Determination of Nutritional Efficiency of Selenium Contained in Processed Skipjack Meat by Comparison with Selenite

Munehiro YOSHIDA,* Kimikazu IWAMI,** and Kyoden YASUMOTO***1

Department of Food Science and Technology, Faculty of Agriculture, Kyoto University, Sakyo-ku, Kyoto 606, Japan
(Received January 25, 1984)

Summary The nutritional efficiency of selenium (Se) contained in two kinds of processed fish meat was appraised. Rats were fed on a 20% casein diet deficient in Se (0.046 µg/g diet) for 2 weeks, and were then fed on the basal diet supplemented with 0.08 µg/g of Se as sodium selenite, boiled meat of skipjack or dried strip of skipjack for an additional 8 days. The Se-supplementation caused a significant increase of the Se concentration and the glutathione peroxidase activity in the rat liver. Although significant differences in hepatic Se levels were not observed among the rats fed on the Se-supplemented diets, the elevation of the hepatic enzyme activities of the rats fed on the skipjack-supplemented diets was only 45 to 53% that of the rats fed on the selenite-supplemented diet. Amounts of excretion of both fecal and urinary Se of the rats fed on the diets supplemented with the skipjacks were higher than those of the selenite-administered rats. These results indicate that the nutritional efficiency of the Se in the skipjack meat is about 50% that of selenite and that unknown factor(s) other than luminal absorption contribute to the low availability of the Se in the skipjack meat.

Key Words selenium, glutathione peroxidase, bioavailability of selenium, selenium in skipjack, retention of selenium

Selenium (Se) is an essential trace element in animal nutrition (1, 2) and is an integral component of the enzyme glutathione peroxidase [EC 1.11.1.9, GSH-Px](3, 4). Since the strong suggestion of the Chinese Academy of Medical Sciences that a fatal cardiopathy in Chinese children (Keshan disease) may be related to a deficiency of Se (5, 6), great interest in Se in human nutrition has been aroused. In an early stage of our studies, we found that the total daily Se intake of Japanese adults was about 200 µg per capita(7). This value quantitatively meets the

1 ‹g "c@ O

Present address: * Department of Public Health, Kansai Medical University, Moriguchi, Osaka 570, Japan, ** Department of Agricultural Chemistry, Faculty of Agriculture, Kyoto Prefectural University, Sakyu-ku, Kyoto 606, Japan, and *** Research Institute for Food Science, Kyoto University, Uji, Kyoto 611, Japan
Recommended Dietary Allowances as laid out in 1980 by the Food and Nutrition Board (8). However, it has been established that Se in foods occurs in diverse chemical forms and has different bioavailability in preventing and curing Se deficiencies (9–12). In particular, Se in fish, which is one of the principal Se sources in the Japanese diet, has lesser bioavailability (13–16). Thus, evaluation of the nutritional efficiency\(^2\) of fish-Se is important in qualitative assessment of Se intake in Japan. In the present investigation, to appraise the nutritional efficiency of fish-Se, utilization of Se contained in two kinds of processed skipjack meat (boiled meat of skipjack\(^3\) and dried strip of skipjack\(^4\)) with reference to GSH-Px was compared with that of selenite-Se in rat liver.

**MATERIALS AND METHODS**

Boiled meat of skipjack and dried strip of skipjack were obtained from a local retail store in the district of Kyoto city and were ground in Centri Mill. The Se contents of the boiled meat and the dried strip were 1.99 µg/g and 2.47 µg/g, respectively.

Male Wistar rats, weighing 50 to 60 g, were housed in hanging wire-meshed cages in a humidity (60%)-temperature (22–24°C) controlled room with a 12-h light (6:00–18:00)-dark cycle. The rats were fed *ad libitum* for 2 weeks on a basal 20% casein diet deficient in Se. The basal diet contained: (in %) vitamin-free casein, 20; potato starch, 50; sucrose, 15; soybean oil, 8; salt mixture (Harper’s salt type B (19)), 4; vitamin mixture (obtained from Oriental Yeast Co., Tokyo (15)), 1; and cellulose powder, 2. The Se content of the basal diet was 0.046 µg/g diet. The rats were divided into 7 groups and, for an additional 8 days, were daily fed 12 g of the basal diet supplemented with Se at 11:00. Se was added as sodium selenite, boiled meat of skipjack or dried strip of skipjack at 0.04 or 0.08 µg Se/g diet. Deionized water was provided *ad libitum* during the entire experimental period. Feces and urine were collected at 10:00 on the 4th to 7th days after the beginning of the Se supplementation. At the end of experimental period, all the rats were killed by decapitation before noon and the livers were excised. An approximate 1 g portion of liver was homogenized in 9 volumes of cold saline. The homogenate was centrifuged at 105,000 \(\times g\) for 60 min and the soluble fraction thus obtained was used for GSH-Px assay. GSH-Px assay was carried out as described previously (10). Another 1 g

