HUMAN HEALTH RISKS ASSOCIATED WITH CHEMICAL AND MYCROBIOLOGICAL CONTAMINANTS IN FISH - A Mini Review

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Abstract

Fish meat consumption has gained a lot of popularity in Europe in the last years. It is considered to be a great alternative for red meat because it provides large amounts of Omega-3 fatty acids and vitamin D. These components lower the risk of cardiovascular disease, reduce the risk of autoimmune diseases, are essential for growth and development, can contribute to mood elevation and can prevent cognitive decline, and eye disease. Unfortunately the benefits can sometimes be accompanied by a risk associated with chemical and microbiological contaminants.

The aim of this paper is to review some recently published studies concerning the groups of chemical compounds and bacteria found in fish meat, which can have negative effects on human health. In order to raise awareness, aspects related to dangerous persistent organic pollutants and zoonotic bacteria are described. The frequency of encountering them is discussed, the ways in which they can reach the human body are specified and a critical comparison of their consequences is performed.

Keywords: chemical contaminants, fish, human health, microbiological contaminants.

INTRODUCTION

Worldwide, fish and fish products are appreciated for being an important source in the diets of human beings. This is the reason for which the demand of fish meat has increased in the last decades around the world, forcing us to guarantee safe, edible fish in the international trade market.

Fish and fish products are an important source of ω-3-polyenic acids with five and six double bonds (Fangkai Han, 2016). These components are commonly called fatty acids and represent a valuable point of supply in nutrients, highly recommended in our daily nutrition (Hellberg et al., 2012; Ibrahim et al. 2011).

Despite the fact that fish meat is recommended to prevent a series of disorders or illnesses, or to secure some vitamins and nutrients which are mostly needed in certain maladies (Hellberg et al., 2012), this special category of white meat carries a hard burden with it in our current time (Lee et al., 2010). Dangerous chemical contaminants and bacteria are often present in fish muscle, adipose tissue or even organs (Fernandes et al., 2015). This mixed load partly exists due to human interference in natural ecosystems, especially when referring to chemical compounds.

A previous estimated growth of world population, guided humans towards a less healthy approach of the contaminants-nature situation on the long-term (Nicolopoulou-Stamati et al., 2016). The massive use of chemicals in the past, such as fertilizers and pesticides, in the expansion and protection of crops which were thought to provide the necessary food for all people, was discovered decades ago to have negative effects on human health (Kim et al., 2016). Their initial beneficial role in boosting plants used for animal and human nourishment - to attain more animal products and sustain life on the planet- turned up creating concerning issues starting from the base of the food chain pyramid to the top (Binukumar and Gill, 2011) (Ene et al., 2014).

Persistent Organic Pollutants (POPs) is the name attributed to organochlorine compounds, polychlorinated biphenyls (PCBs) and other chemical groups due to their persistence in the
environment and their bioaccumulation characteristic. Studies have shown that POPs have the ability to cross from soil and water (Neamtu et al., 2009) to plants and animals (Shakeri et al., 2015) to which they clearly cause disturbances (Berg et al., 2016), so that they can make their way up to superior organisms such as humans (Figure 1).

The risk for humans is mainly the chronic toxicity, following the ingestion of small quantities of POP residues from fish, fish products and other animal origin products (Carpenter, 2011). Acute toxicity can also appear in human subjects who make direct contact with pesticides through inaccurate handling (Sumon et al., 2016). Animals tend to concentrate the POPs from water and feed in their adipose tissue (e.g. organochlorine compounds and PCBs) and pass them to humans through food ingestion (Cioca et al., 2017b; Fernandes et al. 2015).

Once entered in the human body, the residues start perturbing the normal function of the organism and focus their action on enzyme systems, on vitamins and hormones (endocrine disruptors), as well as their carcinogenic activity. Additionally, humans can come in direct contact or through the consumption of raw fish, with a wide range of harmful bacteria. Such biological contaminants can also be accumulated in fish tissue or body surface and therefore to be transmitted to humans along the food chain or simply by working with fish. Undoubtedly, the most commonly disseminated are microbial pathogens which can cause a various range of infections and intoxications in humans.

