Journal of Hazardous Materials 203–204 (2012) 13–21

Contents lists available at SciVerse ScienceDirect

Journal of Hazardous Materials

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

Mercury and stable isotope signatures in caged marine fish and fish feeds

Sarayut Onsanit, Min Chen, Caihuan Ke, Wen-Xiong Wang*

State Key Laboratory for Marine Environmental Science, College of Oceanography and Environmental Science, Xiamen University, Xiamen 361005, China

ARTICLE INFO

Article history:
Received 23 July 2011
Received in revised form 16 October 2011
Accepted 6 November 2011
Available online 26 November 2011

Keywords:
Caged fish
Total mercury
Methylmercury
Biomagnification
Stable isotope
Risk assessment

ABSTRACT

Total mercury (THg) and methylmercury (MeHg) concentrations were determined in four species of marine caged carnivorous fish, one species of herbivorous fish and three types of fish feeds (dried pellet feed, forage fish and fish viscera), collected from five cage sites in the rural areas along Fujian coastline, China. For the carnivorous fish, the concentrations of THg and MeHg ranged from 0.03 to 0.31 μg/g and from 0.02 to 0.30 μg/g on wet weight basis, respectively. The concentrations were lower for the herbivorous fish with both within the range of 0.01–0.03 μg/g. Out of the three tested fish feeds, tuna viscera contained the highest level of mercury (0.20 μg/g THg and 0.13 μg/g MeHg), with pellet feed containing the lowest level (0.05 μg/g THg and 0.01 μg/g MeHg). The calculated trophic transfer factor of MeHg was the highest (12–64) for fish fed on pellet feeds, and was the lowest for fish fed on tuna viscera. A significant relationship was found between Hg concentrations in caged fish and in fish feeds, thus Hg was primarily accumulated from the diet. Furthermore, the stable isotope $\delta^{15}N$ was positively correlated with the Hg concentration in two caged sites, indicating that $\delta^{15}N$ may be a suitable tool for tracking mercury in caged fish. We conclude that fish farming may be a good way of reducing the human exposure to Hg because mercury levels can be carefully controlled in such farming systems.

1. Introduction

Over the past decades, marine fish farming along the coastline of China has been experiencing a dramatic growth due to both domestic and foreign demands. The southern Fujian province has witnessed an unprecedented growth in its marine caged fish industry, with the farmed fish generally including species such as the red seabream (*Pagrus major*), the black seabream (*Acanthopagrus schlegelii*), the Japanese seabass (*Lateolabrax japonicus*), the red drum (*Sciaenops ocellatus*), the yellow croaker (*Larimichthys croceus*) and the grouper (*Epinephelus* spp.). Farming of these fish species requires low investment and easy routine farming management. As a result of fish farming, the fish feed industry has also grown dramatically in the region. Almost all the caged marine fish in this area are carnivorous fish that can grow rapidly with high commercial values.

In practice, the farmers generally feed the farmed fish with two different types of feed. One type is the forage fish or trash fish (any small fish that has little value as a food fish) such as the anchovy or clupeids. Moreover, tuna viscera and squid viscera as the byproducts from seafood processing are also used as feed for caged fish [1,2], which can increase the palatability of feeding for these carnivorous fish [3,4]. Another type is the dried artificial feed pellet produced by animal feed factories. The diet composition (fresh fish and artificial feed) of caged fish varies due to the instability of the raw material supply. Recently, Hardy and Lee [5] concluded that the challenges for the aquaculture industry in the 21st century include not only the large quantity needed to meet the increasing demand but also maintaining the seafood quality to prevent mercury contamination.

Due to the biomagnification of mercury (mainly MeHg) in marine fish, there is now a considerable concern regarding the safety of fish consumption. Mercury can build up in certain edible freshwater and marine fish as a result of trophic transfer, and food has been implied as the dominant pathway for mercury uptake in fish [6,7]. In fish, the dominant form of accumulated mercury is MeHg, and the highest concentration of mercury is commonly found in fish occupying the top trophic levels, as well as in larger and older fish [8]. Bioaccumulation of mercury in fish through dietary exposure and trophic transfer are the dominant processes defining the exposure to the fish itself and to human health from fish consumption. Previous studies have reported mercury contamination in Fujian coastal areas [8–10]. There have been some reports of total mercury (THg, ranging from 0.003 to 1.34 μg/g) in economic marine fish from estuary and coastal waters in China [10–12].

