Radical-Scavenging Activities of Fish and Fishery Products

Mosammat Nazmanara Khanum,1 Tomoko Yamaguchi,1 Sachiko Hiroshi,2 Fumi Muraoka,2 Hitoshi Takamura2 and Teruyoshi Matoba2,*

1Graduate School of Human Culture, 2Department of Food Science and Nutrition, Nara Women’s University, Kitaauya-Nishimachi, Nara 630-8506, Japan

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A total of 45 Japanese and Bangladeshi water fish and fishery products were investigated for radical-scavenging activity using a 1,1-diphenyl-2-picrylhydrazyl- HPLC method. Among the 35 Japanese fish and fishery products (37 items), cutlassfish showed the highest activity (565.7 mg Trolox eq/100 g) and seaweed showed the lowest (249 mg Trolox eq/100 g) on a fresh weight basis. Dried bonito, crab (abdomen), Pacific saury, horse mackerel, skipjack, halibear, tuna, sand borer, Pacific mackerel, barracuda and anglerfish showed activities of over 100 mg Trolox eq/100 g. The radical-scavenging activities of 10 Bangladeshi fish and fishery products varied from 37.9 to 202.1 mg Trolox eq/100 g. The stronger activity of cutlassfish was attributed to its silver colored skin. The active component was suggested to be uric acid, the metabolic end-product of guanine.

Keywords: radical-scavenging activity, fish, fishery product, cutlassfish, uric acid

Free radicals generated from various phenomena such as environmental pollution, ultraviolet radiation, radiolysis and several normal metabolic processes in vivo including cellular respiration can cause serious oxidative damage to living cells and tissues. Reactive oxygen species rapidly interact with lipids, proteins and DNA molecules to induce membrane damage, denaturation of proteins, inactivation of enzymes, breakage of strand and base modification of DNA (Cross et al., 1987). The consequences of such interactions are involved in the development of various disease states such as atherosclerosis, cardiovascular disease, cancer and various chronic diseases (Ames, 1989; Tappel, 1991).

Living tissues protect themselves from the oxidative damages of free radicals by not only the quenching and scavenging actions of such enzymes as superoxide dismutase, catalase, peroxidase, but also by low molecular weight compounds like tocopherol, phenolic compounds, ascorbic acid, etc. (Hodnick et al., 1986; Niki, 1991). Besides endogenous defenses, consumption of dietary antioxidants play an important role in protecting against free radicals (Rimm et al., 1993; Willett, 1994). Recently, naturally occurring antioxidants such as flavonoids and the related phenolics, which are present in foods and other biological materials, have been attracting the considerable interest of investigators. A correlation between the increased dietary levels of phenolic compounds and reduced coronary heart disease has been suggested, which may explain the protective effect of vegetable-rich diets on coronary heart disease (Aruoma et al., 1993; Hertog et al., 1993; Hertog, 1994). It is important to note that most of the investigations regarding the inhibitory effect of food components on the oxidative damages of biological membranes have been devoted to the foods of plant origin. Much attention has been paid to the free radical-scavenging activity of fruits, vegetables, teas and various types of beverages (Wang et al., 1996; Caio et al., 1996). Fish is an integral part of the human diet. Nearly 20 years ago, Bang et al. (1980) first suggested that the low mortality rate from coronary heart disease among Greenland Eskimos compared with Danes, may be due to their high consumption of seafood. Since that time, many other investigators have suggested that fish consumption has a protective effect against cardiovascular diseases (Norell et al., 1986; Shekelle & Stampler, 1993; Kromhout et al., 1985, 1995). However, the controversy surrounding the association between fish consumption and coronary heart disease arose from a few negative results (Ascherio et al., 1995; Morris et al., 1995) and inconsistent findings from several studies (Stocovick et al., 1995; Davlgius et al., 1997). Recently, Albert et al. (1998) reported that consumption of fish at least once a week can cut the risk of sudden cardiac death in half. An inverse relationship between the consumption of n-3 polyunsaturated fatty acids and sudden cardiac death has also been reported (Norell et al., 1986). The n-3 fatty acids are important components of all cell membranes, which have been demonstrated to have anti-inflammatory effects, and may have beneficial effects on ulcerative colitis, rheumatoid, arthritis, and asthma (Simopoulos, 1991; Broughton et al., 1997). Epidemiological studies suggest that fish consumption and n-3 fatty acids may have beneficial effects on certain types of cancers (Mishina et al., 1985; Willett et al., 1990). However, the protective effects of other constituents present in fish have yet to be explored. Since cardiovascular disease (Kushi et al., 1995), cancer (Hertog et al., 1995), inflammation (Middleton & Kandaswami, 1992) etc. are considered as free radical-induced diseases, antioxidants which are capable of neutralizing or scavenging free radicals may therefore be of central