The restrictions applied during the Stockholm Convention have partly achieved to eliminate the use of numerous hazardous chemically synthesized solutions. Still, pesticides are available on the black market in less developed and developing countries (Carpenter, 2011). The lack of environmental education encourages oblivious people to continue spraying or even dumping such substances. The infections with pathogenic bacteria are usually accidental, a consequence of a hygiene deficiency or insufficient thermal treatment. Global pollution is making a statement regarding this aspect as well. Microbes are multiplying easier than before, they are more resistant and more aggressive.

The objectives of this paper are to describe the most important chemical and bacterial causative agents of human diseases in fish meat, the frequency and the way in which humans can be exposed to these factors and eventually their toxic effects, in order to increase public awareness concerning the consumption and handling of fish and fish products in the context of European residue monitoring.

**CHEMICAL CONTAMINANTS**

**TYPES OF POPs IN FISH MEAT**

The classification of POPs includes groups like organochlorine compounds (OCs), polybrominated diphenyl ethers (PBDEs), PCBs, dioxins and furans. From these groups, the dioxin and furans are the only substances that humans didn’t create themselves, but appeared when burning chlorinated solutions at low temperatures.

From the group of OCs, some compounds usually stand out more in research studies, but also in the day by day discussions of people with other professions. A very popular chemical contaminant is dichlorodiphenyltrichloroethane (DDT), known to be very effective against mosquitos and intensively used in low developed countries in order to prevent malaria (Carpenter, 2011). DDT is closely followed by gamma-hexachlorocyclohexane (Lindane), Aldrin, Dieldrin. The list could definitely continue with numerous less known substances (Cioca et al., 2017a) which still have an important ongoing impact in our environment, however some clear examples found in samples collected from humans are better described in Table 1.
<table>
<thead>
<tr>
<th>Country</th>
<th>Studied POPs</th>
<th>Most frequently detected compounds</th>
<th>Sample type</th>
<th>Survey period</th>
<th>Age of donors</th>
<th>Conclusions</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia (South East Queensland)</td>
<td>hexachlorobenzene (HCB), β-hexachlorocyclohexane (β-HCH), γ-hexachlorocyclohexane (γ-HCH), oxy-chlordane, trans-nonachlor, p,p′-DDE, o,p′-DDT, p,p′-DDT, Mirex</td>
<td>HCB, β-HCH, trans-nonachlor, p,p′-DDT and p,p′-DDE</td>
<td>Serum</td>
<td>2002/03, 2006/07, 2008/09, 2010/11, 2012/13</td>
<td>All ages</td>
<td>Females had higher levels of POPs than men (especially in the elder category).</td>
<td>(Thomas et al., 2017)</td>
</tr>
<tr>
<td>U.S.A</td>
<td>13 organochlorine compounds (OCs), 10 polybrominated diphenyl ethers (PBDEs), polybrominated biphenyl (PBB) 153, 38 polychlorinated biphenyls (PCBs), 17 polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDDs/Fs), 12 perfluorinated compounds (PFCs)</td>
<td>-</td>
<td>Blood</td>
<td>2003/04</td>
<td>≥ 20 years old</td>
<td>More than 13% of the U.S.A. population may have 10 POPs each at concentrations in the top decile.</td>
<td>(Pamarega et al., 2016)</td>
</tr>
<tr>
<td>Tanzania (Arusha)</td>
<td>HCB, α-HCH, β-HCH, γ-HCH, ΣHCH, oxychlordane, cis-Chlordane, trans-Nonachlor, ΣCHL, p,p′-DDE, p,p′-DDD, p,p′-DDT, ΣDDTs Dieldrin, Endosulfan I, Endosulfan sulfone, ΣEndosulfan, PCB-28, PCB-52, PCB-101, PCB-118, PCB-138, PCB-153, PCB-180, ΣPCB-65, ΣPCB-70</td>
<td>Dichlorodiphenytrichloroethane (DDT) and its metabolites, dieldrin, PCB-153</td>
<td>Milk</td>
<td>-</td>
<td>19–24, 25–30</td>