---

\(^2\) The word “nutritional efficiency” is used to mean quantitative bioavailability.

\(^3\) Boiled meat of skipjack is listed in Standard Tables of Food Composition in Japan (4th revised edition) under the name of “Namari” (item number 8-52) and is made by steaming skipjack meat (17).

\(^4\) Dried strip of skipjack is listed in the Tables under the name of “Katsuo-bushi” (item number 8-54) and is made as follows: Skipjack meat is boiled, smoked and dried. A mold (*Asp. glaucus*) is grown on the smoke-dried skipjack meat in order to remove fat and impart an aroma. Thereafter, dried strip of skipjack is finished by drying this processed skipjack meat in the sun (18).
portion of the liver and the daily feces and urine were digested in a mixture of nitric and perchloric acid, and Se in the digests was then determined fluorometrically (20). Protein in the liver was determined by the method of Miller (21).

Experimental data were tested using variance analysis; when the $F$-test was significant ($p<0.05$), comparisons were made using the Least Significant Difference test to determine which pairs of means were significantly different ($p<0.05$) (22).

RESULTS AND DISCUSSION

During the period of Se-supplementation, all the animals took the 12 g of experimental diets without leavings. In other words, the supplementation of selenite or the processed fish to the basal diet did not affect an appetite of the rodents.

In Table 1 are summarized the hepatic GSH-Px activity and Se content of the rats fed on the Se-supplemented diets for 8 days. The enzyme activity and the Se content were significantly raised by supplementation with 0.04 $\mu$g/g of Se in selenite or in the boiled meat but not in the dried strip. This indicates that the dried strip contains an unavailable form of Se. The dried strip of skipjack was made by a complicated process including treatment with a mold (17). It is likely that this unavailable Se has been formed by the mold during the food processing. Compared to the supplementation with 0.04 $\mu$g/g Se, the supplementation with 0.08 $\mu$g/g Se caused significantly higher elevation in the enzyme activity and the Se content. However, though a significant difference between the selenite-administered rats and the boiled meat-administered rats was not observed as regards the hepatic Se level,

<table>
<thead>
<tr>
<th>Supplement</th>
<th>Glutathione peroxidase activity (unit/mg protein)</th>
<th>Selenium content ((\mu)g/g liver)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No supplementation</td>
<td>0.145 $\pm$ 0.013$^a$</td>
<td>0.137 $\pm$ 0.006$^a$</td>
</tr>
<tr>
<td>+0.04 $\mu$g Se/g diet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium selenite</td>
<td>0.199 $\pm$ 0.005$^b$</td>
<td>0.181 $\pm$ 0.006$^b$</td>
</tr>
<tr>
<td>Skipjack, boiled meat</td>
<td>0.200 $\pm$ 0.024$^b$</td>
<td>0.171 $\pm$ 0.011$^b$</td>
</tr>
<tr>
<td>Skipjack, dried strip</td>
<td>0.129 $\pm$ 0.014$^a$</td>
<td>0.139 $\pm$ 0.006$^a$</td>
</tr>
<tr>
<td>+0.08 $\mu$g Se/g diet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium selenite</td>
<td>0.443 $\pm$ 0.029$^d$</td>
<td>0.214 $\pm$ 0.006$^c$</td>
</tr>
<tr>
<td>Skipjack, boiled meat</td>
<td>0.279 $\pm$ 0.029$^e$</td>
<td>0.220 $\pm$ 0.012$^e$</td>
</tr>
<tr>
<td>Skipjack, dried strip</td>
<td>0.302 $\pm$ 0.014$^c$</td>
<td>0.196 $\pm$ 0.006$^{be}$</td>
</tr>
</tbody>
</table>

Values are means $\pm$ SEM ($n=4$); values in the same column not sharing a common superscript differ significantly ($p<0.05$).

