Original Article

The available utilization of selenium from some inedible tissues of marine products-II:
The distribution of selenium in several species of fish at lower trophic level in the marine ecosystem

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Abstract

The selenium distribution in the scales or skin as the some inedible tissues and the ordinary muscle of several species of fish at lower trophic levels in marine ecosystem (Japanese sardine *Sardinops melenostictus*, Silver-stripe herring *Spratelloides gracilis*, Japanese horse mackerel *Trachurus japonicas*, Chub mackerel *Scomber japonicas*, Pacific saury *Cololabis saira* and Flying fish *Cypselurus agoo agoo*), generally called "*Aomono*" in Japanese, containing a small amount of mercury with a large amount of polyunsaturated fatty acid, was investigated in order to clarify the possibility of the available utilization of selenium from those tissues, in relation with the mercury distribution involving the tissues. As a result, each selenium level in the scales or skin in all subjected fish was about the same or somewhat higher than that involving muscle. On the other hand, the mercury level was extremely low compared with the muscle and Se/Hg (the molar ratio of selenium to mercury) as an indicator of the safety of marine products was extremely high compared with that involving muscle, suggesting that the scale or skin will be usually inedible but significantly safe tissue in which low levels of heavy metals such as mercury will tend to accumulate, as in the case of a preceding paper. Moreover, in the present study, the similar results were also obtained for the pectoral fin characteristics of Flying fish. These findings suggest that the available utilization of selenium can also be expected from pectoral fin in addition to the scales or skin of fish, including the improvement of environment.

Key words

selenium, mercury, distribution, inedible tissue, lower trophic level

1. Introduction

The scales or the skin of fish are usually discarded as an inedible tissue. Therefore, if the selenium level of such discarded tissues is about the same or higher compared with that of the ordinary muscle as an edible tissue, in addition to no mercury accumulation, the available utilization of selenium will be expected as an essential element (not only detoxification of mercury) from the inedible tissues of marine products, including the improvement of environment. The selenium distribution in the scales or skin as inedible tissues of several species of fish (Yellow tail *Seriora quinqueradiata*, Red sea bream *Pagrus major* and Puffer *Takihugu rubripes*) in relation with the mercury distribution involving tissue has already been reported (Kai et al., 2013). As a result, each selenium level in the scales or skin was about the same or somewhat higher than that involving muscle of those fish, but the mercury level was surprisingly low or nearly zero.

In recent years, it has been well known that several species of fish generally called "*Aomono*" in Japanese are a very important diet in daily life due to the existence of a large amount of polyunsaturated fatty acid (PUFA) as one of antioxidants (Kimura and Miyashita, 2003; Ulven et al., 2014). On the other hand, it is also known that there will be low mercury accumulation in these fish bodies, because these fish are located at lower trophic levels in the marine ecosystem. This suggests that the mercury levels of these low cost fish are significantly lower than those of the usually tasted and consumed fish in our preceding study (Kai et al., 2013). Then, it will be very noteworthy to investigate if the selenium level of such discarded tissues is about the same or higher compared with that of the ordinary muscle, in addition to lower or little mercury accumulation, because the available utilization of selenium may be newly found from the inedible tissues, in addition with that of PUFA such as EPA, DHA etc. from the edible tissue.

In the present paper, the selenium distribution in some inedible tissues of the several species of fish at lower trophic levels in marine ecosystem was investigated in order to clarify the possibility of the utilization of selenium from those discarded tissues, in relation with the mercury distribution involving tissue.

2. Materials and methods

2.1 Materials

Five kinds of Japanese sardine *Sardinops melenostictus* from Mie Prefecture, Japanese horse mackerel *Trachurus japonicas* from Oita Prefecture, Chub mackerel *Scomber japonicas* from

Yamaguchi Prefecture, Pacific saury Cololabis saira from Hokkaidou, Silver-stripe herring *Spratelloides gracilis*, and Flying fish *Cypselurus agoo agoo* from Kagoshima Prefecture were submitted in the present study, respectively. The ranges of body length of Japanese sardine, Silver-stripe herring, Japanese horse mackerel, Chub mackerel, Pacific saury and Flying fish were 14.6 to 15.4, 4.5 to 5.6, 17.3 to 21.5, 31.8 to 35.4, 30.0 to 31.5 and 27.5 to 30.0 cm (14.9, 5.0, 19.4, 34.0, 31.0 and 29.2 cm (as each mean concentration). There was little difference of the degree of growth between the same species in each sampled fish.

In the present study, the ordinary muscle and the scale or skin (plus pectoral fins only in the case of Flying fish) as inedible tissues were removed from these fish bodies, and stored in a freezer at −30 °C until analyzed.

