The POPs to which seafood consumers are most likely exposed are dioxins and PCBs. The Stockholm convention on POPs initially identified twelve POPs, called as ‘dirty dozen’ include 9 pesticides, 2 industrial chemicals and 1 unintentional by product. They are aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene, polychlorinated biphenyls (PCBs), dioxins and furans. Later nine new chemicals were again added to Stockholm convention. The chromatographic techniques mainly Gas chromatography (GC), Gas chromatography-tandem mass spectrometry (GC-MS/MS) and Liquid chromatography-tandem mass spectrometry (LC-MS/MS) are used for the analysis of pesticide residues.

Antibiotics

Illegal use of antibiotics for veterinary purposes has become a matter of public concern. Antibiotics are used in aquaculture as prophylactics, as growth promoters and for treatment of diseases. They are usually administered in feeds and most commercial shrimp feeds contain antibiotics. The feeding of antibiotics as growth promoters is associated with decrease in animal gut mass, increased intestinal absorption of nutrients and energy sparing. But inappropriate and frequently abusive, use of antibiotics can affect human health. The two major concerns are the presence of antimicrobial residues in edible tissues and the emergence of antimicrobial resistance, which represents a huge threat to public health worldwide.

The greatest potential risk to public health associated with antimicrobial use in aquaculture is the development of a reservoir of transferable resistance genes in bacteria of aquatic environments. The antibiotics lose their efficacy over time because of the emergence and dissemination of resistance among bacterial pathogens.

For veterinary drugs without ADIs/MRLs, regulatory authorities generally adopt a zero tolerance approach. Antibiotics such as chloramphenicol and nitrofurans (metabolites namely AZO- 3-amino-oxazolidinone; AMOZ- 3-amino-5-morpholinomethyl-1,3-oxazolidin; AHD- 1-aminohydantoin; SEM- semicarbazide) are banned for animal intended for food production. European Union monitors the misuse of banned antimicrobials using an analytical method that has a prescribed minimum required performance limit (MRPL). Using LCMSMS method EU laboratories are equipped to detect traces of prohibited carcinogenic antibiotics like chloramphenicol up to 0.3 ppb and nitrofurans up to 1 ppb levels. Many of the antibiotics are listed as prohibited substance in fish and fishery products. In India the tolerance limit has been set only for the following antibiotics

Antibiotic	MRL (ppm)
Tetracycline	0.1
Oxytetracycline	0.1

Trimethoprim	0.05
Oxolinic Acid	0.3

The monitoring of antimicrobial residues in fish tissues requires sensitive and selective analytical methodologies to verify the accomplishment of the legal framework and reach the desirable high standards of quality and food safety. The methods can be microbiological, immunochemical or physico chemical. European council directive 96/23/EC, 1996 gives direction on measures of monitoring residues in live and animal products. It specifies spectrometric detection, GC, HPLC, ELISA and LC-MS/MS methods.
