Original Article

The behavior of selenium and mercury in cultured fish-VII:
The influence of the fasting upon the mercury and selenium distribution

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Abstract
Both mercury and selenium distribution in the ordinary muscle of Japanese scad (*Decapterus maruadsi*), preserved under a fasting environment, was investigated in order to clarify the influence of fasting, which is generally performed before shipment in culture facilities, upon the metabolism of some trace components in the fish body. As a result, it is shown that both levels of mercury and selenium (especially low oxidation state of selenium) gradually decreased with the decrease of body weight during the fasting and consequently there was a positive correlation ($r_o = 0.99$) between both levels. These findings suggested that both elements may also be excreted as a detoxified substance such as mercuric selenide by means of fasting until shipment.

Key words
distribution, fasting, Japanese scad, mercury, selenium

1. Introduction

In culture facilities, fasting has been traditionally performed during a specific term until shipment for the purpose of improving the quality of the fish, through the decrease of excessive lipid with the excretion of the stomach contents from the fish body by preserving a cultured adult fish under a fasting environment.

On the other hand, we have already reported the profiles of mercury distribution in cultured olive flounder, sea bream and amberjack, in relation to those of selenium distribution (Kai et al., 2007; 2008; 2009; 2010, 2011).

As a result, a gradual decrease in the levels of both mercury and selenium was observed with the weight gain from the juvenile to the adult stage. Here, the fasting period for each species is little known, and also there is no data of both elements in sampled fish during this period.

Therefore, in the present paper, in order to draw a general conclusion about the behavior of mercury and selenium in cultured fish in more detail, the influence of fasting upon the metabolism of some trace components in the fish body using Japanese scad were observed and by clarifying the variations of mercury and selenium distribution during this period until shipment the metabolism of both elements was postulated.

2. Materials and methods

2.1 Materials

The Japanese scad, *Decapterus maruadsi*, used in this study were caught at the Kanesaki fishing port in Fukuoka Prefecture. The mean fork length and body weight of sampled fish (n = 20) were 25.0 ± 2.0 cm and 120.1 ± 15.1 g, respectively. Those samples were immediately transported to the aquarium (2 × 3 × 1.7 m) in the ship, and then preserved in the fish cage (10 × 10 × 8 m, mesh size 43.3 mm) for up to 33 days under a fasting environment.

The fasting period was categorized as three stages, i.e., stage (A), (B) and (C) which is preserved for 0 day (wild), 20 days and 33 days in the fasting environment. The sampling was done as follows; five individuals were used at stage (A), ten and five individuals were used at stages (B) and (C), respectively.

In the present study, the ordinary muscle was removed from these fish bodies, and stored in a freezer until analyzed, and then submitted for analysis.

2.2 Methods

2.2.1 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).

2.2.2 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 the sulfur of the thiol group or the 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).

3. Results and discussion

3.1 Mercury distribution

The range of T-Hg in the sampled fish was 0.01_7 to 0.05_7 μg/g, and each mean concentration in stages (A), (B) and (C) were $0.05_1 \pm 0.00_6$ μg/g, $0.02_7 \pm 0.01_0$ μg/g, and $0.02_1 \pm 0.00_4$ μg/g, respectively. Each mean mercury level is shown in Figure 1.

As Figure 1 shows, each mercury level in the ordinary muscle of stage (A) was the highest, and tended to drastically decrease to stage (B), and then was lowest in stage (C). This may suggest that there was an excretion of mercury from the fish body with the gradual decrease of the weight due to such fasting.

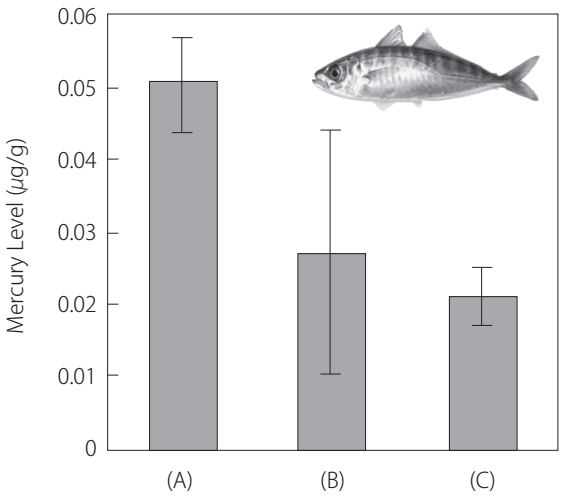

Figure 1: Mercury level in ordinary muscle of Japanese scad ((A) 0 (wild), (B) 20 and (C) 33 days) after fasting

3.2 Selenium distribution

The range of T-Se in the sampled fish was 0.26_5 to 0.37_3 μg/g, and each mean concentration in stages (A), (B) and (C) were $0.34_1 \pm 0.03_2$ μg/g, $0.31_0 \pm 0.02_8$ μg/g, and $0.30_0 \pm 0.03_5$ μg/g, respectively. The mean selenium levels are shown in Figure 2.

As Figure 2 shows, each total selenium level in the ordinary muscle of stage (A) was the highest, and tended to gradually decrease to about the same levels at stage (B) and stage (C). On the other hand, the range of [Org. Se + Se (IV)] in the sampled fish was 0.20_8 to 0.08_1 μg/g, and each mean concentration in stages (A), (B) and (C) were $0.17_1 \pm 0.03_7$ μg/g, $0.15_8 \pm 0.03_9$ μg/g, and $0.12_4 \pm 0.04_3$ μg/g, respectively. Se (VI) was nearly constant ($0.16_0 \sim 0.17_0$ μg/g) during the fasting period.