*To whom correspondence should be addressed.

Abbreviations: Tris, tris(hydroxymethyl)aminomethane; AMP, adenosine 5'-monophosphate; GMP, guanosine 5'-monophosphate; IMP, inosine 5'-monophosphate; DPPH, 1,1-diphenyl-2-picrylhydrazyl.
importance in the prevention of these diseases.

Therefore, it is very important to assess the antioxidant
activity of fish and fishery products to obtain a better
understanding of their protective effect against free radical-
induced diseases. In this study, the radical scavenging activi-
ties of 45 fish and fishery products (including a few processed
fish products) were investigated. We focused on 35 Japanese
fish and fishery products commonly consumed by Japanese
people and 10 Bangladeshi fish and fishery products com-
monly consumed by Bangladesh. We have determined the free radical-scavenging activity as a measure of the
antioxidant properties of various fish and fishery products.

Materials and Methods

Materials  Japanese fish and fishery product samples
were purchased from local supermarkets in Nara in either
fresh, boiled, or frozen condition. The samples were collected
regularly and studied as soon as possible. Bangladeshi fish
were purchased in frozen condition from a Bangladeshi shop
(Shonali Trade International) in Tokyo. The fish were stored
at −50°C until evaluated.

Tris(hydroxymethylamino)methane (Tris) was obtained
from Aldrich Chemical Co. (Milwaukee, WI). Adenosine
5′-monophosphate (AMP), guanosine 5′-monophosphate
(GMP), inosine 5′-monophosphate (IMP), 1,1-diphenyl-2-
pyrlyhdrazyl (DPPH), and uricase (4.95 U/mg) were
purchased from Nacalai Tesque Inc. (Kyoto). Trolox (6-
hydroxy-2,5,7,8-tetramethylchroman-2-carboxonic acid), hypox-
anthine, guanosine, guanine, and ethanol and methanol of
HPLC-grade were obtained from Wako Pure Chemical
Industries (Osaka). Distilled water purified by Milli-Q Labo
(Millipore, Tokyo) was used throughout the experiment.

Determination of moisture content  Before measuring
the radical-scavenging activity, moisture content of all the
samples was determined according to the standard method of

Preparation of sample extract  To obtain a water-
soluble extract, 10 g of an edible part, which includes muscle
and skin, was excised from each fish and homogenized with
a small amount of water by a homogenizer (Nissei AM-8
homogenizer). The resulting homogenate was diluted with
ultra pure water and the volume was adjusted to 50 ml. The
obtained solution was then centrifuged at 3000×g for 20 min
at 4°C and the supernatant was further centrifuged at 15,000×
g for 20 min at 4°C. The supernatant finally obtained was
filtered through a micro-filter (Cosmonice W, 0.45 μm, 13
mm i.d.) and the filtrate was used as the water-soluble extract
of the sample.

To obtain an ethanol extract, 30 ml of ethanol was added
to the residual sample after water extraction, and shaken for
1 h with a mechanical shaker. The resulting suspension was
then centrifuged at 3000×g for 20 min at 4°C. The super-
natant obtained was designated as extract 1. Another 20 ml of
ethanol was added to the remaining residual sample, and
extracted again for 1 h with a mechanical shaker. The
resulting suspension was then centrifuged at 15,000×g for 20
min at 4°C, and the supernatant obtained was designated as
extract 2. Extracts 1 and 2 were then combined and filtered
through a micro-filter. The filtrate was used as the ethanol-
soluble extract of the sample.

