Microbial update
fish and fish products

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Fish and shellfish are a major staple food in most parts of the world and are second only to meat as the major animal protein in most diets. Whilst foods such as 'meat' form relatively well defined groups of raw materials, 'fish' constitutes a large range of types (some sources recognise over 20,000 identified species), caught over a wide range of conditions (from the arctic/antarctic to the tropics, in fresh or salt water and harvested both from 'wild' and 'farmed' environments).

If we move away from the raw material itself, fish are made into a wide range of 'added value' products from high cost traditionally smoked chilled fillets, to lower cost frozen breaded fish fingers. Fish products are preserved using almost every food processing technique that has ever been developed (drying, smoking, freezing, canning, fermenting, high pressure processing), and of course, there is the increasing trend towards the consumption of high quality raw fish in the form of sushi.

All of this variety does of course mean that the microbiology of fish and fish products is complex and can cover a wide range of both quality and safety related issues. Initially, in this article, the microbiology of raw fish will be considered.

Freshly caught fish

Micro-organisms are found on all of the outer surfaces and within the intestine of live fish. Skin may contain 10^2-10^6 organisms per cm^2, whilst the gills and intestine can contain 10^3-10^9 organisms per cm^2. The bacterial loading on freshly caught fish tends to reflect the environment from which it was caught, rather than the fish species; those from cold clean waters carry a lower load than those from warm waters.

After catching and death, the microflora may begin to change due to the differing environmental conditions. Usually fish are stored on ice, which will clearly reduce temperature but will also reduce the salt concentration surrounding marine fish. These changes will affect the ability of organisms to grow and will start to change the microflora of the fish.

Temperate water fish

The microflora of wild fish is mainly Gram negative rods belonging to genera such as: pseudomonas, moraxella, acinetobacter, alcaligenes, shewanella, flavobacterium, vibrio and aeromonas. Some Gram positive organisms (bacillus, micrococcus, clostridium) can be found although lactic acid bacteria are rare.

It should be noted that Cl. botulinum is found in the aquatic environment and this should be kept in mind when further processing of fish is done.

The microflora of farmed fish from temperate waters is similar to that of wild fish, however, as farm environments are usually closer to human waste sources, higher contamination with organisms such as listeria can occur.

Tropical water fish

Gram positive organisms such as bacillus and micrococcus tend to be found on fish caught in tropical waters; besides these the flora will tend to be the same as that found on temperate water fish. There are also several human pathogens in tropical waters, for example, Vibrio parahaemolyticus, V. cholera, and V. vulnificus, the potential presence of these organisms should be noted when handling fish from these waters.

The microflora of farmed fish from tropical water does not differ significantly from that of wild fish. However, as farms tend to be near areas of human habitation, the water may be contaminated with higher than normal levels of human and animal waste. This brings concerns of contamination with enteric organisms such as salmonella and Escherichia coli. Such organisms do not survive in colder nutrient deprived temperate waters, but do persist and may even grow in more nutrient rich tropical environments.

Microbiological issues

When fish are live, muscle tissue is considered to be sterile, but after death the barriers to microbiological invasion begin to break down and bacteria are able to grow more freely, although will be rarely found within deep muscle tissue.

At this point the difference in microbiology between fin fish and shellfish should be noted. Molluscs are filter feeders usually found in coastal waters near habitation and contaminants in surrounding waters will be concentrated within the animal by its feeding method. Molluscs can contain human pathogens and as they are often eaten raw, they can constitute a human health risk.

Gastrointestinal illnesses caused by members of the Genus vibrio are often reported, as are viral illnesses. It is interesting that one of the largest outbreaks of food poisoning ever recorded affected nearly 300,000 people in Shanghai and was linked to undercooked mussels contaminated with Hepatitis A.

Various countries have recommendations and regulations designed to reduce the microbiological risks associated with eating molluscs. The risk reduction strategies vary from cleanliness of growing waters, depuration after harvest, microbiological criteria for shellfish and cooking recommendations and it is recommended that national legislation be consulted when considering this type of shellfish.

Microbiological spoilage

Bacteria will tend to be confined to the surface of the dead fish and this is where growth will occur and spoilage begins. In temperate water fish, bacteria may begin to grow as soon as the fish dies, as the microflora is well adapted to the chill temperatures used for storage.

It has been reported that the time taken for the number of bacteria to double under these conditions may be 24 hours. In tropical water fish, the microflora need time to adapt to chill storage conditions and there is reported to be a lag phase of up to two weeks before growth begins.

The fish microflora will change during storage and reports suggest that pseudomonas and shewanella make up the majority of the population during aerobic iced storage of either temperate or tropical fish.

