Science of the Total Environment 575 (2017) 919–931

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Comparative study of the intake of toxic persistent and semi persistent pollutants through the consumption of fish and seafood from two modes of production (wild-caught and farmed)

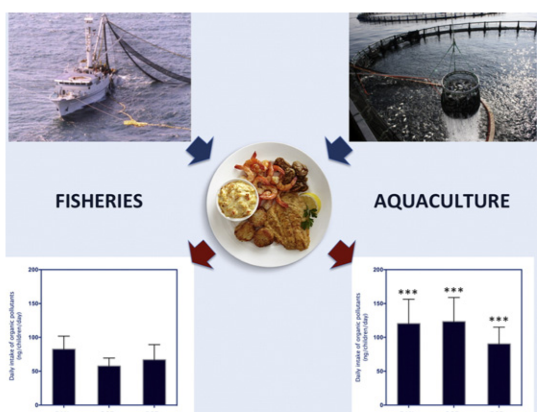
Ángel Rodríguez-Hernández [a], María Camacho [a], Luis A. Henríquez-Hernández [a], Luis D. Boada [a,b], Pilar F. Valerón [a], Annalisa Zaccaroni [c], Manuel Zumbado [a], Maira Almeida-González [a], Cristian Rial-Berriel [a], Octavio P. Luzardo [a,b,*]

[a] Toxicology Unit, Research Institute of Biomedical and Health Sciences (IUIBS), Universidad de Las Palmas de Gran Canaria, 35016 Las Palmas de Gran Canaria, Spain
[b] Spanish Biomedical Research Centre in Physiopathology of Obesity and Nutrition (CIBERObn), Paseo Blas Cabrera Felipe s/n, 35016 Las Palmas de Gran Canaria, Spain
[c] Department of Veterinary Medical Sciences, University of Bologna, Research Group on Large Pelagic Vertebrates, Viale Vespucci 2, 47042 Cesenatico, FC, Italy

HIGHLIGHTS

- Comparative assessment of intake of pollutants through farmed and wild seafood
- Higher levels of total PAHs, total OCPs, and total PCBs in aquaculture products
- Higher levels of carcinogenic PAHs in wild-caught seafood
- Concentrations of elements had a variable pattern between farmed and wild specimens
- Intake of most of these pollutants is higher through consumption of farmed seafood

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 24 August 2016
Received in revised form 17 September 2016
Accepted 17 September 2016
Available online 23 September 2016

Editor: D. Barcelo

Keywords:
Polycyclic aromatic hydrocarbons
Organochlorine pesticides
Polychlorinated biphenyls

ABSTRACT

Adverse effects of chemical contaminants associated with seafood counteract the undoubted benefits for the health of its valuable nutrients. So much so that many dietary guidelines recommend no more than one serving a week of fish and seafood. Although is estimated that aquaculture provides more than 50% of the fish and seafood consumed globally, few research studies have focused in the assessment of the intake of pollutants through aquaculture products. In this study we determined the levels of organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and toxic elements (Pb, Cd, Ni, Al, As, and Hg) in a large sample of farmed and wild-caught seafood, and we estimated the intake of these contaminants in two hypothetical models of consumers: those consuming only farmed fish, and those consuming only wild fish. Measured levels of most organic and many inorganic pollutants were higher in aquaculture products, and consequently intake levels if only such products were consumed would be also significantly higher. Thus, the intake of $\sum$PAHs in adults consuming aquaculture seafood would be 3.30 ng/kg-bw/day, and consuming

* Corresponding author at: Toxicology Unit, Department of Clinical Sciences, Universidad de Las Palmas de Gran Canaria, Paseo Blas Cabrera Felipe s/n, 35016 Las Palmas de Gran Canaria, Spain.
E-mail address: octavio.perez@ulpgc.es (O.P. Luzardo).

http://dx.doi.org/10.1016/j.scitotenv.2016.09.142

Heavy metals
Aquaculture

seafood from extractive fishing 2.41 ng/kg-bw/day ($p < 0.05$); ∑ OCPs, 3.36 vs. 1.85 ng/kg-bw/day, respectively ($p < 0.05$); ∑ PCBs, 2.35 vs. 2.11 ng/kg bw/day, respectively; and the intake of Pb, Ni, As, and Al would be also significantly higher consuming farmed seafood. For children the estimations were very similar, but the difference of intake of PCBs reached statistical significance. The implementation of several decontamination practices in aquaculture would allow not only match the levels of pollution from wild-caught seafood, but also could provide products with much lower levels of pollutants than those, which in turn would allow to increase consumption over the "one serving per week", and so benefit the consumer of the enormous positive health effects of the valuable nutrients of seafood.

