QUALITY AND SAFETY ISSUES IN SMOKED FISHERY PRODUCTS

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Introduction

Smoking is an age-old fish preservation technique. Smoking is a process of exposing fish to smoke from smouldering wood or plant materials to introduce flavour, taste and preservative ingredients into the fish. This process is characterised by the combination of salting, drying, heating and smoking. Due to drying effects and antioxidant and bacteriostatic effects of the smoke, the smoked products have extended shelf-life. The fish is subjected to smoke produced through the incomplete combustion of wood in the form of sawdust or woodchips. Smoke is a highly complex mixture of chemicals like organic acids, alcohols, ammonia, carbon dioxide, carbon monoxide, carbonyls, esters, furans, hydrocarbons, lactones, nitrogen oxides, particulates, phenols and the interaction between smoke and the flesh surface is responsible for characteristic golden-yellow colour, odour, flavour and preservative effect.

Depending upon how the smoke is delivered into the food and smoking temperature, four basic types of smoking can be defined: hot smoking, cold smoking, liquid smoking, and electrostatic smoking. Hot smoking is the traditional smoking method using both heat and smoke, which usually occurs at temperatures above 70 °C. For hot smoked fish and fish products, a minimum thermal process of 30 min at or above 62.8 °C is required by USFDA. Therefore, after hot smoking, products are fully cooked and ready for consumption. In cold smoking the core temperatures do not exceed 30 °C. Thus, cold smoked products are not cooked and typically heavily salted. Compared to hot smoking, cold smoking runs longer, has a higher yield and retains the original textural properties much better than the hot-smoked ones. Liquid smoke is smoke condensate that is dissolved in a solvent, such as water or oil. Liquid smoke can be used directly on products by dipping or spraying. It is rapid and much easier to achieve a uniform smoke flavour than traditional cold and hot smoking processes, although the flavour and colour from the traditional smoking cannot be exactly duplicated. However, the application of liquid smoking may be expensive compared to other methods. Electrostatic smoking is another rapid way to smoke fish where fish are sent into a tunnel where an electrostatic field is created. Smoke particles are given a positive charge and deposit onto the surface of the fish which are negatively charged.

The codex standard deals with smoked, smoke-flavoured and smoke-dried fish prepared from fresh, chilled or frozen raw material. Smoked fish is prepared from fish that has undergone a hot or cold smoking process. The smoke must be applied either through smoking or smoking by regenerated smoke or application of smoke condensates. The end product must have smoked sensory characteristics. It allows for the use of spices and other optional ingredients. Whereas smoke-flavoured fish is prepared from fish that has been treated with smoke flavours, without undergoing a smoking process. It must have a smoked taste. For smoke-flavoured fish the spices and other optional ingredients can be used. On the other hand, smoke-dried fish is prepared from fish that has undergone a combined smoking and drying process and may include a salting process. The smoke must be applied through a smoke-drying process traditional for the respective country or an industrial smoke-drying process and the end product must have smoke-dried sensory characteristics. Spices and other optional ingredients can be used.

Potential major hazards associated with smoking of fish and fishery products

Biological hazards

1) Listeria monocytogenes: Typical temperature used for cold smoking is 22-28˚C. However, this temperature is not sufficient to eliminate the risk from *Listeria monocytogenes*, a gram positive, facultative anaerobic, psychrotropic bacteria causing deadly septicaemia, meningitis, spontaneous abortion, and foetal death in adult human beings. Comparatively high temperature used in hot-smoking process and long-time of exposure to that temperature (60-70˚C for 2-3 h) can inactivate the *L. monocytogenes* effectively. At the same time listericidal process should be validated to ensure that the treatments are effective and can be applied continuously. But the hot smoked products are susceptible to post-process contaminations from many of the micro-organisms due to improper handling and storage of the products. Sufficient heat treatment, proper hygienic handling and cold chain maintenance during distribution can reduce the risk of biological hazards in smoked fish and fishery products.

