Effect of catch areas on chemical composition and heavy metals concentration of chub mackerel (*Scomber japonicus*)

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Abstract: The chemical composition and heavy metals content of chub mackerel caught at two different areas were investigated. Jeju mackerel (J-mackerel) showed a higher percentage of crude fat and lower moisture, crude protein, and ash compared to Pusan mackerel (P-mackerel) ($p < 0.05$). The fatty acid composition of J-mackerel showed higher levels of 14:0, 18:1n-7, 20:1n-9, 18:3n-3, and 20:5n-3 compared to P-mackerel ($p < 0.05$). Total amount of amino acid in J- mackerel was 177.35 ± 3.63 mg/g and that in P-mackerel was 213.05 ± 9.06 mg/g. There were significant differences in aspartic acid, glutamic acid, alanine, and leucine ($p < 0.01$). P-mackerel had significantly higher contents of Cd, Cr, Cu, Hg, and Zn compared to J-mackerel ($p < 0.05$). The heavy metals contents of both P- and J-mackerel were less than maximum levels in the Korea Food Code.

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1. Introduction

Fish is a globally important food resource and especially oily fish is rich in very long-chain n-3 polyunsaturated fatty acids such as eicosapentaenoic acid (20:5n-3, EPA) and docosahexaenoic acid (22:6n-3, DHA). Chub mackerel (*Scomber japonicus*) is considered traditionally to be "blue" oily fish and is essentially a near coastal species, with a vertical distribution ranging at depths between 0 and 300 m. Adults carry out reproductive migrations from deeper shelf-break waters to shallow coastal areas [1]. World captures of chub mackerel reached 3.4 million ton in 1978; since then, they have been decreasing to a minimum of 1.2 million ton in 1991 but, in recent years, have slightly recovered up to 1.9 million ton in 2008 [2]. The production of chub mackerel reached 0.18 million ton, making up 14.3% of the coastal and offshore capture. The highest production area of chub mackerel in Korea is Pusan with about 0.16 million ton in 2009, followed by Jeju Island [3]. It is recommended that the consumption of 2 servings per week of fish high in EPA and DHA is associated with a reduced risk of both sudden death and death from coronary artery disease in adults [4].

Heavy metals have been recognized as the most important pollutants in the coastal sea. The major sources of pollution include effluent discharges by industries, atmospheric depositions of pollutants, and occasional accidental spills of toxic chemicals. It has been known that a diet high in fish was linked to beneficial outcomes for an increasing number of diseases and medical conditions [5]. However, fish also contains heavy metals such as Hg, Pb and Cd and especially Hg is a well-known and widespread environmental neurotoxicant [6]. Fish like chub mackerel being a favorite food of people in Korea, the high consumption of it could lead to chronic disorders if this fish would contain high concentrations of these heavy metals. Therefore, it is important to determine heavy metal concentrations in fish muscle. For this reason, the aim of this study was to determine total concentrations of As, Cd, Cr, Cu, Hg, Ni, Pb and Zn, and chemical composition as well in muscle of chub mackerel caught at two different regions because chub mackerel from Pusan and Jeju are commonly caught and consumed in Korea.

2. Material and Methods

2.1. Samples

Fresh chub mackerel were purchased in the Jagalchi fish market of Korea. Catch information was confirmed by the Suhyup which is a fish vendor. Chub mackerels were caught at offshore from Jeju (126°0'–126°5'E, 33°0'–33°5'N, J-mackerel) and Pusan (130°0'–130°5'E, 34°5'–35°0'N, P-mackerel) of Korea. J- and P-mackerel were sampled from February 2011. The sizes in the experiments were as follows: total length 34.3 ± 0.4 cm and total weight 375.0 ± 17.2 g for J-mackerel; total length 33.0 ± 0.7 cm and total weight 332.5 ± 24.7 g for P-mackerel. Mackerel were gutted, eviscerated, and filleted on two sides. Mackerel fillets were cut into small pieces, homogenized in a homogenizer (HMF-985, Hanil, Korea), packed separately in polyethylene packs and stored at –20°C until used analyses of chemical compositions and metals content.

2.2. Analysis of proximate composition

Moisture content was determined by drying sample in an oven at 105^{o}C until constant weight was obtained. Crude fat was determined using the Soxhlet extraction method. Crude protein content was determined by the Kjeldahl nitrogen using a 6.25 conversion factor. Ash content was determined by incineration in a muffle furnace at 550^{o}C for 24 h [7].

2.3. Measurement of fatty acid composition

Sample lipids were extracted with chloroform-methanol (2:1 v/v) according to the method of Bligh and Dyer [8]. Fatty acid methyl esters were prepared with 14% BF_3/methanol and analyzed with a gas chromatograph (CP-3380, Varian, USA) using a flame-ionization detector, as described previously [9].

2.4. Analysis of amino acid

The sample was hydrolysed with 6 N HCl at 110^{o}C for 24 h. The hydrolysed sample was dried in a rotary vacuum evaporator. The residue was then dissolved in distilled water and filtered through a 0.2 µm glass filter. The amino acid profiles of an aliquot were determined using an amino acid analyzer (L-8800, Hitachi, Japan).