Measurement of the radical-scavenging activity  Radical-
scavenging activities of water and ethanol-soluble extracts
were assayed according to the DPPH-HPLC method of
Yamaguchi et al. (1998a). The sample extract (200 μl) was
incubated in 0.5 mM DPPH-methanol solution (1 ml) and
100 mM Tris-HCl buffer (800 μl), pH 7.4 for 20 min at room
temperature in the dark. The reaction mixture was then
subjected to a reversed phase HPLC analysis. The analysis
was carried out using a TSK-GEL Octyl-80 TSK (4.6×150 mm)
column equipped with a Shimadzu SPD-10AV UV-VIS
detector at 517 nm at room temperature. Methanol/water (70:
30, v/v) was used as the mobile phase at a flow rate of 1 ml/
min. The Tris-HCl buffer (1 ml) incubated in the DPPH
solution (1 ml) was analyzed as a control. Trolox, a stable
antioxidant, was used as a standard and 200 μl of ethanol-
Trolox solution (50 μM) was assayed similarly during each
run. Radical-scavenging activity was calculated from the
following equation and expressed as mg Trolox eq/100 g of
the edible part:

mg Trolox eq = (A - B) / (A - C) × 5 × 2/1000 × D / 0.2
× 100 / 10 × 250.29 / 1000

where A: peak area of control, B: peak area of sample, C:
peak area of Trolox, D: dilution factor, 250.29: molecular
weight of Trolox

The combined activities of the water-soluble and ethanol-
soluble extracts were used as the total activity of an individual
sample. All the data are presented as the mean value of three
determinations.

Effect of uricase enzyme on the radical-scavenging
activity of cutlassfish  The water soluble extract of cutlass-
fish (200 μl) was incubated in 100 μl uricase solution (0.2
mg/ml of 50 mM phosphate buffer, pH 7.8) for a period of 1,
10, 20, 40 and 60 min at 20°C. An aliquot of the incubated
sample (200 μl) was analyzed to determine the radical-
scavenging activity. The phosphate buffer solution (100 μl)
was used as a blank in the absence of the enzyme solution.

Results and Discussion

The identities of the different fish and fishery product
specimens used in this study are presented in Table 1.

Radical-scavenging activities of Japanese fish and
fishery products  Table 2 shows the radical-scavenging
activities of the 35 Japanese samples. There are 37 items in
Table 2, since young and adult yellowtail were regarded as
different items and abdomen and legs of crab were separately
analyzed. The activities of the various fish and fishery
products varied from 24.9 to 565.7 mg Trolox eq/100 g of
edible part on a fresh weight basis. The highest activity was
observed in cutlassfish and the lowest was found in seaweed.
Dried bonito, red crab (abdomen), Pacific saury, horse
mackerel, skipjack, halibut, tuna, sand borer, Pacific
mackerel, barracuda and angler fish showed activities of over
100 mg Trolox eq/100 g of the edible part (fresh weight
basis). Others showed activities below 100 mg Trolox eq/100
g of the edible part on a fresh weight basis. Among the raw
fishes, kelp bass showed the lowest activity (36.0 mg Trolox
eq/100 g of edible part). The radical-scavenging activity of
Table 1. Identities of different specimens used in the investigation.