If storage conditions are altered, for example, by vacuum packing or storage under carbon dioxide, then the flora will change, Pseudomonas being inhibited by the lack of oxygen, whilst shewanella can grow anaerobically and Photobacterium phosphoreum is able to grow in the presence of higher levels of carbon dioxide.

Microbiological hazards

A number of different types of possible human pathogens can be associated with fresh fish including Cl. botulinum, members of the enterobacteriaceae, such as, salmonella, shigella and E. coli, various vibrio species, Listeria monocytogenes and even staphylococci and Bacillus spp. which can become associated with fish during handling and transport.

The risks to human health associated with these organisms will be dependent on the handling, processing and preservation of the fish after catching.

The microbiology of fish can change fairly rapidly after catching and killing, as the application of chilled temperatures, together in some cases with mild preservatives, such as, low levels of salt, change the types of flora able to grow on the product.

Many potential pathogens will survive under these conditions, but few are able to grow. Those able to grow include psychotropic C. botulinum and Listeria monocytogenes.

Additionally, consideration of the growth of histamine producing organisms (for example, some members of the lactic acid bacteria) should be made.

Levels of histamine up to 200mg/kg have occasionally been reported in cold smoked salmon, but these types of fish are not epidemiologically linked to scombroid toxicity.

Presence of parasites could also be an issue in fresh/lightly preserved fish intended to be eaten without cooking. Parasites are killed by freezing and various countries have legislation covering the freezing of such fish.

Processed fish

Fish are processed in many different ways in different parts of the world. Heavy salting, freezing, drying, hot smoking, canning and pasteurisation are all recognised methods of fish preservation. All affect the micro-organisms on the fish in different ways and will

result in a different type of microflora and different risks from spoilage organisms and pathogens. The key to any preservation system is for the manufacturer to understand how the process works and what needs to be controlled to get a safe stable product, and to employ the principles of HACCP to achieve this.

To give some examples, a correctly processed canned fish will be commercially sterile and can be stored at ambient temperatures for long periods without spoilage or risk to consumer safety. Once the can is opened, the contents become open to contamination and as there is usually no preservation system within the product, the contaminating organisms will be able to grow. Therefore, canned fish products should be consumed shortly after opening.

In dried or frozen fish, the microflora is prevented from growing by the storage conditions used and the product may have a long shelf life in the preserved state.

However, the organisms will usually remain viable over long storage periods. So whilst the product will not microbiologically spoil, or allow the growth of possible pathogens, spoilage organisms or pathogens that are present may remain alive.

Thus, when the product is thawed, or rehydrated, these organisms will be able to grow once more and the product needs to be handled with the same care that it was before the preservation system was applied.

In chilled fish products, the only barrier to microbial growth is low temperature. Reducing storage temperature reduces the number and types of micro-organisms able to grow and should reduce the growth rate of those that are able to grow. However, even at very low chill temperature (for example, <3°C), some organisms will still be able to grow and this means that chilled products will always have a short shelf life that must be determined by the manufacturer before placing the product onto the market.

At this point it would be useful to mention modified atmosphere packing and vacuum packing (MAP/VP). These procedures are designed to change the gas atmosphere in which the product is stored. Generally the standard atmospheric gas composition is changed to one in which oxygen is removed and carbon dioxide is added. This inhibits the growth of aerobic spoilage organisms, which usually has the effect of increasing shelf life. The key food safety issue that arises with the use of MAP/VP is the potential to allow the growth of the pathogen, Clostridium botulinum.

This organism will only grow in conditions where oxygen is absent and can produce a toxin in foods, which if consumed can cause paralysis and even death. There is a particular type of C. botulinum that is able to grow at low temperatures, that could be a risk in chilled MAP/VP fish products.

Manufacturers of such products must be aware of the risk and employ suitable control measures to prevent growth and toxin formation by this organism.

Conclusions

Fish and shellfish are a very important part of the human diet worldwide. They are extremely varied food products, with numerous different fish species, from marine and fresh water, from cold temperate waters and warm tropical environments, they can be farmed or wild, and they can be processed and preserved in numerous different ways. All of the above variations affect the microbiology of the fish, its shelf life and safety. Producers and manufacturers of fish products have to understand their raw materials, the processes and packaging systems they use and their finished product from a microbiological perspective, in order to control the microbiology, and thus, the shelf life and safety of these products.

History has shown that, whilst this may appear complex, it has been achieved all around the world, even in the absence of 'complex' technology, thus providing an important protein source to populations everywhere. ■

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