The Presence of Arsenic as Heavy Metal Contaminant on Salmon: A Risk Assessment

Titik Budiati *
* Food Technology Division, School of Industrial Technology, Universiti Sains Malaysia, Penang, Malaysia
* School of Industrial Technology, Universiti Sains Malaysia, Minden, Penang 11800, Malaysia
Email: titik.budiati@gmail.com, +60(4)6533813 ext. 2992

Abstract-- Salmon is a kind of fish which has good nutrition for human but it can be contaminated by heavy metal such as arsenic. In risk assessment, the provisional tolerable weekly intake (PTWI) for inorganic arsenic is 15 μg/kg b.w./week and the organic forms of arsenic present in sea foods need different consideration from the inorganic arsenic in water. There are no reports of toxicity in man or animals from the consumption of organoarsenicals in seafood. Organic arsenic compounds such as arsenobetaine and arsenocholine seem not to be converted to inorganic arsenic in vivo and not genotoxic in mammalian cells in vitro. Therefore, arsenobetaine and arsenocholine from fish and sea food consumption is not considered to represent a significant health risk.

Index Term-- Salmon, arsenic, risk assessment.

I. INTRODUCTION

Nowadays, the question of whether to eat fish or not has made fish consumption a real dilemma. On the one hand, more and more people think about the positive effects of eating fish instead of meat, since the healthy fatty acids such as omega-3 and omega-6 are present. On the other hand, a lot of studies have shown the potential adverse health effects that fish consumption can have on humans.

Species, season, diet, location, life stage, and age have a major impact on both nutrient and contaminant levels in fish [8]. Contaminants in fish derive predominantly from their diet, and levels of bioaccumulation of contaminants are higher in fish that are higher in the food chain [8]. It was reported that it is not possible to control the diet of wild fish, the levels of contaminants, and of some nutrients. However, in farmed fish this can be modified by altering the fish feed. Furthermore, a difference that can be found between the wild fish and farmed fish is the amount of healthy fatty acids, such as long chain polyunsaturated fatty acids (LC n-3 PUFA), that can be found in lower amounts in farmed fish than in the wild fish [8]. Consumption of one to two servings a week of fish is beneficial to human health.

In spite of the beneficial effects that fish consumption provides, fish can harbor a number of biological and chemical hazards, such as toxic compounds, POPs, pathogenic bacteria, and viruses, which can survive the processing steps. Unfortunately the chemical contaminants are stored within the lipid component of the fish [15] so they are well protected when entering the human body.

In general, food of animal origin contributes to about 80% of the overall human exposure to dioxins. The contamination can vary widely depending on the origin of the foodstuff. Meat, eggs, milk, farmed fish and other food products may be contaminated above background levels from feedingstuffs. Such contamination may be due to a high level of local environmental contamination, for example from a local waste incinerator, to incidents, such as in 1999 in Belgium, or to a high content of dioxins in fishmeal and fish oil. Wild fish from certain polluted areas may be highly contaminated. [9].

Fish can indeed contribute significantly to the human dietary exposure to many contaminants, but in this risk assessment we would like to focus in heavy metal contaminant such as arsenic. The aim of this study is to determine the risk assessment of salmon due to the presence of arsenic as heavy metal contaminant.

II. APPROACH

A survey and evaluation of the data on arsenic speciation in salmon was performed in order to determine published concentrations of total arsenic and inorganic arsenic in tissues of wild and farmed salmon that are consumed by humans, and to determine the availability of data on other potential arsenic compounds of concern. This article focuses on the results of the survey that are relevant to the risk assessments issue of determining percentage of total arsenic that is present as inorganic arsenic in salmon at arsenic-contaminated sites or at sites where arsenic is a potential contaminant. Sources of data included journal articles and WHO documents, with a focus on reports that provided speciated arsenic results. Previous reviews were also consulted to identify relevant primary literature.