<table>
<thead>
<tr>
<th>Japanese name</th>
<th>English name</th>
<th>Scientific name</th>
<th>Bengali name</th>
<th>English name</th>
<th>Scientific name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ajii</td>
<td>Horse mackerel</td>
<td>Trachurus japonicus</td>
<td>Aor</td>
<td>Riverine catfish (1)</td>
<td>Mystus aor</td>
</tr>
<tr>
<td>Ankoj</td>
<td>Anglerfish</td>
<td>Lepidotomus seirigenus</td>
<td>Besi</td>
<td>Freshwater shark</td>
<td>Wallago attu</td>
</tr>
<tr>
<td>Asara</td>
<td>Short-necked clam</td>
<td>Pogonias japonica</td>
<td>Chital</td>
<td>Featherback</td>
<td>Notopterus chitala</td>
</tr>
<tr>
<td>Ebio (Tabaebi)</td>
<td>Shrimp</td>
<td>Penaeus orientalis</td>
<td>Ich</td>
<td>River shad</td>
<td>Hilbus ichu</td>
</tr>
<tr>
<td>Hamachi, Buri</td>
<td>Yellowtail (young, adult)</td>
<td>Seriola quinqueradiata</td>
<td>Pangaj</td>
<td>Riverine catfish (2)</td>
<td>Pangasias pangasias</td>
</tr>
<tr>
<td>Hamaguri</td>
<td>Hard Clam</td>
<td>Meretrix Jusorita</td>
<td>Pul</td>
<td>Indian minor carp</td>
<td>Barbus stigma</td>
</tr>
<tr>
<td>Hamo*</td>
<td>Pike conger</td>
<td>Muraenexox cinereus</td>
<td>Rui</td>
<td>Indian common carp</td>
<td>Labeo rohitai</td>
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<td>Hime</td>
<td>Japanese flounder</td>
<td>Paralichthys olivaceus</td>
<td>Sharputi</td>
<td>Indian major carp</td>
<td>Burbus sarana</td>
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<td>Hotategai</td>
<td>Scallop</td>
<td>Parmitopsetincthus yessoensis</td>
<td>Shol</td>
<td>Snake headed fish</td>
<td>Chana striata</td>
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<tr>
<td>Ika (Samunika)</td>
<td>Squid</td>
<td>Ommastrephes soxi pacificus</td>
<td>Chapa</td>
<td>Semi-fermented Indian</td>
<td>minor carp</td>
</tr>
<tr>
<td>Iwashi</td>
<td>Japanese pilchard</td>
<td>Sardimorphus melanostoma</td>
<td>Kaki*</td>
<td>Crab</td>
<td>Chionooeces japonicus</td>
</tr>
<tr>
<td>Kani</td>
<td>Oyster</td>
<td>Sphyranoa schegeli</td>
<td>Kamasu</td>
<td>Barracuda</td>
<td>Chionooeces japonicus</td>
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<tr>
<td>Kani (Benitsawagani)</td>
<td>Flatfish</td>
<td>Limanda herzensteli</td>
<td>Kusu*</td>
<td>Kelp bass</td>
<td>Stereoldiastichanyi</td>
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<tr>
<td>Katsu*</td>
<td>Skipjack</td>
<td>Katsuowonensus pelamis</td>
<td>Maguro*</td>
<td>Tuna</td>
<td>Thunnus thynnus</td>
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<td>Kawayagi</td>
<td>Filefish</td>
<td>Stephanolepis cirrhifer</td>
<td>Managastu*</td>
<td>Butterfish</td>
<td>Pampus argentius</td>
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<td>Katsu*</td>
<td>Sandborer</td>
<td>Sillago japonica</td>
<td>Saba</td>
<td>Pacific mackerel</td>
<td>Scomerb Japunios</td>
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<tr>
<td>Kusu*</td>
<td>Kelp bass</td>
<td>Stereoldiastichanyi</td>
<td>Sake (Shirocake)*</td>
<td>Salmon</td>
<td>Oncorhynchus keta</td>
</tr>
<tr>
<td>Maguro*</td>
<td>Tuna</td>
<td>Thunnus thynnus</td>
<td>Samma</td>
<td>Pacific saury</td>
<td>Cololabas saura</td>
</tr>
<tr>
<td>Nigama*</td>
<td>Spanish mackerel</td>
<td>Scrombomorus niphonius</td>
<td>Savara*</td>
<td>Spanish saury</td>
<td>Cololabas saura</td>
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<tr>
<td>Saba</td>
<td>Pacific mackerel</td>
<td>Scrombomorus niphonius</td>
<td>Sayori*</td>
<td>Halfbeak</td>
<td>Hemirhamps sajori</td>
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<tr>
<td>Sake</td>
<td>Pacific mackerel</td>
<td>Scrombomorus niphonius</td>
<td>Tati (Mادي)</td>
<td>Sea bream</td>
<td>Chrysophrys majus</td>
</tr>
<tr>
<td>Shioi*</td>
<td>Cutlassfish</td>
<td>Trichiurus lepturus</td>
<td>Tako (Madako)**</td>
<td>Octopus</td>
<td>Octopus vulgare</td>
</tr>
<tr>
<td>Tai (Mادي)</td>
<td>Sea bream</td>
<td>Trichiurus lepturus</td>
<td>Tara</td>
<td>Atlantic cod</td>
<td>Gadus macrocephalus</td>
</tr>
<tr>
<td>Wakame*</td>
<td>Seaweed</td>
<td>Underia pinnatifida</td>
<td>Chirunjenakao*</td>
<td>Small dried sardine</td>
<td>Spatula sox</td>
</tr>
<tr>
<td>Kasuobushi*</td>
<td>Dried bonito</td>
<td>Spatula sox</td>
<td>Nibishi*</td>
<td>Tiny dried sardine</td>
<td>Chirunjenakao*</td>
</tr>
<tr>
<td>Suru*</td>
<td>Dried squid</td>
<td>Spatula sox</td>
<td>Aot</td>
<td>Riverine catfish</td>
<td>Mystus aor</td>
</tr>
</tbody>
</table>