<td>The main findings were the wide-ranging concentrations of DDTs and dieldrin; Despite the occurrence of potential harmful chemicals in the Tanzanian breast milk, mothers should been encouraged to breastfeed their infants, as the nutritional, immunologic and developmental benefits from breastfeeding may outweigh the possible negative effects from chemical exposure.</td>
<td>(Müller et al., 2017)</td>
</tr>
<tr>
<td>Russia (Eastern Siberia)</td>
<td>HCB, α-HCH, γ-HCH, ΣHCH, α-γ-HCH, p,p′-DDE, p,p′-DDD, p,p′-DDT, ΣDDTs, DDE/DDT PCB-28, PCB-52, PCB-101/90, PCB-153, PCB-138, PCB-180, 6ΣPCB, 7ΣPCB</td>
<td>DDTs &gt; PCB &gt; HCB &gt; ΣHCHs</td>
<td>Milk</td>
<td>-</td>
<td>-</td>
<td>A relatively homogeneous contamination across almost the whole region; The population of Irkutsk Region undergoes both environmental and occupational exposure to POPs.</td>
<td>(Mamontova et al., 2017)</td>
</tr>
<tr>
<td>Croatia (Zadar)</td>
<td>PCB-28, PCB-52, PCB-101, PCB-138, PCB-153, PCB-180 (six indicator congeners), PCB-77, PCB-126, PCB-169 (three non-ortho congeners), PCB-105, PCB-114, PCB-118, PCB-123, PCB-156, PCB-157, PCB-167, PCB-189 (eight mono-ortho congeners), PCB-60, PCB-74 and PCB-170, hexachlorobenzene (HCB), α-, β-, γ-hexachlorocyclohexanes (α-HCH, β-HCH, γ-HCH), 1,1-dichloro-2,2-di(4-chlorophenyl)ethene (p,p′-DDE), 1,1-dichloro-2,2-di(4-chlorophenyl)ethane (p,p′-DDD), and 1,1,1-trichloro-2,2-difluoromethylene (p,p′-DDE)</td>
<td>ΣPCBs &gt; ΣDDTs &gt; ΣHCHs &gt; HCB</td>
<td>Milk</td>
<td>2011</td>
<td>24–45</td>
<td>Levels were lower in samples from multiparae than in primiparae samples; POPs found in this study should not raise concern for mothers or breastfed infants.</td>
<td>(Klinčić et al., 2016)</td>
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<tr>
<td>Croatia (Zagreb)</td>
<td>α-HCH, HCB, ΣHCH, γ-HCH, p,p′-DDT, p,p′-DDE, p,p′-DDD, PCB-28, PCB-52, PCB-74, PCB-101, PCB-123, PCB-156, PCB-157, PCB-167, PCB-189</td>
<td>Σα-HCH, Σβ-HCH, Σγ-HCH, p,p′-DDT, p,p′-DDE, p,p′-DDD, PCB-60, PCB-101, PCB-123, PCB-156, PCB-180</td>
<td>Milk</td>
<td>2009/10, 2009/11</td>
<td>22–37, 20–33</td>
<td>PCB and OCP were found to be in the lower part of the concentration ranges found in other European countries; Clear decreasing trend of organochlorine levels in the human milk samples collected from donors living in Zagreb during a 10-year period; The most toxic PCB congeners were not found in any of the samples.</td>
<td>(Klinčić et al., 2014)</td>
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<tr>
<td>Poland (central Poland)</td>
<td>PCB-81, PCB-77, PCB-123, PCB-118, PCB-114, PCB-105, PCB-126, PCB-167, PCB-156, PCB-157, PCB-169, PCB-189</td>
<td>Milk</td>
<td>2008/10</td>
<td>23-24</td>
<td>22-38</td>
<td>The median concentration of PCDD/Fs and dl-PCBs found in breast milk samples (n = 40) from the Polish mothers (5.8 – rural and 7.7 pg. WHO TEQ/g fat in urban area) is one of the lowest in comparison with other European countries</td>
<td>(Kamińska, 2014)</td>
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<tr>
<td>Saudi Arabia (Eastern district of Saudi Arabia)</td>
<td>p,p' -DDD, p,p' -DDE, p,p' -DDT, ΣDDT, Dieldrin, ΣDieldrin, Lindane, Heptachlor epoxides</td>
<td>p,p' -DDE, p,p' -DDD, Lindane (γ -HCH), Dieldrin, Endrin, A-heptachlor</td>
<td>Milk</td>
<td>-</td>
<td>18-30</td>
<td>DDE, DDD and HCH were the main contributors to the total OCs detected in human milk; The concentrations of OCs residue found in mothers’ milk from the study area were generally far below the MRL; Risk assessment for infants weight 3.5 kg and ingest 750 ml of human milk daily, presented that the EDIs of total DDT and Lindane ingested daily by infant feed on mother milk were far below the ADI standard issued by European Food Safety Authority; The EDI of Dieldrin and Heptachlor, for infant, were higher than the ADI standard accepted by EU.</td>