1. Introduction

Regular consumption of fish is widely recommended worldwide by government and health organizations because it represents a valuable source of the very long-chain polyunsaturated fatty acids eicosapentaenoic acid and docosahexaenoic acid (PUFAs) and essential nutrients such as vitamin D, iodine and selenium (Kromhout et al., 2016; Mozaffarian and Ludwig, 2010). Numerous studies have established beneficial associations between moderate consumption of fish and risk factors for several diseases, such as obesity and metabolic syndrome (Torris et al., 2014), cardiovascular disease and stroke (Ndanuko et al., 2016; Shen et al., 2015), hypertension (Ndanuko et al., 2016), kidney disease (Ndanuko et al., 2016), neurodegenerative diseases (Pan et al., 2015), and even cancer (Eltweri et al., 2016; Lovegrove et al., 2015; Vaughan et al., 2013). The contribution of PUFAs in fish has also proved beneficial to all stages of human development, from the moment of conception to maturity and aging (Gil and Gil, 2015).

Despite all the benefits attributable to the PUFAs from fish, usually dietary guidelines recommend that consumption of this food is limited to one serving per week (Kromhout et al., 2016; Mozaffarian and Ludwig, 2010). This is mainly due to the potential adverse effects of chemical contaminants that are usually present in fish (e.g. heavy metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), dioxins, furans and chlorinated pesticides (OCPs)) (Rodriguez-Hernandez et al., 2016; Tang et al., 2016; Zhang et al., 2016). Paradoxically, many adverse effects attributable to chemical contaminants in fish are opposed to the benefits of PUFAs, such as degenerative effects on nervous system, alteration of the immune system, and increased risk of cardiovascular disease or cancer, among others (Gil and Gil, 2015; Rodriguez-Hernandez et al., 2016). Thus, the dietary recommendations have to take into account the chemical load that is present in the commercial fish species. Therefore, the monitoring of chemical contamination in fish is crucial to establish the risk-benefit ratio from fish consumption. The majority of dietary guidelines conclude that with the current level of chemical contamination of fish at a consumption level of one serving per week there is no evidence for toxicological risks if a variety of different types of fish are eaten (Kromhout et al., 2016; Mozaffarian and Ludwig, 2010).

During the last decades, the consumption of seafood from aquaculture has been steadily increasing, as farmed fish represent an affordable alternative to wild-caught fish for many consumers worldwide. Thus, since 2012 available data indicate that aquaculture already provides more food to people than extractive fishing (57 vs. 43%) (APROMAR, 2014; FAO, 2014). The European Commission intends to further boost the growth of the aquaculture industry as a means to meet future demands seafood, and as an important potential source of employment and economic development (Tornero and Hanke, 2016). While one of the negative highlights of aquaculture production is related precisely with chemical pollution that this activity produces in the environment (Cole et al., 2009; Grigorakis and Rigos, 2011; Leung et al., 2015), it is also true that the controlled conditions in which this activity is carried would enable the control of pollution levels, both in the environmental water as in the final product. This is, fish farming (unlike extractive fishing) theoretically would allow the management of pollution levels in fish (mainly through the control of the contamination in feed), and therefore producing safer products. Subsequently, by diminishing the risks associated to chemicals in farmed fish, the consumption of this beneficial food could be higher. For all these reasons, as a preliminary step, it is necessary to know the levels of contamination of fish taking into account their mode of production. In the case of aquaculture, this information is needed to further verify the effectiveness of possible measures aimed to reduce the levels of these contaminants.

The aquaculture industries are required to verify that the levels of chemical contaminants in products comply with current legislation, and that the chemicals in their products are below the maximum residue levels (MRLs) before being put on the market (EC, 2005; EC, 2011). However, this kind of routine controls usually seeks only the compliance of current regulations and are made in the products taken individually (each individual fish or seafood species farmed). With regard to the levels of exposure to chemicals (such as organochlorine pesticides, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, or heavy metals) in the human population through the consumption of the variety of fish and shellfish that are part of the diet, there are also many available scientific studies worldwide (Groth, 2016; Naji et al., 2016; Rodriguez-Hernandez et al., 2016). There are also many studies comparing levels of contamination found in aquaculture species compared to individuals of the same species obtained from extractive fishing at sea (Airaksinen et al., 2015; Kelly et al., 2011). However, relatively little scientific research has made a comparative study of human exposure to chemicals considering the mode in which the fish is obtained (Cirillo et al., 2010; Cirillo et al., 2009), and as far as we know, none in the Spanish population. This gap in knowledge is what has motivated the design of this study, which is aimed to (i) determine the level of contamination by PCBs, OCPs, PAHs, and heavy metals of the wild-caught and farmed seafood species most consumed in Spain, and (ii) estimate the daily dietary exposure of seafood consumers to these pollutants considering two theoretical groups of consumers: a) those who would consume only wild-caught seafood, and b) those who would consume only farmed seafood. The goal was to determine whether relative differences in pollutants occurred between the consumption of wild or farmed seafood in Spain.

2. Material and methods

2.1. Sampling

Using the data of the pattern of food consumption in Spain we sampled the most consumed species of fish (whitefish and bluefish), and other seafood (crustaceans and bivalve molluscs), both from aquaculture production and wild-caught (AECOSAN, 2006; AECOSAN, 2011). Whenever available we sampled the same species from both methods of production. A total of 84 pooled samples from the main commercial seafood species were analyzed (52 pooled samples from fishing species and 32 pooled samples from aquaculture species). Each pooled sample was formed from 4 different pieces of each seafood (complete individuals in the case of species of fish or shellfish small, or fillets in the case