2) Clostridium botulinum: The toxin produced by *Clostridium botulinum* can lead to botulism, serious illness and death to the consumer. Even a few micrograms of intoxication can lead to ill-health with symptoms like weakness, vertigo, double vision, difficulty in speaking, swallowing and breathing, abdominal swelling, constipation, paralysis and death. By achieving proper salt concentration in processed fish, proper refrigeration during storage and reduced oxygen packaging like Modified Atmosphere Packaging (MAP) of the products can prevent

the occurrence of *C. botulinum* in smoked fish and fishery products. Salt along with smoke effectively prevents the toxin formation. In cold smoked fish and fishery products, which undergoes mild heat processing, the presence of spoilage organisms prevents the growth of *C. botulinum* and toxin production. Whereas in hot-smoked products, high temperature application causes damages to spores of *C. botulinum* thus prevents the toxin formation. Same process also prevents the prevalence of spoilage organisms and thus extends the shelf life of the product. Thus, the time-temperature combination for smoking, along with salt concentration plays critical roles in safety and quality aspects of the smoked fish and fishery products.

3) Parasites: Presence of parasites like nematodes, cestodes, trematodes and any other extraneous matter can be considered as hazard. Particular attention needs to be paid to cold smoked or smoke-flavoured products, which should be frozen before or after smoking if a parasite hazard is present.

Chemical hazards

1) Polycyclic Aromatic Hydrocarbons (PAHs): PAHs are large class of organic compounds containing two or more fused aromatic rings made up of carbon and hydrogen atoms. Incomplete combustion(pyrolysis), during smoking can lead to formation and release of PAHs into the smoked product. Some of them are carcinogenic and mutagenic substances causing serious health issues to the consumers. Processing procedures such as smoking, drying, roasting, baking, frying and barbecuing/grilling can lead to formation of PAHs in food items. Many reports indicate that individual PAHs in smoked fish can go up to a level of 200µg/Kg. Among the 33 PAHs evaluated by the Scientific committee on Food (SCF, 2002) of EU, 15 were found to be having mutagenicity/Geno toxicity in somatic cells of experimental animal in-vivo. They are benzo[a]anthracene, benzo[b]-, benzo[j]- and benzo[k]fluoranthene, benzo[ghi]perylene, benzo[a]pyrene, chrysene, cyclopenta[cd]pyrene, dibenz[a,h]anthracene, dibenzo[a,e]-, dibenzo[a,h]-, dibenzo[a,i]-, dibenzo[a,l]pyrene, indeno[1,2,3-cd]pyrene and 5-methylchrysene. The carcinogenic and genotoxic potentials of PAH are largest among the high molecular weight PAH, i.e., compounds with 4 rings or more. Among that benzo[a]pyrene regarded as potentially genotoxic and carcinogenic to humans. They can cause long-term adverse health effects following dietary intake of PAH.

The PAH contamination in smoked products can be significantly reduced by using indirect smoking process instead of direct smoking of the fish. In indirect smoking, the smoke generated

in an external smoking kiln, under controlled conditions, is used for smoking process. The smoke produced can be even, washed before coming into contact with the food material processed. In addition to that, use of lean fish for smoking, and cooking at lower temperature for longer time can also reduce the PAH contamination significantly. If the smoke condensate is used for smoking, usage of smoke condensate from reputed reliable resources approved by competent authority can effectively reduce the occurrence of PAH contamination in the final product. The formation of PAH in smoked fish can be minimised by following Code of Practice for the Reduction of Contamination of Food with Polycyclic Hydrocarbons (PAH) from Smoking and Direct Drying Processes (CAC/RCP 68-2009) given by Codex Alimentarius Commission.

2) Histamine: Histamine poisoning is associated with Scombroid fishes and other dark meat fishes. These fishes having high content of free histidine, which during spoilage are converted to histamine by bacteria like *Morganella morgani*, *Klebsiella pnuemoniae* and *Hafnia alvei*. Histamine is heat stable, even cooking or canning cannot destroy it. Presence of other biogenic amines like cadaverine and putrescine will act as potentiators for histamine production. As per Codex standards, the maximum allowable histamine content in smoked fishes is 200 mg/Kg for species like Scombridae, Clupeidae, Engraulidae, Coryphaenidae, Pomatomidae, and Scomberesocidae. Low temperature storage (< 4°C) of fishes right from catch can effectively reduce the production of histamine in fishes.