<td>(Hajjar and Al-Salam, 2016)</td>
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<tr>
<td>Spain (Almeria)</td>
<td>Abamectin, Tebuconazole, Azadirachtin, Acetamiprid, Spinosad, Cyprodinil, Fluodioxonil, Myclobutanil, Chlorthalonil, Fluopicolide, Propanocarb, Copper oxychloride, Spiromesifen, Mepaniyprin Pyrimethanil, Methomyl, Bacillus thuringiensis, Dimethomorph, Azoxyxobrin, Thiophanate methyl, Imidacloprid, Indoxacar, Cypermethrin, Deltamethrin</td>
<td>-</td>
<td>Blood</td>
<td>2011</td>
<td>18-66</td>
<td>Chronic occupational exposure to pesticides of lower toxicity elicit mild toxic effects, particularly targeting the skin and eyes, as well as subtle subclinical (biochemical) changes of unknown long-term consequences.</td>
<td>(García-García et al., 2015)</td>
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<tr>
<td>Brazil (Rio Branco)</td>
<td>α-HCH, β-HCH, γ-HCH (lindane), HCB, Heptachlor, Heptachlor epoxide, Heptachlor epoxide, α-Chlordane, γ-Chlordane, trans, Nonachlor, p,p' -DDT, o,p' -DDT, p,p' -DDE, o,p' -DDE, p,p'-DDD, Endosulfan, Endosulfan, Aldrin, Endrin, Dieldrin, Mirex, Methoxychlor, Pentachloranisole, DDT/DDT ratio</td>
<td>p,p'- dichlorodiphenylmethane (p,p'-DDE), lindane (γ-hexachlorocyclohexane), heptachlor, p,p'- dichlorodiphenyltrichlor oethane (p,p'-DDT)</td>
<td>Blood</td>
<td>2010/11</td>
<td>18-30</td>
<td>The observed occurrence of p,p'-DDE (32%) and lindane (20%), and the low DDT/DDT ratio, may indicate higher historical exposure to the insecticides DDT and Lindane in this population relative to other OC pesticides; Exposure to OC pesticides in Rio Branco, Acre, seems to be low.</td>
<td>(Freire et al., 2017)</td>
</tr>
<tr>
<td>Tunisia (Bizerte)</td>
<td>HCB 25, α-HCH, β-HCH, γ-HCH, δ-HCH, HCHs, α-HCH/β-HCH, α-HCH/γ-HCH, o,p' -DDE, p,p'-DDE, o,p'-DDD, p,p'-DDT, DDTs, p,p'- DDT/p,p'-DDD, OCPs, PCB 18, PCB 28/31, PCB 52, PCB 44, PCB 101, PCB 149, PCB 118, PCB 153, PCB 138, PCB 180, PCB 170, PCB 194, PCBs</td>
<td>p,p'-DDA, p,p'-DDT, HCB and β-HCH; DDTs&gt;PCBs&gt;HCB=HCHs</td>
<td>Adipose tissue</td>
<td>-</td>
<td>20-85</td>
<td>Fish consumption may be an important contributor of PCBs adipose tissue content of PCBs in Tunisian people; Continuous source of illegal use of DDT and decreasing trend in the levels of exposure of HCB, HCHs and PCBs; A lack of age-dependent increase in confections of all studied OCs for men; The trend of increasing HCB, DDTs and PCB 118 concentrations with increasing age were observed for women.</td>
<td>(Achoura et al., 2017)</td>
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</table>
WAYS OF EXPOSURE
Directly, people can be more aggressively exposed to chemical contaminants (e.g. insecticides, fungicides) as an outcome of occupational, agricultural and household use. Occupational exposure can generate Parkinson disease, all forms of haemapoethic cancers, breast cancer in women, bladder cancer, meningioma (Kim et al., 2016).
Crops spraying with pesticides by people that have not received a proper training in this type of activity, who cannot safely handle the solutions and do not know how to protect themselves, can cause symptoms such as nausea or vomiting, headaches, blurred vision and eye irritation, but also respiratory problems (Sankoh et al., 2016, Sumon et al., 2016). Inhaling, skin-to-skin contact, accidentally drinking or exposing the eyes to vapors can cause acute symptoms with hazardous consequences that could even lead to death. If the concentration and the toxicity are high, the risks are proportionally higher (Sabra and Mehana, 2015). If the person lives after the direct exposure, after causing the intended damage of the organism, POPs can be again released in the environment through urine, sweat or exhaled hair.