Japanese fish samples were purchased in a raw condition unless otherwise specified. Bengali fish samples were purchased in a frozen condition. Edible parts included muscle and skin and excluding head, gut, and bone were used for analysis unless otherwise specified. *Frozen, **Boiled, 1Whole body excluding shell, 2Whole body excluding head and shell, 3Muscle only, 4Whole.

mollusk ranged from 36.4 (short-necked clam) to 49.9 (hard clam) mg Trolox eq/100 g on a fresh weight basis. Among the four processed products, dried bonito showed the highest activity (182.3 mg Trolox eq/100 g) followed by dried small sardine (56.2 mg Trolox eq/100 g) and tiny sardine (48.6 mg Trolox eq/100 g). On a moisture-free basis, the order of activity for the investigated fish species was similar to that obtained on a fresh weight basis (Table 2), which indicated that these species possess species-specific activities.

Radical-scavenging activities of Bangladesh fish and fishery products Table 3 shows the radical-scavenging activities of 10 fish and fishery products in Bangladesh. The activity of raw Bangladesh fish varied from 84.7 to 135.3 mg Trolox eq/100 g on a fresh weight basis. The highest activity was observed in featherback (135.3 mg Trolox eq/100 g) and the lowest value was found in riverine catfish (37.9 mg Trolox eq/100 g). The only processed fish (chapa shutki) prepared by the semi-fermentation of Indian minor carp showed an activity of 202.1 mg Trolox eq/100 g of the edible part. It should be noted that the Bangladesh fish in this study were purchased in a frozen condition, and therefore the effect of freezing and thawing on their activities cannot be excluded. However, the radical-scavenging activities of all the Bangladesh fish were considerably high and the values were comparable to those of Japanese fish.

Groupwise radical-scavenging activities of investigated fish species All the fish species and invertebrates investigated in this study were divided into four categories: white muscle fish, red muscle fish, crustacean (crabs and shrimps), and mollusks. Figure 1 shows the radical-scavenging activities of these four categories. White muscle fish showed various levels of radical-scavenging activity, with the activity of cutlassfish remarkably higher than others. Red muscle fish and crustaceans (shrimps and crabs) also exhibited a higher level of radical-scavenging activity, while mollusks showed the lowest level.

Comparison of the radical-scavenging activities of fish and vegetables Vegetables are well known to contain compounds that protect against various diseases (Ames, 1983; Doll, 1990; Ascherio et al., 1992). These compounds are
ascorbic acid, tocopherol, flavonoids, etc., which have been found to possess antioxidant and free radical-scavenging activity in foods (Bors & Saran, 1987; Hertog et al., 1993; Mehra et al., 1995; Cao et al., 1996). Cabbage and Chinese cabbage have been reported to show antioxidant activity against hydroxyl (OH·) and peroxyl (ROO·) radicals (Cao et al., 1996). These vegetables also showed a high activity (75.0 and 25.0 mg Trolox eq/100 g, respectively, on a fresh weight basis) against the DPPH-radical (Yamaguchi et al., 1998b). However, almost all the fish species in this study exhibited higher activity (Tables 1 and 2) than those of the two vegetables.