2.2 Methods

2.2.1 Determination of selenium

The oxidation number of selenium exists as −2, +4, and +6 in aquatic organisms. The minus divalent selenium exists as an organic form, and this form will be the selenide species assigned to the selenohydryl groups (–SeH or SeHg and SeCd) substituting for sulfur of the thiol group or bonding to heavy metals such as Hg and Cd. The chemical forms of the plus tetravalent and hexavalent seleniums will be selenite and selenate species joined to two neighboring thiol groups in the protein, respectively (Gasiewicz and Smith, 1978; Cappon and Smith, 1981; Iwata et al., 1982).

The total selenium concentration and the concentration of the low oxidation states of selenium (selenide and selenite species) (abbreviated as T-Se and [Org.Se + Se (IV)], respectively) in each specimen were then measured using gas chromatography with an electron capture detector(Toei and Shimoishi, 1981). The concentration of the selenate species was estimated by the difference between T-Se and [Org.Se + Se (IV)], and abbreviated as Se (VI).

2.2.2 Determination of mercury

The total mercury concentration in each specimen was measured by a flow injection analysis system using cold vapor atomic absorption spectrometry (FIAS-CV-AAS) preceded by a wet digestion in a microwave oven, and abbreviated as T-Hg (Aduna de Paz et al., 1997).

3. Results and discussion

3.1 Selenium distribution

3.1.1 Japanese sardine

The ranges of [Org.Se + Se (IV)], Se (VI) and T-Se in the ordinary muscle were 0.29_4 to 0.49_3, 0.01_0 to 0.11_5 and 0.37_3 to 0.50_3 μg/g ($0.38_2 \pm 0.03_8$, $0.06_3 \pm 0.02_0$ and $0.44_5 \pm 0.02_5$ μg/g as each mean concentration), respectively. Those in the skin were 0.52_6 to 0.94_9, 0.08_0 to 0.17_7 and 0.64_8 to 1.06_9 μg/g ($0.64_5 \pm 0.07_8$, $0.12_0 \pm 0.01_6$ and $0.76_5 \pm 0.08_0$ μg/g as each mean concentration), respectively.

3.1.2 Silver-stripe herring

The ranges of [Org.Se + Se (IV)], Se (VI) and T-Se in the ordinary muscle were 0.25_4 to 0.39_0, 0.03_4 to 0.13_5 and 0.29_9 to 0.52_5 μg/g ($0.31_8 \pm 0.02_6$, $0.08_7 \pm 0.01_8$ and $0.40_5 \pm 0.03_9$ μg/g as each mean concentration), respectively. Those in the skin were 0.80_7, 0.89_6 and 1.70_3 μg/g as each mean concentration of one specimen combined with five individuals because the sample size was very small as described above, respectively.

3.1.3 Japanese horse mackerel

The ranges of [Org.Se + Se (IV)], Se (VI) and T-Se in the ordinary muscle of cultured species were 0.13_7 to 0.26_6, 0.03_3 to 0.16_2 and 0.23_6 to 0.41_7 μg/g ($0.22_3 \pm 0.03_7$, $0.10_1 \pm 0.05_5$ and $0.32_4 \pm 0.03_8$ μg/g as each mean concentration), respectively. Those in the scales were 0.15_2 to 0.29_5, 0.03_3 to 0.54_6 and 0.23_0 to 0.81_7 μg/g ($0.23_7 \pm 0.02_5$, $0.18_4 \pm 0.09_3$ and $0.42_2 \pm 0.11_2$ μg/g as each mean concentration), respectively.

3.1.4 Chub mackerel

The ranges of [Org.Se + Se (IV)], Se (VI) and T-Se in the ordinary muscle were 0.32_4 to 0.69_8, 0.06_1 to 0.24_1 and 0.46_6 to 0.75_3 μg/g ($0.43_2 \pm 0.06_9$, $0.15_4 \pm 0.03_4$ and $0.58_6 \pm 0.05_0$ μg/g as each mean concentration), respectively. Those in the skin were 0.08_8 to 0.22_3, 0.03_8 to 0.23_0 and 0.13_5 to 0.39_6 μg/g ($0.14_0 \pm 0.02_5$, $0.09_6 \pm 0.03_5$ and $0.23_6 \pm 0.04_8$ μg/g as each mean concentration), respectively.