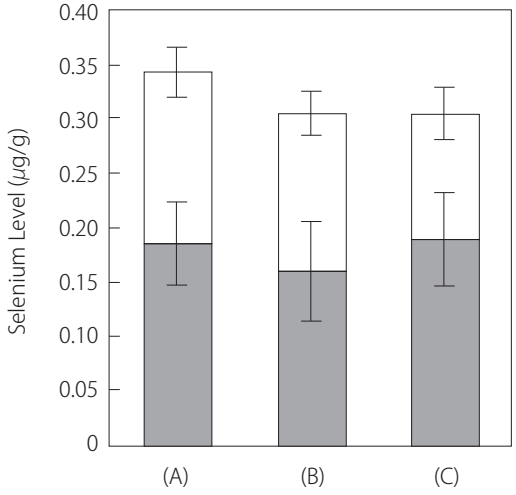

Figure 2: Selenium level in ordinary muscle of Japanese scad ((A) 0 (wild), (B) 20 and (C) 33 days) after fasting (☐: {Org Se + Se (IV)}; ■: Se (VI))

These results may suggest that selenium level (especially the low oxidation state of selenium) gradually decreased with the decrease of body weight during fasting, as is the case of mercury level (Nickerson and Falcone, 1963).

3. Conclusion

As shown in the figures, both levels of mercury and selenium (especially low oxidation state of selenium) gradually decreased with the decrease of body weight during fasting. Then, by estimating a regression curve between both levels, the linear correlationship was clarified. As a result, there was a significantly positive correlation ($r_0 = +0.99$). Moreover, both decreases of the content of lipid and lactic acid, as an indicator the stress, were also observed by Tanaka, as one of the coworkers in the present study, and these findings will soon be submitted for publication in another journal.

Therefore, these findings suggest that both elements will be excreted as a detoxified substance such as mercuric selenide (Kai et al., 2004; 2006), in addition to improvement of the quality of the fish, by means of fasting until shipment.

References

Aduna de Paz, L., Alegria, A., Barbera, R., Farre, R., and Lagarda, M. J. (1997). Detrmination of mercury in dry-fish samples by microwave digestion and flow injection analysis system cold vapor atomic absorption spectrometry. *Food Chemistry*, Vol. 58, Nos.1 & 2, 169-172.

Cappon, C. J., and Smith, J. C. (1981). Mercury and Selenium content and chemical form in fish muscle. *Archives of Environmental Contamination and Toxicology*, Vol. 10, 305-309.

Gasiewicz, T. A., and Smith, J. C. (1978). Properties of the cadmium and selenium complex formed in vivo and in vitro. *Chemico-Biological Interactions*, Vol.23, 171-178.

Iwata, H., Matsunaga, T., Kito, H., and Hayashi, M. (1982). Dedradation of methyl mercury by selenium. *Life Sciences*, Vol. 31, 859-866.

Kai, N., Takahashi, Y., Kondo, M., Takeshita, N., Inoue, S., Tanoue, Y., and Nagai, T. (2007). The behavior of selenium and mercury in cultured fish-I: The profile of selenium distribution in cultured olive flounder. *ITE Letters*, Vol. 8, No.5, 106-109.

Kai, N., Takahashi, Y., Kondo, M., Takeshita, N., Inoue, S., Tanoue, Y., and Nagai, T. (2008). The behavior of selenium and mercury in cultured fish-II: The profile of mercury distribution in cultured Olive flounder. *ITE-IBA Letters*, Vol. 1, No. 5, 431-435.

Kai, N., Takahashi, Y., Kondo, M., Takeshita, N., Inoue, S., Tanoue, Y., and Nagai, T. (2009). The behavior of selenium and mercury in cultured fish-III: The profile of selenium and mercury distribution In cultured olive flounder using extruder pellet. *ITE-IBA Letters*, Vol. 2, Nos. 5 & 6, 38-44.

Kai, N., Takahashi, Y., Kondo, M., Takeshita, N., Inoue, S., Tanoue, Y., and Nagai, T. (2010). The behavior of selenium and mercury in cultured fish-IV: The profile of mercury distribution in red sea bream. *ITE-IBA Letters*, Vol. 3, No. 4, 31-35.

Kai, N., Takahashi, Y., Kondo, M., Takeshita, N., Inoue, S., Tanoue, Y., and Nagai, T. (2011).The behavior of selenium and mercury in cultured fish-V: The profile of selenium distribution in red sea bream. ITE-IBA Letters, Vol. 4, No. 2, 15-20.

Kai, N., Takahashi, Y., Kondo, M., Takeshita, N., Inoue, S., Tanoue, Y., and Nagai, T. (2011). The behavior of selenium and mercury in cultured fish-VI: The profile of mercury distribution in cultured amberjack. *ITE-IBA Letters*, Vol. 4, No. 2, 21-24.

Kai, N., Inoue, S., Yamamoto, K., Sakai, T., Murata, H., Hamada, M., Tanoue, Y., and Nagai, T. (2004). The oxidation state and the distribution of selenium in the ordinary muscle of freshwater fish under breeding environment. *ITE Letters*, Vol. 5, No. 5, 472-474.

Kai, N., Inoue, S., Ueno, S., Tanoue, Y., and Nagai, T. (2006). The oxidation state and the distribution of selenium in jellyfish in a breeding environment. *ITE Letters*, Vol. 7, No. 5, 462-464.

Nickerson, W. J., and Falcone, G. (1963). Enzymatic reduction of selenite. *Journal of Bacteriology*, Vol. 85, 763-771.

Toei, K., and Shimoishi, Y. (1981). Detemination of ultra-micro amounts of selenium by gas chromatography with electron-capture detection. *Talanta*, Vol. 28, 967-972.

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