Vol. 30, No. 4, 1984
the elevation of the hepatic GSH-Px activity in the boiled meat-administered rats was only 45% of that in the selenite-administered rats. This result indicates that the unavailable Se exists not only in the dried strip but also in the boiled meat which was made by steaming skipjack meat.

Cantor et al. have reported that the nutritional efficiency of Se in fish (tuna and herring) is only 22 to 25% that of selenite for preventing exudative diathesis in chicks (13). Similarly, Douglass et al. have shown that the nutritional efficiency of Se is 54 to 58% greater from tuna as compared to selenite for induction of GSH-Px in rat liver and in rat erythrocytes (14). On the other hand, Gabrielsen and Opstvedt have found that Se in mackerel and capelin is less available than selenite but more available than Se in soybean and corn gluten for restoring GSH-Px activity in Se-depleted chicks (23). The present result described in Table 1 is not inconsistent with these investigations and leads to the conclusion that the nutritional efficiency of fish-Se is about 50% that of selenite using GSH-Px activity as an index.

In Table 2 are shown the daily fecal and urinary Se excretion of the rats fed on the diets supplemented with 0.08 μg/g Se for 8 days, and retention of the supplemented Se was calculated. The amounts of both fecal and urinary excretion of Se derived from the two kinds of processed skipjack meat was significantly higher than those derived from selenite, and consequently, the retention of the Se derived from the processed fish was significantly lower than that of selenite.

The higher fecal Se excretion in the rats fed the processed skipjack suggests that Se in the skipjack was difficult to absorb in the digestive tract. As described in the previous report (15), luminal absorption may be one of the important factors affecting the bioavailability of the Se in processed skipjack. However, higher urinary Se excretion was also observed in the rats fed on the skipjack-supplemented diets. This implies that unknown factor(s) other than luminal absorption contribute to the

Table 2. Fecal and urinary selenium excretion in rats fed on selenium-supplemented diets.
Feeding conditions are the same as described in Table 1. Feces and urine were collected on the 4th to 7th day after the beginning of Se-supplementation. Rats ingested 0.96 μg of the supplemented Se per day during the period of Se-supplementation. Retention was calculated as follows: 100 × \[0.96 - (\text{fecal Se} - 0.058) - (\text{urinary Se} - 0.057)] ÷ 0.96.

<table>
<thead>
<tr>
<th>Supplement</th>
<th>Fecal selenium (μg/day)</th>
<th>Urinary selenium (μg/day)</th>
<th>Retention (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No supplementation</td>
<td>0.058 ± 0.002a</td>
<td>0.057 ± 0.006a</td>
<td>—</td>
</tr>
<tr>
<td>+0.08 μg Se/g diet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium selenite</td>
<td>0.113 ± 0.006b</td>
<td>0.087 ± 0.004ab</td>
<td>91.2 ± 0.4b</td>
</tr>
<tr>
<td>Skipjack, boiled meat</td>
<td>0.254 ± 0.020c</td>
<td>0.118 ± 0.009be</td>
<td>73.3 ± 2.1a</td>
</tr>
<tr>
<td>Skipjack, dried strip</td>
<td>0.288 ± 0.014c</td>
<td>0.135 ± 0.015c</td>
<td>67.9 ± 2.1a</td>
</tr>
</tbody>
</table>

Values are means ± SEM (n = 4); means in the same column not sharing a common superscript differ significantly (p < 0.05).

low availability of Se in processed skipjack meat.

It has been found that the nutritional efficiency of Se in tuna meat is increased to an almost equal extent as selenite when tuna is digested in a mixture of nitric and perchloric acid (13). A chemical form of Se in skipjack meat is considered to be the most important factor for the low availability. Boiled meat of skipjack has been made by a simple process (17), and it has been shown that food processing does not appear to affect Se availability in tuna (16). Accordingly, the unavailable form of Se is surely present in native skipjack meat. The presence of a low molecular weight Se compound in skipjack meat (24) and of a lipophilic Se compound in some kinds of fish (25) has been reported. However, the relation between these non-protein Se compounds and the low availability of fish-Se has not been clarified. Further investigation is needed for explaining the low availability of Se in fish.

REFERENCES