2.5. Measurement of metals content

Mercury content was measured using a direct mercury analyzer (Milestone Sorisole, Bergamo and Italy) without chemical pre-treatment. The other metals (As, Cd, Cr, Cu, Ni, Pb, and Zn) were ashed in a muffle furnace at 500^{o}C for 24 h. Ashes were dissolved with the smallest amount of nitric acid and the resulting solution brought up to 50 mL with twice distilled water. The other metals were determined using inductively coupled plasma (Optima 3000DV, Perkin-Elmer, USA).

2.6. Statistical analysis

Data were presented as mean ± standard deviation (SD). Significant differences between J- and P-mackerel were tested using the independent samples *t*-test (SPSS Inc., Chicago, IL, USA) and $p < 0.05$ was considered significant.

3. Results and Discussion

3.1. Proximate composition

The average contents of moisture, crude fat, crude protein, and ash in J-mackerel were 61.06 ± 3.53, 19.58 ± 3.19, 18.83 ± 0.39, and 1.31 ± 0.14%, respectively; those in P-mackerel were 67.71 ± 0.82, 9.04 ± 1.66, 21.90 ± 0.58, and 1.77 ± 0.12%, respectively. There were significant differences in crude fat and ash between J- and P-mackerel ($p < 0.05$). J-mackerel showed a higher percentage of crude fat and lower moisture, crude protein, and ash compared to P-mackerel. The results obtained confirmed a reverse correlation between moisture and crude fat percentages. In generally, fish shows a negative correlation between muscle lipid content and muscle texture [10, 11]. Chub mackerel from the Bungo Channel of Japan had tougher muscle than that from the Kumanonada Sea, and the difference in muscle texture was speculated to be due to the difference in exercise intensity between these two sea areas [12]. Osako et al. [13] found that the crude lipid content of horse mackerel caught offshore from Tsushima of Japan was higher than that of Nagasaki. The reason for this could be that there are many eddies and upwelling streams offshore from Tsushima that create ocean currents.

Table 1. Comparison of fatty acid composition (area%) of J-mackerel and P-mackerel.

Composition[1]	J-Mackerel	P-Mackerel
14:0	3.97 ± 0.51[2]	2.79 ± 0.14*
16:0	21.74 ± 0.61	20.87 ± 1.14
18:0	6.45 ± 0.34	7.48 ± 0.29*
20:0	0.16 ± 0.16	0.83 ± 0.38
22:0	2.27 ± 0.53	1.51 ± 0.72
Total SFA	34.59 ± 0.41	33.47 ± 0.18*
16:1n–7	4.41 ± 0.67	3.64 ± 0.03
18:1n–9	14.54 ± 2.00	17.70 ± 0.66
18:1n–7	3.68 ± 0.29	3.00 ± 0.15*
20:1n–9	2.27 ± 0.16	1.92 ± 0.07*
22:1n–9	0.15 ± 0.15	0.33 ± 0.01
Total MUFA	25.04 ± 2.95	26.59 ± 0.68
18:2n–6	2.22 ± 0.02	ND
18:3n–3	1.82 ± 0.12	0.75 ± 0.06**
20:4n–6	1.80 ± 0.00	1.58 ± 1.23
20:5n–3	9.54 ± 0.28	7.71 ± 0.36**
22:4n–6	ND	0.35 ± 0.01
22:5n–3	1.58 ± 0.03	1.97 ± 0.05**
22:6n–3	23.41 ± 3.16	27.58 ± 0.01
Total PUFA	40.37 ± 3.36	39.94 ± 0.86
Total n–3 PUFA	36.35 ± 3.34	38.01 ± 0.36
Total n–6 PUFA	4.02 ± 0.02	1.93 ± 1.22
Total lipid (g/100g)	11.85 ± 3.23	5.33 ± 1.18*

[1] SFA, saturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; ND, not detected.

[2] Data were presented as mean ± SD (N = 3); *$p < 0.05$, **$p < 0.01$ significantly different as compared to J-mackerel