3.1.5 Pacific saury

The ranges of [Org.Se + Se (IV)], Se (VI) and T-Se in the ordinary muscle were 0.07_9 to 0.11_6, 0.06_7 to 0.19_5 and 0.17_1 to 0.29_4 μg/g ($0.09_6 \pm 0.00_8$, $0.13_8 \pm 0.02_4$ and $0.23_4 \pm 0.02_4$ μg/g as each mean concentration), respectively. Those in the skin were 0.06_1 to 0.17_7, 0.07_6 to 0.39_8 and 0.22_2 to 0.51_0 μg/g ($0.12_5 \pm 0.04_1$, $0.23_0 \pm 0.09_6$ and $0.35_5 \pm 0.10_9$ μg/g as each mean concentration), respectively.

3.1.6 Flying fish

The ranges of [Org.Se + Se (IV)], Se (VI) and T-Se in the ordinary muscle were 0.10_1 to 0.16_5, 0.10_2 to 0.29_9 and 0.22_5 to 0.40_0 μg/g ($0.12_9 \pm 0.01_2$, $0.17_1 \pm 0.03_5$ and $0.30_0 \pm 0.03_1$ μg/g as each mean concentration), respectively. Those in the scale were 0.08_8 to 0.15_2, 0.08_8 to 0.14_9 and 0.19_1 to 0.23_6 μg/g ($0.10_9 \pm 0.01_1$, $0.11_7 \pm 0.01_2$ and $0.22_6 \pm 0.02_0$ μg/g as each mean concentration), respectively. Those in the pectoral fins were 0.10_3 to 0.19_5, 0.07_4 to 0.08_5 and 0.18_8 to 0.26_9 μg/g ($0.14_9 \pm 0.04_6$, $0.08_0 \pm 0.00_6$ and $0.22_9 \pm 0.04_1$ μg/g as each mean concentration), respectively. The results on the selenium data described above are shown in Figure 1.

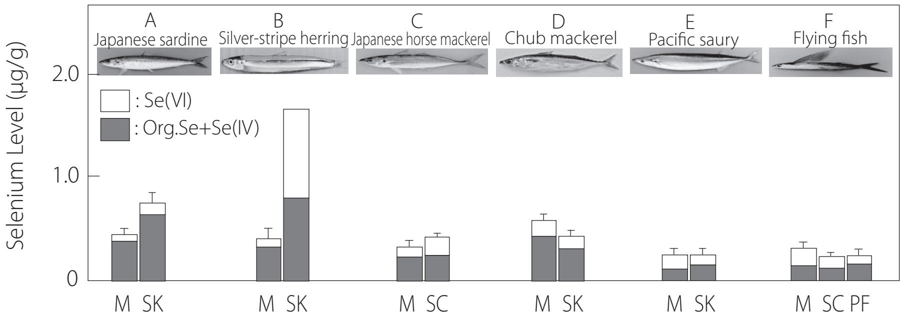

Figure 1: Selenium levels in the subjected fish

Note: M: Ordinary muscle; SK: Skin; SC: Scale; PF: Pectoral fins

3.2 Mercury distribution

3.2.1 Japanese sardine

The range of T-Hg in the ordinary muscle and skin were 0.01_6 to 0.02_2 and 0.00_8 to 0.01_8 μg/g ($0.02_0 \pm 0.00_1$ and $0.01_2 \pm 0.00_2$ μg/g as each mean concentration), respectively.

3.2.2 Silver-stripe herring

The range of T-Hg in the ordinary muscle and skin were 0.00_7 to 0.01_4 and 0.00_2 to 0.01_4 μg/g ($0.01_0 \pm 0.00_2$ and $0.00_6 \pm 0.00_3$ μg/g as each mean concentration), respectively.

3.2.3 Japanese horse mackerel

The range of T-Hg in the ordinary muscle and scales were 0.02_7 to 0.03_6 and 0.00_2 to 0.00_4 μg/g ($0.02_9 \pm 0.00_1$ and $0.00_3 \pm 0.00_1$ μg/g as each mean concentration), respectively.

3.2.4 Chub mackerel

The range of T-Hg in the ordinary muscle and skin were 0.00_9 to 0.01_3 and 0.00_3 to 0.01_0 μg/g ($0.01_3 \pm 0.00_2$ and $0.00_6 \pm 0.00_1$ μg/g as each mean concentration), respectively.

3.2.5 Pacific saury

The range of T-Hg in the ordinary muscle and skin were 0.04_8 to 0.06_7 and 0.00_6 to 0.02_6 μg/g ($0.05_5 \pm 0.00_3$ and $0.01_5 \pm 0.00_4$ μg/g as each mean concentration), respectively.

3.2.6 Flying fish

The range of T-Hg in the ordinary muscle, scales and pectoral fins were 0.02_8 to 0.15_2, 0.00_3 to 0.00_7 and 0.00_2 to 0.00_8 μg/g ($0.07_5 \pm 0.02_6$, $0.00_4 \pm 0.00_1$ and $0.00_4 \pm 0.00_1$ μg/g as each mean concentration), respectively. The results on the mercury data described above are shown in Figure 2.