3) Biotoxins: Biotoxins causing a number of food-borne diseases. The poisoning due to biotoxins are caused by consuming finfish/shell fish containing poisonous tissues with accumulated toxins from plankton they consumed. Paralytic shellfish poisoning (PSP), diarrheic shellfish poisoning (DSP), amnesic shellfish poisoning (ASP), and neurotoxic shellfish poisoning (NSP) are mostly associated with shellfish species such as oysters, clam and mussels. The control of biotoxin is very difficult. They cannot be destroyed by any of the processing methods like cooking, smoking, drying or salting. Environmental monitoring of plankton and proper depuration process of the bivalves only can reduce the occurrence significantly.

The safety and quality issues encountered during the production of smoked products during various steps of its production:

1) Selection of raw material

Top-quality fish are needed to produce a top-quality smoked product. The important step in proper fish handling is to quickly bleed, clean and chill the fish. Generally, the fish shouldn't be accepted if it is known to contain parasites, undesirable microorganisms, pesticides, veterinary drugs or toxic, decomposed or extraneous substances harmful to human health. When fish and shellfish is found to be unfit for human consumption it should be appropriately handled- processed/ disposed. Temperature is the most important factor affecting the rate of fish and shellfish deterioration and multiplication of microorganisms. For species prone to scombrotoxin production, temperature should be effectively controlled to prevent the formation of histamine.

2) Salting/Brining

Proper salting is the key step for the flavour and safety of the smoked fish product. It brings the taste and also reduces the water activity (a_w) in the product, so that bacterial growth can be inhibited in the smoked fish. Salting is done commonly as dry salting or brining. Efficiency of salt penetration into the fish tissue is affected by several factors, such as species, physiological state of fish (rigor), fish quality (fresh/frozen) fish dimension (thickness), brine concentration, brine time, brine to fish ratio, brine temperature, fat content, texture, etc.

The major hazards and defects include microbiological, chemical and physical contamination, scombrotoxin, undesired texture, decomposition/ physical damage. While salting, it should be taken care that fish size is uniform. To ensure a uniform salt distribution throughout the fish, it should be equilibrated under refrigeration conditions. The time-temperature selected for salting/ brining should not allow for the development of histamine in relevant fishes. The fish should not be subjected to temperature abuse. Brine should be prepared from food grade salt and water of potable quality. Monitoring of salt content of brine and it should be replaced at regular interval. Reuse of brine should be avoided and if it is to be recycled brine must be appropriately processed to minimize microbiological hazards. The vats and other equipments used during the process should be corrosion resistant.

3) Pre-drying, Hanging and Racking

After brining fish is rinsed and air dried before smoking. Drying will help smoke deposit evenly on the fish surface during smoking since smoke does not deposit well on a wet surface. Drying process, gives a nice coating on fillets to help seal in moisture, natural juices, flavours and provides a better-looking finished product like glossy skin forms on the cut surface pellicle. In cold smoking, a certain amount of drying prior to smoking helps in producing the pellicle.

The hot smoking can be carried out immediately after racking because pellicle is destroyed by heat. Racking aids in the formation of the pellicle and reduces drying time during the smoking. It provides maximum exposure of the fish to the smoke. For this purpose, racks are more widely used today, but some products still require the use of speats, or spits, to be threaded through the neck, eyes or the gill and mouth of the hanging fish.

The main hazards/ defects encountered are microbiological contamination by *Staphylococcus aureus*, fungal contamination, scombrotoxin, physical contamination, physical damage and decomposition. During the racking and hanging operation, fish should be hung in manner that allows for adequate and smooth flow of air/ smoke. Since, pathogen *S. aureus* gets competitive advantage via brining, it is essential to adhere to strict time-temperature and sanitation controls to avoid risk of contamination and microbial growth. The drying should ensure that loss of water makes it stable during smoking, further excess loss of waters should be avoided for good texture. The drying should be carried out under controlled conditions of air flow, temperature and humidity. To avoid microbial growth and scombrotoxin formation, prolonged exposure to ambient temperature should be avoided.