Indirectly, POP residues can be transmitted to humans through daily food intake, fish meat being a very good vector due to its capacity of accumulating residues from water, sediments, and feed.
Samples taken from Inuit people have revealed high amounts of POP residues. The specific diet consisting in plenty of fish and fats is the way in which chemical contaminants easily entered the human body, behaving as markers of inflammation which might later provoke rheumatoid arthritis, atherosclerosis or hence cardiovascular disease (Schæbel et al. 2017; Wu et al. 2016).
Another recently discovered path that POPs use to find their way in is the ingestion of contaminated supplements based on fish oil. The primary goal of these supplements was to improve human health. Hong, 2015 showed in his study conducted on rats, that if POP residues are present in supplements containing fish oil, then the supplements can cause the negative effects on antioxidant capacity and lipid peroxidation processes (Alewu et al., 2011).
EFFECTS IN FISH
Some of the effects of POPs in animal organisms can give information about their possible action in the human body. For this, studies use fish collected from their natural environment or fish as experimental animals. The biomonitoring of especially edible fish is important (Fernandes et al., 2015).
Berg et al., 2016 revealed that chemical contaminated fish showed symptoms of endocrine disruption (changes in the adrenal and gonadal axis parameters). Some physiological functions like reproduction and weight homeostasis were negatively influenced as well (Berg et al., 2016). Oxidative damage in tissues, a higher number of white blood cells and low liver transaminase activity are possible with Endosulfan combined with lambdacyhalothrin (Bacchetta, 2016). Other signs present in fish were developmental anomalies and lethal or sublethal effects (Mensah et al. 2014; Murthy et al. 2015).
Fish liver is one of the most susceptible organs to POPs, but there are other locations possible inside the body where POPs can be discovered or where they raise disorders (e.g. kidney, brain).
EFFECTS ON HUMAN HEALTH
Women are more susceptible to some POPs (e.g. PCBs) than men (Wu et al., 2016). The most dangerous effect of POPs is manifested in pregnant women, babies and small children. These are the most sensitive categories, which captivated the attention of researches from all over the world. The ingestion of chemical contaminated fish can affect the reproductive capacity but also neurobehavioral development, especially when DDTs or mixtures of substances are involved. Numerous recommendations with safer foods from this perspective, are placed as an alternative for fish in expecting women diets and sometimes, even avoiding or not consuming fish at all is considered proper (Binnington et al., 2014). Fat fish such as salmon, tuna and crustaceans, but also other seafood (e.g. eel) coming from polluted areas should be especially kept away from pregnant women due to their capacity to
accumulate large amounts of lipophilic POPs (van den Dungen, 2016; Mendez et al. 2009; Mori and Todaka, 2017). Children who are still developing are more susceptible to the effects of chemical contaminants. Substances such as PCBs can interfere with their metabolic health (Lee et al., 2016), while others can cause dreadful illnesses (e.g. lymphoma, leukemia) (Kim et al., 2016; Wu et al., 2016). Also, children who were exposed before being born are linked to more reduced IQs, inability to focus or cope with frustration (Carpenter, 2011). In adults, the cognitive tests revealed an increased cognitive impairment risk for men and women with higher levels of POPs in their bodies (Kim et al., 2016).