The radical-scavenging activity of cutlassfish. To determine the effect of freshness on the radical-scavenging activity, cutlassfish was purchased from a local supermarket in Nara and two department stores in Nara (department store A) and Osaka (department store B), and analyzed accordingly. Two samples purchased from the supermarket and department store A were frozen and sliced while the other fish collected from department store B was kept fresh and intact. The activities of the three samples varied widely (Table 4). The

![Fig. 1. Groupwise radical scavenging activity of investigated fish species. Total activity on a fresh weight basis was used for groupwise classification.](image)

Fig. 1. Groupwise radical scavenging activity of investigated fish species. Total activity on a fresh weight basis was used for groupwise classification.

Table 3. Radical scavenging activity of Bangladesh fish.

<table>
<thead>
<tr>
<th>Item</th>
<th>Radical scavenging activity (mg Trolox eq/100 g)</th>
<th>Fresh weight basis</th>
<th>Dry weight basis</th>
<th>Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water extract</td>
<td>Ethanol extract</td>
<td>Total</td>
<td>Water extract</td>
<td>Ethanol extract</td>
</tr>
<tr>
<td>Semi-fermented carp</td>
<td>118.2</td>
<td>83.9</td>
<td>202.1</td>
<td>118.2</td>
<td>83.9</td>
</tr>
<tr>
<td>Indian minor carp</td>
<td>122.7</td>
<td>12.6</td>
<td>135.3</td>
<td>122.7</td>
<td>12.6</td>
</tr>
<tr>
<td>Featherback</td>
<td>108.5</td>
<td>15.3</td>
<td>123.8</td>
<td>108.5</td>
<td>15.3</td>
</tr>
<tr>
<td>Indian common carp</td>
<td>64.4</td>
<td>43.9</td>
<td>108.3</td>
<td>64.4</td>
<td>43.9</td>
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<tr>
<td>Riverine catfish (1)</td>
<td>81.3</td>
<td>23.4</td>
<td>104.7</td>
<td>81.3</td>
<td>23.4</td>
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<tr>
<td>Indian major carp</td>
<td>72.9</td>
<td>14.4</td>
<td>87.3</td>
<td>72.9</td>
<td>14.4</td>
</tr>
<tr>
<td>Indian minor carp</td>
<td>71.5</td>
<td>13.2</td>
<td>84.7</td>
<td>71.5</td>
<td>13.2</td>
</tr>
<tr>
<td>Snake headed fish</td>
<td>59.2</td>
<td>24.7</td>
<td>83.8</td>
<td>59.2</td>
<td>24.7</td>
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<tr>
<td>Fresh water shark</td>
<td>46.7</td>
<td>12.8</td>
<td>59.5</td>
<td>46.7</td>
<td>12.8</td>
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<tr>
<td>Riverine catfish (2)</td>
<td>27.6</td>
<td>10.3</td>
<td>37.9</td>
<td>27.6</td>
<td>10.3</td>
</tr>
</tbody>
</table>

The data is presented on a fresh weight basis.

![Fig. 2. Different parts of cutlassfish. 1, head; 2, back; 3, middle; 4, abdomen; 5, tail.](image)

Fig. 2. Different parts of cutlassfish. 1, head; 2, back; 3, middle; 4, abdomen; 5, tail.
sample purchased from the supermarket had the highest activity (565.7 mg Trolox eq/100 g of fresh sample), while those purchased from department stores A and B showed activities of 267.1 and 204.0 mg Trolox eq/100 g, respectively. These variations among the different samples may be related to differences in their freshness. It is reasonable to assume that the fish collected from the two department stores were fresher than that from the supermarket. Therefore, the result shown in Table 4 suggested that fresh cutlassfish has a lower radical-scavenging activity than the less fresh fish. However, the effects of the season of purchase or other factors cannot be excluded.

