The available utilization of selenium from some inedible tissues of marine products-III: The distribution of selenium in several species of shellfish

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Abstract
Each selenium distribution in the midgut gland, as one of the inedible tissues and whole muscle of the several species of bivalves and snails, was investigated in order to clarify the possibility of the available utilization of selenium from the inedible tissues of shellfish, in relation with mercury distribution involved in those tissues. Both levels in the midgut gland in all subjected shellfish was significantly high as that involving the whole muscle and low oxidation states of selenium species existed dominantly in both tissues. On the other hand, the Se/Hg (the molar ratio of selenium to mercury) in the midgut gland of those shellfish as an indicator of the safety of marine products was about the same or higher compared with that involving whole muscle, suggesting that the midgut gland is usually inedible but a significantly safe tissue. However, because the heavy metals such as mercury will tend to accumulate higher in the midgut gland compared with the whole muscle, as a result, the decrease of the molar fraction of bioavailable species of Se(VI) was observed in the midgut gland. These findings suggested that the available utilization of selenium will not be expected from the midgut gland of shellfish, as was not the case of several species of fish previously reported.

Key words
selenium, mercury, distribution, midgut gland, shellfish

1. Introduction
If the selenium level in inedible tissues of fish and shellfish is about the same or higher compared with that of an edible tissue, in addition to little 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.

Therefore, it has already been reported that the selenium distribution in the scales or skin as the inedible tissues of several species of fish in relation with the mercury distribution involving tissue (Kai et al., 2013; 2014). 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, however the mercury level was surprisingly low or nearly zero.

In recent years, it has been well known that the midgut gland is one of the tissues in relation to the shellfish poison and so not usually ingested and discarded to avoid a risk (Asakawa et al., 1986; Takata et al., 2004). Then, it is noteworthy to investigate if the selenium level of such discarded tissues in shellfish 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 such as the scales or the skin of fish.

In this present paper, the selenium distribution in the midgut gland was investigated as one of inedible tissues of the several species of shellfish in order to clarify the possibility of the utilization of selenium from those tissues, in relation with the mercury distribution involved in the tissue.

2. Materials and methods
2.1 Materials
Five individuals of bivalves and snails were submitted in this present study.

2.1.1 Bivalves
The ranges of shell length of Pen shell *Atrina pectinata* from Saga Prefecture and Scallops *Patinopecton yessoensis* were 9.1 to 11.0 and 12.8 to 14.1 cm, respectively.

2.1.2 Snails
Five individuals of herbivorous and carnivorous species were submitted in this present study.

2.1.2.1 Herbivorous species
The ranges of shell length of Turban shell *Turbo comtus* and Matsubagai *Cellana nigrolineata* from Yamaguchi Prefecture were 6.0 to 7.0 and 4.0 to 5.0 cm, respectively.

2.1.2.2 Carnivorous species
The ranges of shell length of Whelk *Babylonia japonica* from Kagoshima Prefecture and Veined rapa whelk *Rapana venosa* from Fukuoka Prefecture were 4.5 to 5.0 and 10.0 to 10.2 cm, respectively.

There was little difference of the degree of growth be-
between the same species in each shellfish described above.

In the present study, the whole muscle and the midgut gland as inedible tissues were removed from these shellfish 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 is the selenide species ascribed to the selenohydryl groups (–SeH or SeHg and SeCd) substituting for 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 are 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 low oxidation states of selenium (selenide and selenite species) (abbreviated as T-Se) and \([\text{Org. Se} + \text{Se(IV)}]\), 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 \([\text{Org. Se} + \text{Se(IV)}]\), 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 Bivalves

3.1.1.1 Pen shell

The ranges of \([\text{Org. Se} + \text{Se(IV)}]\), Se(VI) and T-Se in the whole muscle were 0.09 to 0.25, 0.01 to 0.16, and 0.17 to 0.33 \(\mu g/g\) (0.15 ± 0.04, 0.08 ± 0.04, and 0.23 ± 0.05 \(\mu g/g\) as each mean concentration), respectively. Those in the midgut gland were 0.53 to 0.99, 0.02 to 0.29, and 0.60 to 1.17 \(\mu g/g\) (0.73 ± 0.15, 0.14 ± 0.08, and 0.88 ± 0.19 \(\mu g/g\) as each mean concentration), respectively.