Criteria considered in assessing reliability of the data included analysis of those type of salmon, reporting of methods and recovery of arsenic from the samples. Few of the reports, however, satisfied all of these criteria, and laboratory methods and data reporting were not consistent across studies.
Results expressed per mg wet weight tissue were not converted to a common basis because tissue water content was not reported for many of the studies and is variable depending on the tissue type. The percentage of inorganic/total arsenic is not affected by whether the concentration values for a sample are expressed on a wet weight basis.

III. RESULT AND DISCUSSION

Risk assessment is the scientific evaluation of the probability of occurrence and severity of known or potential adverse health effects resulting from human exposure to foodborne hazards. The process consist of hazard identification, hazard characterization, exposure assessment and risk characterization.

Hazard Identification

A wide variety of contaminants may be present in fish such as arsenic. Arsenic usually occurs in waters as inorganic oxides in the pentavalent form. Arsenic is a ubiquitous, naturally-occurring element. Increased levels of arsenic in water and soil can be found in certain areas as a result of leaching from rock into ground water, and possible geothermal activity [21]. Levels of arsenic are most constant in deep ocean waters, while levels in surface waters show seasonal variation [4]. Trivalent forms of arsenic are more toxic to humans and aquatic organisms and are usually only present under anaerobic conditions. From the data found in literature they show that the highest contribution of heavy metals in salmon is from Arsenic, with 3.3 mg/Kg. Arsenic has a very complex chemistry in the marine environment, and occurs in various chemical forms and more than 20 different chemical forms have been identified and characterised. The inorganic arsenic compounds are the most toxic, particularly As\(_2\)O\(_3\). Methylated arsenic compounds occur naturally in the environment as a result of biological activity [17]. Reduction and methylation by microorganisms occur in the more superficial photic zone which sufficient sunlight penetrates to support photosynthesis; levels of methylation correlate with photosynthetic activity [1],[2]. Accordingly, in addition to As\([\, V]\), surface waters contain small amounts of inorganic arsenite (As\([\, III]\)), methyl arsonate (MA) and dimethyl arsinate (DMA).

The sequence starts with phytoplankton which readily take up arsenate from water via trans-membrane transport systems normally dedicated to the uptake of essential phosphate anions [9], [13], [20]. Following uptake, phytoplankton rapidly detoxify arsenate by reduction and methylation, resulting in the formation of arsenic-containing sugars as well as minor amounts of DMA and other methylated arsenical compounds [16], [18]. In addition to arsenobetaine, other organic and inorganic arsenic compounds have been found in fish that are common components of the human diet. The proportion of inorganic arsenic in those foods is generally low, less than 1–4% of total arsenic [11], [14].

Total arsenic concentrations (all values in mg/kg wet weight) in the farmed fish were significantly higher than in the wild fish. However, inorganic arsenic was not detectable (limit of detection, 4 ng/g wet weight) in these samples, indicating that arsenic was present in fish tissues in the relatively nontoxic organic form. Cobalt, copper, and cadmium were significantly higher in wild fish than in farmed fish. Differences between farmed and wild salmon for the other metals were not detected. No significant differences were found in metal concentrations among farmed salmon from different regions, nor were significant differences found between the two wild salmon species with the exception of cadmium (\(p = 0.025\)). [10].
As with organic contaminants, the main exposure route to heavy metals is through the diet. After absorption into blood, heavy metals distribute rapidly to the brain, liver, kidney, fat or bone depending on the metal in question and its chemical form. Fish is the main source of arsenic in the diet, and greater than 90% of the arsenic found in marine fish is present as arsenobetaine, which is considered non-toxic. While the fate of organic arsenicals has not been clearly defined in man, arsenobetaine from seafood is known to be readily absorbed (75–85% bioavailability) and rapidly excreted. [9]