* Corresponding author at: Division of Life Science, The Hong Kong University of Science and Technology (HKUST), Clear Water Bay, Kowloon, Hong Kong. Tel.: +852 2358 7346; fax: +852 2358 1559.
E-mail address: wwang@ust.hk (W.-X. Wang).

0304-3894/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.jhazmat.2011.11.021

The consumption of marine fish is recommended because they are good nutritional sources of omega-3 fatty acids associated with health benefits. MeHg is a form of mercury that is easily absorbed through the gastrointestinal tract with an efficiency of 90–95% [13]. Thus, although the consumption of marine fish is beneficial, it can also present a risk to humans [14–17]. Many countries are concerned with the health risk of mercury in edible fish. Human health issues from MeHg contamination in fish have been addressed by the World Health Organization (WHO), the UN Food and Agriculture Organization (FAO), the US Environmental Protection Agency (EPA), the US Food and Drug Administration (FDA), and other organizations in several countries [18–20]. These agencies have issued threshold guidance for fish consumers to limit their MeHg exposure from fish consumption. However, there has not been any report of mercury concentration in marine caged fish from Fujian, which now probably hosts one of the largest fish farms in China [21].

In this study, we specifically quantified the THg and MeHg in marine caged fish collected from five marine fish cage sites in Fujian province. Mercury concentrations in five species from different rural cage sites (from the south to the north of Fujian's coastal waters) were compared. Moreover, the stable isotopes of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) were used as a tool to track the trophic position of the caged fish. Human risk assessments of mercury for average Chinese people consuming cage-reared fish were performed. We focused our study on the caged fish farm mainly because of its very unique system in fish feed practice, thus the biomagnification of Hg may be very different from what is naturally observed in wild fish populations. We also examined the difference in Hg bioaccumulation in caged fish fed on different fish feeds.

2. Materials and methods

2.1. Fish samples

In June 2009, five marine fish species, including the red seabream (*P. major*), the red drum (*S. ocellatus*), the black seabream (*A. schlegelii*), the Japanese seabass (*L. japonicus*), and the rabbitfish (*Siganus fuscessens*), were collected from five fish cages along the Fujian coastline. Fish feeds including the dried pellet feed and fresh feeds (forage fish and fish viscera) were also sampled to monitor the mercury sources in the caged fish culture. The farming in Fujian marine caged fish generally used these fish diets. The forage fish included a variety of small fish such as anchovy and clupeids, while the commercial dried pellets were prepared from fish meal, bean meal, corn or wheat gluten, squid viscera meal, fish oil, and scarp of seed Agro byproducts. The sampling stations from south to north were Dongshan (23°44.539′N, 117°31.081′E), Xiamen Bay (24°21.353′N, 118°04.342′E), Xinghua (25°18.335′N, 119°14.303′E), Fuqing (25°41.169′N, 119°35.167′E), and Luoyuan (26°21.615′N, 119°43.163′E) (Fig. 1). Ten market-sized fish for each species were sampled from each cage station (approximately 500 g for red seabream, 800 g for red drum, 1000–1200 g for seabass, 400 g for black seabream and 100 g for rabbit fish, Table 1). *L. japonicus* and *A. schlegelii* were not available at the Dongshan cage site. *S. fuscessens* was available only at the Dongshan and Xiamen Bay cage sites. Only the Xiamen Bay site was sampled for all five fish species. No gender difference was considered in this study. Fish of similar size were collected to minimize any potential influence of fish size on mercury concentration. Dorsal fish muscle tissues (white muscle) were dissected with clean stainless steel knife and washed with deionized water and then placed in clean ziplock plastic bags

Fig. 1. Sampling sites of caged fish along the coastline of Fujian province.