Depending on their chemical structure, similar POPs can alter human health through identically or at least very much related actions. Some like OCs act more as initiators of chronic disease, while others like dioxins and PCBs can add being even cancers-causing factors (Kim et al, 2016; WHO, 2016, Wu et al. 2016). Contrary to ω-3 fatty acids’ ability to prevent cancer build-up, a melanoma analysis conducted on people that have been eating chemical contaminated fish from a lake in U.S.A. for many years, suggested a high incidence of melanoma (Green, 2015)

Carpenter, 2011 and Gascon et al. 2013 state that early exposure to POPs can have repercussions on the immune system making not only animals die from immunosuppression, but also children to become more sensitive to respiratory diseases.

In the last decade, the interest in whether POPs are being involved or not in obesity and diabetes grew. A rich diet in fatty fish such as salmon was demonstrated to contribute in the development of insulin resistance which leads to diabetes type 2 (Carpenter, 2011; Ibrahim et al., 2011; Kim et al., 2016; Marushka et al., 2017; Turyk et al. 2015). Eating fat automatically increases the chances of obesity for which POPs appear to be a providing factor (Le Magueresse-Battistoni et al., 2014). Trying to lose weight in such cases can convert into an issue also. Rapid weight loss can set free POP residues which were previously held in the adipose tissue, directly into the bloodstream (Lee et al, 2017; Rouhou et al, 2016). From blood, POPs can reach any organ or system in the body. Adverse effects of weight loss can be correlated with this flow, but more studies have to be performed in this way in order to demonstrate it.

MYCROBIOLOGICAL CONTAMINANTS

THE BACTERIAL MICROFLORA OF FISH

Different studies have indicated that fish contain bacterial populations on or in their skin, digestive tract, gills, muscles (Austin, 2002). Mostly, the area of bacterial species isolated is associated with marine environment of the fish, and fluctuates with various factors such as season, salinity of the habitat, feeding type, etc. (Gonzalez et al., 2001). Due to the contaminated water, bacterial colonization can be observed on gills and skin surface, being generally accepted that bacteria found on fish skin are the same as the ones found in the polluted water, including species as Aeromonas spp (Aeromonas hydrophila, A. bestiarum, A. caviae, A. jandaei, A. veronii), Proteus spp, Moraxella spp, Pseudomonas flourescens, Enterobacter aerogenes, Micrococcus luteus, Vibrio fluvialis, Flexibacter spp, Providencia spp. (González-Rodríguez , 2002) The gill microflora is being mostly populated by Achromobacter, Bacillus, Flavobacterium and Micrococcus.

The contamination of the digestive tract and fish muscles is put on the record thanks to contaminated feed and water, plus the failure of immunological resistance (María Cecilia Guzmán, 2004).

Normally, the internal organs (kidney, liver, spleen) and muscles of healthy fish are germ-free, although recent studies have described the presence of bacteria (Pseudomonas spp, Vibrio spp including V. fischeri, V. pelagi), and there were various discussions if the fish muscle is sterile or not ( Evelyn and McDermott, 1961). Microflora of fish guts appears to differ with the complexity of fish gastrointestinal tract, the type of fish feed; the species present in the intestines seem to be those from the environment and the highest bacterial culture was found in detritus eaters (Balasubramanian et al., 1992).

According to the European Food Safety Authority (EFSA), a wide range of bacteria such *Campylobacter*, *Listeria*, *Salmonella*, *E. coli* can be responsible for foodborne outbreaks, threatening public health directly (EFSA, 2014). Nonetheless, not all the pathogens are incriminated in the foodborne outbreaks. Considering the consumption of fish and fish products, however, some bacterial species like *Listeria monocytogenes*, *E. coli*, *Vibrio* spp, *Salmonella* spp, *C. botulinum*, *Streptococcus iniae*, *Mycoplasma* spp, present a lot of interest, due to their ample dispersion in the marine environment, and also to the high morbidity and mortality rates for human beings.