4) Smoking and smoke flavouring

The main hazards and defects encountered during cold and hot smoking are natural toxins, impregnated material in wood, paints, chemicals, undesirable flavour, parasites and microbiological contamination, chemical contamination from smoke, tar and ash, poor colour, flavour and texture, growth of *C. botulinum, L. monocytogenes*, scombrotoxin and decomposition.

It should be taken care that the plant material/ wood used for smoking should be free from natural toxins, paints, chemicals, fungal growth and should be stored in dry environment. The guidelines regarding PAH reduction i.e., Code of Practice for the Reduction of Contamination of Food with Polycyclic Aromatic Hydrocarbons (PAHs) from Smoking and Direct Drying Processes (CXC 68-2009) should be carefully followed. It is essential to control and monitor the smoking process time and temperature so as to avoid microbial contamination and scombrotoxin formation in susceptible species. This helps in effective control of *L. monocytogenes* and damage to the spores of non-proteolytic *C. botulinum*. Hot smoking temperature should reach at thermal centre of the product. In the cold smoking process the temperature of the products is kept below the coagulation temperature for the proteins of the flesh of the fish. The process should be monitored to achieve the desired colour, taste and

texture. The smoking process should be carried out under hygienic conditions and smoking time should be validated for enough reduction in water content of the product.

The smoke-dried fish is either ready-to-eat or rehydrated before consumption. The fish for smoke-drying should be sufficiently dried to reduce the water content of the skin and flesh for uniform distribution of smoke over product surfaces. Time and temperature of the smoke-drying process should be monitored to achieve the desired texture, water activity and reduce the generation of PAHs. The smoking and drying process should be carried out until final moisture content of the product is less than 10 % or water activity is below 0.75. The cooling of the smoke-dried product should be done under controlled conditions. the packaging should give sufficient protection to the product from moisture absorption. The package should be clearly labelled regarding storage and preparation before consumption.

The smoke flavour can be applied in many ways and at different stages. The heating is optional for this type of product. The smoke flavour treatment should be given in a manner which prevents the formation of scombrotoxin as well as controls the microbial growth. Smoke flavour should not be used to mask poor quality fish. The smoke condensate should be obtained from a reliable and approved source and applied with regards to regulatory approval. Dilutions done, if any, must be with food grade material or potable water as per regulatory approval.

Cooling/ Slicing/ Packaging/ Storage

The major hazards and defects during the steps are- microbiological contamination, scombrotoxin formation, survival of parasites, poor taste and texture, decomposition, freezer burn and undeclared allergens. Cooling should be done in a controlled environment to avoid cross contamination and rapid enough so as to minimize the microbial growth. Before slicing the smoked fillets should be cold tempered to facilitate mechanical slicing. The hygiene and sanitation of cutters/ blades and belts is critical to avoid contamination. All smoked products, whether hot or cold smoked, require slow cooling to room temperature, immediately followed by chilling to 4 °C, and if required, quick freezing and storing at -18°C. Smoked products can be vacuum packed, shrink packed, canned/retorted, packed in wooden boxes, MAP/ CAP packed. Smoked products may be chilled or frozen prior to packaging. Reduced oxygen packed products should have additional hurdles like freezing, refrigeration, lower water activity to avoid growth of *C. botulinum*. In case of MAP/ CAP regular monitoring is deemed suitable. The time-temperature required for freezing should be enough to kill the parasites. During the storage regular monitoring of the storage temperature is essential. It also aids in controlling the

microbiological growth i.e., *L. monocytogenes, C. botulinum* and other pathogens like *S. aureus*. The label should include the storage temperature, shelf-life, other handling and storage conditions for safety and quality. The label should also have instructions regarding thawing conditions and usage.

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