3.1.1.2 Scallops

The ranges of \([\text{Org. Se} + \text{Se(IV)}]\), Se(VI) and T-Se in the whole muscle were 0.07 to 0.12, 0.02 to 0.34, and 0.11 to 0.43 \(\mu g/g\) (0.09 ± 0.01, 0.11 ± 0.09, and 0.21 ± 0.10 \(\mu g/g\) as each mean concentration), respectively. Those in the midgut gland were 0.59 to 0.91, 0.02 to 0.32, and 0.66 to 1.04 \(\mu g/g\) (0.70 ± 0.11, 0.14 ± 0.09, and 0.84 ± 0.19 \(\mu g/g\) as each mean concentration), respectively.

3.1.2 Snails

3.1.2.1 Herbivorous species

3.1.2.1.1 Turban shell

The ranges of \([\text{Org. Se} + \text{Se(IV)}]\), Se(VI) and T-Se in the whole muscle were 0.10 to 0.16, 0.01 to 0.07, and 0.16 to 0.18 \(\mu g/g\) (0.14 ± 0.01, 0.04 ± 0.01, and 0.18 ± 0.00 \(\mu g/g\) as each mean concentration), respectively. Those in the midgut gland were 0.43 to 0.75, 0.02 to 0.33, and 0.46 to 0.98 \(\mu g/g\) (0.57 ± 0.05, 0.10 ± 0.05, and 0.67 ± 0.10 \(\mu g/g\) as each mean concentration), respectively.

3.1.2.1.2 Matsubagai

The ranges of \([\text{Org. Se} + \text{Se(IV)}]\), Se(VI) and T-Se in the whole muscle were 0.09 to 0.12, 0.01 to 0.04, and 0.11 to 0.16 \(\mu g/g\) (0.10 ± 0.00, 0.03 ± 0.00, and 0.13 ± 0.00 \(\mu g/g\) as each mean concentration), respectively. Those in the midgut gland were 0.14 to 0.37, 0.00 to 0.06, and 0.15 to 0.39 \(\mu g/g\) (0.23 ± 0.04, 0.04 ± 0.01, and 0.27 ± 0.04 \(\mu g/g\) as each mean concentration), respectively.

3.1.2.2 Carnivorous species

3.1.2.2.1 Whelk

The ranges of \([\text{Org. Se} + \text{Se(IV)}]\), Se(VI) and T-Se in the whole muscle of cultured species were 0.21 to 0.30, 0.08 to 0.51, and 0.34 to 0.78 \(\mu g/g\) (0.25 ± 0.01, 0.22 ± 0.07, and 0.48 ± 0.07 \(\mu g/g\) as each mean concentration), respectively. Those in the midgut gland were 0.67 to 1.38, 0.10 to 1.08, and 0.87 to 2.17 \(\mu g/g\) (1.06 ± 0.14, 0.48 ± 0.18, and 1.55 ± 0.28 \(\mu g/g\) as each mean concentration), respectively.

3.1.2.2.2 Veined rapa whelk

The ranges of \([\text{Org. Se} + \text{Se(IV)}]\), Se(VI) and T-Se in the whole muscle were 0.09 to 0.16, 0.00 to 0.10, and 0.14 to 0.24 \(\mu g/g\) (0.12 ± 0.01, 0.06 ± 0.01, and 0.19 ± 0.01 \(\mu g/g\) as each mean concentration), respectively. Those in the midgut gland were 0.74 to 0.90, 0.13 to 0.25, and 0.99 to 1.08 \(\mu g/g\) (0.84 ± 0.03, 0.20 ± 0.02, and 1.04 ± 0.01 \(\mu g/g\) as each mean concentration), respectively.