**FOODBORNE PATHOGENS RELATED WITH FISH AND FISH PRODUCTS**

*Mycobacterium* spp

Mycobacteria are a class of rod-shaped bacteria, acid-fast, that do not stain by traditional methods. For these species procedures such as Ziehl-Nielsen staining and biopsy are necessary in order to isolate and detect them (Beran et al., 2006). Mycobacteria are the most well-known zoonotic fish-borne bacterial germs, affecting a large range of fish species worldwide, being responsible for the affection called mycobacteriosis (fish tuberculosis) (Novotny et al., 2004), a chronic progressive disease, causing granulomatous inflammation, in viscera and muscles, as well as ulcerative skin lesions (Gauthier, 2009). Injuries tend to be observed two to four weeks after exposure to the mycobacterium. Usually, disease in humans appears as superficial granulomatous inflammation of the extremities because of the cooler temperatures, and in some instances long term effects involve deeper tissues, resulting in tenosynovitis, osteomyelitis, arthritis and a non-responsive immune system. (Petrini, 2006). The most commonly detected species involve: *M. marinum, M. fortuitum, M. chelonea*. The human population contacts fish pathogenic mycobacteria due to exposure of wounds and skin abrasion to polluted water, as well as injuries contracted by handling infected fish or by seafood preparation and processing. (Rhodes et al., 2004). The diagnosis is difficult, usually based on the ability of mycobacterium (particularly *M. marinum*) to mimic other disorders such as gout, chronic infections, rheumatoid arthritis. Infections with *M. marinum* are clinically and histologically indistinguishable from tuberculosis. Moreover, *M. marinum* and other non-tuberculous mycobacteria (NTM) can lead to cross-reactivity to skin tests based on purified protein derivative (PPD) of *M. tuberculosis* and *M. avium* (Kobashi et al., 2009). Antibiotic therapy is necessary to treat the skin condition, but in deep lesions the surgical excision is often indispensable. (Lewis et al., 2003).

*Clostridium botulinum*

*Clostridium botulinum*, of the genus *Clostridium*, is a spore forming bacteria, associated with foodborne botulism that grows in anaerobic conditions. (Novoslavskij et al., 2015). The main habitat of this germ is widely spread in nature, from soil ground to marine environments. Virulence of the bacteria consists in producing a neurotoxin that causes botulism, a disease which attacks the central nervous system causing descending paralysis in humans (Barash and Amon, 2014). *C. botulinum* produces seven types of toxins, in which Typ E is the one implicated most in human cases associated with fish meat consumption. Sometimes Type A and B can be also involved (Lindström et al., 2006). Sometimes type A and B also involved (Hyyatia, 1998). The existence of *C. botulinum* in fish can be related to direct contact with polluted water environments and ingestion of *C. botulinum* spores from sediments and contaminated feed (Leclair et al., 2006). *Clostridium botulinum* can pose a threat to public health when processing technics are improper and insufficient to eliminate botulinum spores from raw fish.

*Enterobacteriaceae*

Enterobacteriaceae are ubiquitously distributed in a widely range of environments and hosts,
and a various number of pathogenic species have been isolated from fishes, including enteropathogenic E. Coli and Salmonella spp, bacterial causative agents of gastroenteritis in humans. (EFSA, 2014)

The contamination of fish with pathogenic E. coli possibly occurs by handling of fish or during the production process (McCoy et al., 2011). Some outbreaks concerning E. coli have been described in Brazil where authors have isolated 18 enterotoxigenic strains of E. coli (ETEC) from fresh fish (Vieira et al., 2001) and in Japan, an enterohaemoragic strain (EHEC) from salted salmon roe (Asai et al., 1999).

Some Shiga-toxin producing strains are capable to cause foodborne diseases.

Salmonella is a mesophilic organism and is not a usual inhabitant of water environments (Kumar et al., 2009). The presence of the bacteria in the aquatic climate is mainly explained by hygiene failures during production (Amagliani et al., 2012). Salmonella can also be isolated from fresh water, not just from seafood, this being explained by the contamination of the water source. Salmonella can be divided in more than 2500 serovars. (Agbaje et al, 2011)

Nonetheless, some serovars are described as being major dominants in fish meat and aquatic habitats, such Salmonella enterica ser. Bareilly, ser. Ohio, ser. Newport, ser. Derby, ser. Typhimurium, ser. Washington etc. Other salmonella including Salmonella enterica ser. Enteritidis, ser. Typhi, ser. Paratyphi B, were mentioned as common serotypes isolated from seafood (Rahimi et al., 2013). In conclusion, the prevalence of E. coli and Salmonella serovars in fish and water environments is a widespread concern in food handling and poor hygiene during the capture, transport, and processing of fish.