Then, Se/Hg (the molar ratio of selenium to mercury) of the ordinary muscle and the scales or the skin in all sampled fish species were estimated at molar basis as the indicator on the safety of marine products, from the point of the toxicological view of a trace amount of heavy metals such as mercury.

Each mean value of Se/Hg in the ordinary muscle and the scales or the skin of Japanese sardine, Silver-stripe herring, Japanese horse mackerel, Chub mackerel, Pacific saury and Flying fish were 57.79 and 188.98, 108.64 and 283.83, 10.95 and 123.38, 38.21 and 83.36, 10.88 and 59.30 and 18.02 and 141.33, respectively. On the other hand, the mean value of Se/Hg in the pectoral fins of Flying fish was 250.45. The results on the estimated value described above are shown in Figure 3.

4. Conclusion

From the profiles of selenium and mercury distribution shown in Figures 1 and 2, it is clear that those of fish at lower trophic levels in the marine ecosystem are about the same as the cases of Yellow tail, Red sea bream and Puffer described

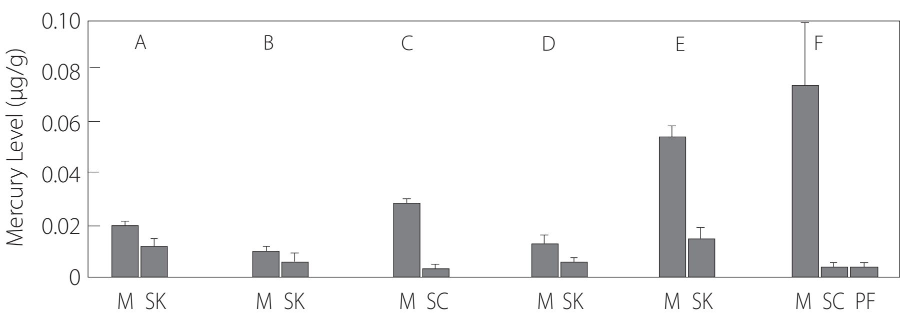

Figure 2: Mercury levels in the subjected fish

Notes: M: Ordinary muscle; SK: Skin; SC: Scale; PF: Pectoral fins. A, B, C, D, E and F refers to each subjected fish in Figure 1, respectively.

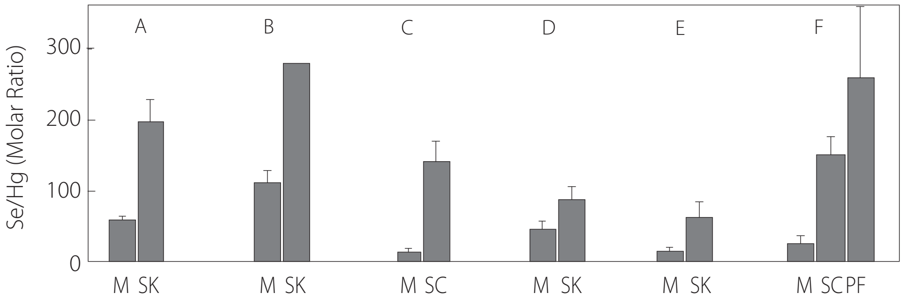

Figure 3: Se/Hg (molar ratio) in the subjected fish

Notes: M: Ordinary muscle; SK: Skin; SC: Scale; PF: Pectoral fins. A, B, C, D, E and F refers to each subjected fish in Figure 1, respectively.

in a preceding paper (Kai et al., 2013), that is, that the selenium levels of the discarded tissues are about the same or higher compared with those of the ordinary muscle, in addition to lower or little mercury accumulation. Furthermore, from the profile of estimated value shown in Figure 3, each distribution profile of the value of Se/Hg in the ordinary muscle and the scales or the skin was also about the same, and those mean values were larger than 1, suggesting that those sampled marine products are generally safe against toxicity due to the accumulation of mercury. Especially, it will be also very noteworthy that that value in the inedible tissue such as pectoral fins of Flying fish in addition with scale or skin was extremely high compared with those in the ordinary muscle. These findings mean that the new utilization of selenium as an essential element will be expected using discarded tissues containing the present inedible tissues as in the case of previous reported fish (Kai et al., 2013), and moreover that the improvement of the environment will be performed by such utilization.

In further studies, we using another species of fish, and shell, crustaceans or seaweeds etc., the possibility of the overall utilization of selenium from discarded or inedible tissues in marine products should be clarified.

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