2.2. Hazard characterization

The epidemiological data found that arsenic has a little evidence with cancer risk [19]. Inorganic arsenic has been recognized as a human poison since ancient times, and large oral doses (above 60,000 ppb in water) can result in death. The most characteristic effect of long-term oral exposure to inorganic arsenic is a pattern of skin changes. These include patches of darkened skin and are often associated with changes in the blood vessels of the skin. Skin cancer may also develop. Swallowing arsenic has also been reported to increase the risk of cancer in the liver, bladder, and lungs. The Department of Health and Human Services (DHHS) has determined that inorganic arsenic is known to be a human carcinogen (a chemical that causes cancer) [6]. Inorganic arsenic is more toxic than organic forms and inorganic arsenic is classified by the International Agency for Research on Cancer (IARC) as “carcinogenic to humans” (Group 1) on the basis of “sufficient evidence” for an increased risk for cancer of the urinary bladder, lung and skin [12]. Besides cancer induction, chronic human exposure to arsenic in drinking water (mainly inorganic arsenic) has also been associated with peripheral vascular diseases, cardiovascular diseases and possibly with diabetes and reproductive effects [12]. EPA also has classified inorganic arsenic as a known human carcinogen. Almost no information is available on the effects of organic arsenic compounds in humans. Studies in animals show that most simple organic arsenic compounds (such as methyl and dimethyl compounds) are less toxic than the inorganic forms. In animals, ingestion of methyl compounds can result in diarrhea, and lifetime exposure can damage the kidneys. Lifetime exposure to dimethyl compounds can damage the urinary bladder and the kidneys [6].

Arsenic and its metabolite are chemicals that bioaccumulate in tissues of aquatic organisms but do not biomagnify in the aquatic food chain. The bioaccumulation factor (BAF) for arsenic in salmon is 5.79. [15]. The average biological half-life is about 60 days (rats/rabbits) due to the accumulation of arsenic in the erythrocytes. For humans, half-life is shorter because of a fast excretion of arsenic [5].

2.3 Exposure assessment

The identification of a "practical threshold" for hyperpigmentation, keratosis, other possible vascular complications, human chronic, can serve as a basis for an assessment of the safety of exposure to arsenic. Developmental effects are the primary concern regarding arsenic exposure and have been demonstrated in both animal and human studies. The data derive NOAEL as 0.0008 mg/kg/day upon which a chronic oral MRL as 0.014 mg/kg/day [19] and Provisional Tolerable Weekly Intake (PTWI) for arsenic is 15 μg/kg b.w./week.

2.4. Risk Characterization

Quantitative and qualitative characterization and statistical uncertainties

Marine organisms accumulate arsenic, predominantly as non-toxic arsenobetaine and arsenocholine. Products like fishmeal and fish oil have been identified as major sources of feed contamination with arsenic, and it is likely that the measured arsenic represents predominantly these organic compounds. The EU maximum level for arsenic in fish feed is 6 mg/kg and for inorganic arsenic is 2 mg/kg. [9].

In 1988, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) confirmed its previously established provisional tolerable weekly intake (PTWI) for inorganic arsenic of 15 μg/kg b.w./week [22] and noted that organic forms of arsenic present in seafood need different consideration from the inorganic arsenic in water. There are many regional and ethnic populations who consume large quantities of fish that result in organoarsenic intakes of about 50 μg/kg b.w./day. There are no reports of toxicity in man or animals from the consumption of organoarsenicals in seafood.

Organic arsenic compounds such as arsenobetaine and arsenocholine seem not to be converted to inorganic arsenic \textit{in vivo} as they are eliminated unchanged from the body. Arsenobetaine and arsenocholine are also not genotoxic in mammalian cells \textit{in vitro}. Therefore, arsenobetaine and arsenocholine from fish and sea food consumption is not considered to represent a significant health risk.

IV. CONCLUSIONS

Products like fishmeal and fish oil have been identified as major sources of feed contamination with arsenic. The maximum level of arsenic in fish feed is 6 mg/kg and for inorganic arsenic is 2 mg/kg.
The provisional tolerable weekly intake (PTWI) for inorganic arsenic of 15 μg/kg b.w./week and noted that organic forms of arsenic present in sea foods need different consideration from the inorganic arsenic in water.

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