Since the radical-scavenging activity of cutlassfish was considerably higher than the activities of other fish species, a detailed study was made of the activity of this fish. A fresh fish was obtained from a department store and the activity of the edible part of the whole body was determined. The body was then divided into five regions: head, back, middle, abdomen and tail (Fig. 2), and a regional determination of the activity was performed on a fresh weight basis (Table 5). The activity of the tail region was the highest (253.2 mg Trolox eq/100 g) followed by the abdomen (217.2 mg Trolox eq/100 g), head (190.6 mg Trolox eq/100 g), back (184.7 mg Trolox eq/100 g) and middle region (158.7 mg Trolox eq/100 g). The activity of the skin region was very high as shown in Table 6. Therefore, the variation among the different parts seemed to arise from the percentage of the skin in the samples. Furthermore, samples closer to skin showed comparatively higher activities (Table 5). In addition, the muscle in the tail was very thin, and therefore the percentage of skin in the sample of the tail region was naturally higher than those in other parts of the fish.

The results shown in Table 5 indicated that the silver colored skin of this fish might contribute to its higher level of radical-scavenging activity. To test this hypothesis, the middle part of a fresh fish from a department store was separated into muscle and skin, and the activities of these two portions were compared with that of the whole fish sample (Table 6). A halfbeak which is very similar to the cutlassfish with respect to its tail color, was also analyzed and compared with the cutlassfish (Table 6). However, in the halfbeak, the variation among the different portions was not as prominent as was observed in the cutlassfish. The activity of cutlassfish skin, however, was extremely high compared with those of the other parts.

The skin of cutlassfish is covered with a silver color pigment known as guanine. This compound is used to shine artificial pearls. It has been reported that loss of this silver color pigment caused rapid deterioration in the freshness of the cutlassfish (Okabe, 1995). Therefore, the radical-scavenging activity of this fish was assumed to be related to the persistence of guanine on its skin.

The radical-scavenging activity of guanine and related compounds

<table>
<thead>
<tr>
<th>Item</th>
<th>Radial scavenging activity (mg Trolox eq/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water extract</td>
</tr>
<tr>
<td>Head</td>
<td>149.8</td>
</tr>
<tr>
<td>Back</td>
<td>151.1</td>
</tr>
<tr>
<td>Middle</td>
<td>122.6</td>
</tr>
<tr>
<td>Abdomen</td>
<td>176.8</td>
</tr>
<tr>
<td>Tail</td>
<td>212.9</td>
</tr>
</tbody>
</table>

The data is presented on a fresh weight basis.

Table 6. Comparative radical scavenging activity of cutlassfish and halfbeak.

<table>
<thead>
<tr>
<th>Item</th>
<th>Radial scavenging activity (mg Trolox eq/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whole fish</td>
</tr>
<tr>
<td>Cutlassfish</td>
<td>320.7</td>
</tr>
<tr>
<td>Halfbeak</td>
<td>171.4</td>
</tr>
</tbody>
</table>

The data is presented on a fresh weight basis. Only the activity of water soluble extract has been used.
as that of Trolox (a stable antioxidant). This result suggested that uric acid contributes to the radical-scavenging activity of cutlassfish.

**Effect of uricase on the activity of cutlassfish**

In animals other than man and the anthropoid apes, uric acid is further degraded to allantoin (Mazur & Harrow, 1971). This compound did not show any radical-scavenging activity (data not presented). Uricase is responsible for the oxidative degradation of uric acid to allantoin. To determine the effect of uricase on the activity of cutlassfish, the water-soluble extract of a fresh fish was incubated with the enzyme for periods of 1, 10, 20, 40, and 60 min at room temperature and the activities were assayed. The activity decreased with increasing incubation time (Fig. 3). A 7% reduction was observed when the sample was incubated with the enzyme for 1 min, while 55% reduction was found in the case of 60-min incubation. This result indicated that the radical-scavenging activity of cutlassfish was reduced gradually with the degradation of uric acid to allantoin. However, the content of guanine or uric acid was not determined in the present investigation, therefore, the contribution of uric acid to the total activity cannot be quantified. Further studies are in progress.

Prevention of free radical-induced diseases through the consumption of foods having antioxidant activity is a great concern to diverse fields of research, particularly to food nutrition. Diets high in fruits and vegetables are associated with lower incidence of various of these diseases, especially coronary diseases and cancers. This study showed that fish also possessed considerable free radical-scavenging activities. Therefore, a balanced diet containing enough fish, vegetables and fruits could be the most effective in protecting the body from various oxidative stressors.

**References**