The analytical data of selenium in all samples described above are shown in Figure 1.

3.2 Mercury distribution

3.2.1 Bivalves

3.2.1.1 Pen shell

The range of T-Hg in the whole muscle and midgut gland were 0.00 to 0.01, and 0.02 to 0.04 \(\mu g/g\) (0.00 ± 0.00, and 0.00 ± 0.00 \(\mu g/g\) as each mean concentration), respectively.

3.2.1.2 Scallops

The range of T-Hg in the whole muscle and midgut gland were 0.00 to 0.00, and 0.02 to 0.02 \(\mu g/g\) (0.00 ± 0.00, and 0.00 ± 0.00 \(\mu g/g\) as each mean concentration), respectively.
3.2.2 Snails

3.2.2.1 Herbivorous species

3.2.2.1.1 Turban shell

The range of T-Hg in the whole muscle and midgut gland were 0.00, to 0.00, and 0.00, to 0.02, µg/g (0.00 ± 0.00, and 0.01 ± 0.00, µg/g as each mean concentration), respectively.

3.2.2.1.2 Matsubagai

The range of T-Hg in the whole muscle and midgut gland were 0.00, to 0.02, and 0.00, to 0.03, µg/g (0.01 ± 0.00, and 0.02 ± 0.00, µg/g as each mean concentration), respectively.

3.2.2.2 Carnivorous species

3.2.2.2.1 Whelk

The range of T-Hg in the whole muscle and midgut gland were 0.02, to 0.06, and 0.02, to 0.17, µg/g (0.04 ± 0.00, and 0.12 ± 0.02, µg/g as each mean concentration), respectively.

3.2.2.2.2 Veined rapa whelk

The range of T-Hg in the whole muscle and midgut gland were 0.03, to 0.08, and 0.08, to 0.19, µg/g (0.05 ± 0.01, and 0.15 ± 0.02, µg/g as each mean concentration), respectively.

The analytical data of mercury in all samples described above are shown in Figure 2.

4. Conclusion

From the profiles of selenium and mercury distribution shown in Figures 1 and 2, it was clear that those of shellfish are significantly different to the cases of previous papers (Kai et al., 2013; 2014), that is, that the selenium levels of the midgut gland as discarded tissues are also high compared with those of the whole muscle, in addition to higher mercury accumulation. Furthermore, from the estimated value of selenium molar fraction shown in Figure 3, [Org.Se+Se(IV)] molar fraction of the midgut gland was about the same or somewhat higher than that of the whole muscle in the subjected shellfish, suggesting that some Se(VI) species as metabolized in a living body after eating, exists in the midgut glands. These findings mean that the new utilization of selenium as an essential element will be not expected using the midgut gland as inedible tissues of shellfish.

In the shellfish, each molar ratio of T-Hg to T-Se in both tissues was also calculated as an indicator of safety against toxicity due to the accumulation of mercury (Kai et al., 2013; 2014; 2016). The ranges of each mean molar ratio of the whole muscle and midgut gland were 8.35 to 259.39 and 17.16 to 233.11, respectively. The involved ratios are shown decreasing with the increase of trophic level on the food chain order at a marine ecosystem in Figure 4, and then all of those mean values were larger than 1, suggesting that those
sampled marine products are generally safe against toxicity due to the accumulation of mercury.

On the other hand, Figure 4 suggests that the higher the trophic level is, the lower the involved Se/Hg (molar ratio) is in a marine ecosystem, because those values of tuna or marine mammals are nearly 1 (Kai et al., 2000; Koeman, et al., 1973). Therefore, Se/Hg (molar ratio) may also be used as an indicator of the high and low order of trophic level on the food chain in relation to the increase of mercury accumulation with the trophic level on the food chain as in Figure 2.

In further studies, it is important to clarify, using crustaceans or seaweeds etc., the possibility of the overall utilization of selenium from the discarded or inedible tissues in marine products.

References


(Received: September 4, 2017; Accepted: September 13, 2017)