Vibrio spp

Vibrio spp are widely distributed in estuary waters and fish habitats (Feldhusen, 2000). A variety of fish pathogenic species can cause diseases including Vibrio anguillarum the causative agent of red pest in eels, V. ordalii causes septicaemia in salmonids, V. salmonicida causes cold water vibriosis, V. vulnificus causes warm water vibriosis, V. wodanis causes winter ulcer disease in Atlantic salmon (Gauthier, 2014). Among Vibrio spp. that cause diseases in humans the most significant is V. cholerae, particularly the toxin strains that belong to O1 serogroup. However, V. cholerae is hardly reported as a disease agent in fishes. The non-cholera human vibriosis are caused by V. parahaemolyticus and V. vulnificus (Gauthier, 2014). V. vulnificus is a gram-negative pathogen, causing gastroenteritis or septicaemia in humans after ingesting raw seafood. There are three biotypes described for this species: biotype 1 is isolated from water and humans, biotype 2 is isolated from humans and fishes, biotype 3 has been isolated from humans and wound infections and is supposed to be a hybrid between biotypes 1 and 2 (Mahmud et al., 2010). V. parahaemolyticus is the author of acute gastroenteritis, and on rare occasions even septicemia can occur, the pathogen being frequently isolated from fish, mollusks and crustaceans. These pathogens can cause human vibriosis, due to consumption of insufficiently heat-treated fish or fish products (Callol et al., 2015).

Streptococcus iniae

Streptococcus iniae is a Gram-positive, encapsulated coccus, that causes meningoencephalitis and high losses in finfish aquacultures (Agnew and Barnes, 2007). S. iniae was first identified in 1976, in dolphins causing multiple subcutaneous abscesses. Humans tend to develop a bacteraemic cellulitis developed in 16-24h after a percutaneous injury (Facklam, 2005), while preparing fish for consumption. The zoonotic risk seems to be correlated especially with older and immunocompromised people (Locke et al., 2007). In fish, the infection results in meningitis and panophthalmitis and is characterized by a high rate of morbidity and mortality. Clinical signs may include: exophthalmia, melanosis, corneal opacity, loss of orientation, emaciation or sudden death (Evans et al., 2008). Fish may get infected by diverse routes of exposure like oral, olfactive route, direct contact, or through cannibalism. Diagnosis in fish should be pronounced as a result of combination between clinical signs, etiological isolation, pathology findings.
**Listeria monocytogenes**

*Listeria monocytogenes* is a pathogenic agent widespread in nature, that can be found in soil, silage, fresh and marine waters sediments. It is the causative agent of listeriosis in human beings (Liu, 2006). The prevalence of listeria is correlated with the degree of human activity. There are more than 13 serotypes described for *L. monocytogenes*, of which certain serotypes (1/2a, 1/2b and 4b) are involved in human cases (Jami et al., 2014), these serotypes being found mostly in fish. *Listeria monocytogenes* and other species, persist in the water climate due to their abilities to survive and multiply at low temperatures (4°C) and by forming biofilms (Budzińska et al., 2012). *Listeria* has been found in processed seafood products, marinated fish, sushi or smoked fish (Tocmo et al., 2014). A low number of listeriosis epidemic episodes have been related with the consumption of fish or fish products in analogy with other foods (EFSA, 2014). Bacterial pathogens can contaminate the fish products during the processing technology. Evisceration and scalding of the fish before marketing can lead to cross-contamination of fish, utensils, personnel, surroundings. Cleaning and sanitation programs were recommended to avoid contamination with *L. Monocytogenes* on the surfaces and equipment during the processing time (Papadopoulos et al., 2010).

**CONCLUSIONS**

A wide range of chemical contaminants and microbes in fish and seafood have been described as potential risks for foodborne outbreaks.

Factors such as human activity, hygiene deficits during handling, transport and processing technologies, contaminated water and air have an important impact in the development of acute and chronic symptoms from POPs and bacteria in humans.

In the case of chemical contaminants, risks can be avoided more through the consumption of less fatty fish, avoiding to eat fish and seafood in case of pregnancy, or to offer it to small children who are still in development phase. The emergence of bacterial microorganisms is based on outbreaks deriving from the consumption of raw or insufficient cooked fish meat. Therefore, a more careful approach towards this could be efficient.

Guidelines such as Good Hygiene Practices (GHP) together with Good Manufacturing Practices (GMP) and the implementation of a Hazard Analysis and Critical Control Point (HACCP) program for fish, fish products and seafood, are some measures that could lower the risks of foodborne diseases.

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