3.2. Fatty acid composition

Fatty acid composition of J- and P-mackerel is shown in Table 1. There were considerable differences in the fatty acid composition between J- and P-mackerel. The difference for the percentages of total saturated fatty acids (SFA) was significant ($p < 0.05$), but there were no significant differences in the percentages of total monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA). J-mackerel showed higher percentages of 14:0, 18:1n–7, 20:1n–9, 18:3n–3, and 20:5n–3 compared to P-mackerel ($p <$ 0.05). The most commonly occurring PUFA were EPA and DHA and the differences for 18:3n–3, 20:5n–3, and 22:5n–3 between J- and P-mackerel were significant ($p <$ 0.01). The fatty acid composition of seafood and marine food ingredients is generally characterized by a relatively low content of saturated fatty acids. A relationship between high intake of SFAs and development of cardiovascular disease is generally accepted, and it is recommended to have a low intake of SFA [4]. The present study indicated that J-mackerel had a significantly higher percentage of SFA than P-mackerel. However, the beneficial effects of fish have traditionally been ascribed to the n-3 PUFA, particularly EPA and DHA. Both epidemiological and interventional studies have demonstrated preventative effect of n-3 PUFA on various diseases [14]. In addition to providing EPA and DHA, regular fish intake may facilitate the displacement of other foods higher in saturated and trans fatty acids from the diet, such as fatty meats and full-fat dairy products. Likewise, just as with PUFA, MUFA also show a marked intra and inter species variation. Unlike SFA percentages, the percentages of MUFA and PUFA were not that different between J- and P-mackerel. Recently, a study on seasonal variations demonstrated that MUFA percentages of chub mackerel were the highest on August, while the percentages of PUFA were the highest in April. The major contributing factors to the seasonal variation of PUFA amounted to 20:5n–3 and 22:6n–3 [15]. The fatty acid composition might be related to the changes in nutritional habits of the fish. Fish lipids differ from those of land animals basically in their richness of very long chain fatty acids. These fatty acids are derived from the tropic chain, due to principally to the richness in algae and marine plankton.

3.3. Amino acid composition

Fish constitutes an important source of protein for many people throughout the world. Protein quality is determined by the content of essential amino acids and the bioavailability which can be absorbed and utilized. Amino acid composition of J- and P-mackerel is shown in Table 2. Total amount of amino acids in J- mackerel was 177.35 ± 3.63 mg/g and that in P-mackerel was 213.05 ± 9.06 mg/g. The main amino acids were glutamic acid, followed by lysine, aspartic acid, and leucine in decreasing amounts. There were no significant differences in tyrosine, phenylalanine, histidine, and proline. Fish muscle contains all of the essential amino acids (EAA) and can be regarded as a complete protein source. The protein quality of most fish may exceed that of terrestrial meat and be equal to an ideal protein. The present study demonstrated that the percentage of EAA in total amino acids (TAA) was 55% and the ratio of EAA to non-essential amino acids (NEAA) was 0.8. FAO-WHO recommended that the percentage of EAA in TAA and ratio of EAA to NEAA approximated to the reference values of 40% and 0.6, respectively [16]. A recent study demonstrated that consumption of mackerel protein led to reduced expression of tumor necrosis factor-α and interleukin-6 in adipose tissue, suggesting that fish proteins carry anti-inflammatory properties that may protect against obesity-linked metabolic complications [17].

Table 2. Comparison of amino acid composition (mg/g) of J-mackerel and P-mackerel

Composition[1]	J-Mackerel	P-Mackerel
Essential		
Arginine	10.11 ± 0.13[2]	12.23 ± 0.31**
Histidine	11.95 ± 0.21	12.77 ± 1.02
Isoleucine	9.01 ± 0.23	10.90 ± 0.34**
Leucine	15.08 ± 0.31	18.30 ± 0.54**
Lysine	18.93 ± 1.26	23.12 ± 2.01*
Methionine	5.54 ± 0.16	6.70 ± 0.33*
Phenylalanine	8.25 ± 0.78	9.86 ± 1.17
Threonine	8.84 ± 0.03	10.85 ± 0.33**
Valine	10.97 ± 0.18	13.18 ± 0.51*
Total EAA	98.68 ± 3.30	117.92 ± 6.55*
Non-essential		
Alanine	9.74 ± 0.04	11.48 ± 0.26**
Aspartic acid	18.48 ± 0.23	22.55 ± 0.63**
Glutamic acid	26.70 ± 0.02	33.04 ± 0.58**
Glycine	7.07 ± 0.27	7.92 ± 0.02*
Proline	6.86 ± 0.13	7.91 ± 0.59
Serine	7.66 ± 0.09	9.38 ± 0.14**
Tyrosine	2.17 ± 0.31	2.86 ± 0.35
Total NEAA	78.67 ± 0.33	95.13 ± 2.52**
TAA	177.35 ± 3.63	213.05 ± 9.06*
EAA/TAA×100	55.63 ± 0.72	55.33 ± 0.72
Total NEAA /total EAA	0.80 ± 0.02	0.81 ± 0.02

[1] EAA: essential amino acids; NEAA: non-essential amino acids; TAA: total amino acids.

[2] Data were presented as mean ± SD (N = 3); *$p <$ 0.05, **$p <$ 0.01 significantly different as compared to J-mackerel.

Table 3. Comparison of metals content (mg/kg) of J-mackerel and P-mackerel

Metal	J-Mackerel	P-Mackerel
As	0.045 ± 0.007[1]	0.053 ± 0.001
Cd	0.004 ± 0.000	0.006 ± 0.000**
Cr	0.063 ± 0.003	0.077 ± 0.002**
Cu	0.247 ± 0.045	0.551 ± 0.114*
Hg	0.039 ± 0.000	0.073 ± 0.009*
Ni	0.003 ± 0.001	0.003 ± 0.001
Pb	0.004 ± 0.002	0.007 ± 0.003
Zn	2.204 ± 0.127	2.896 ± 0.094**

[1] Data were presented as mean ± SD ($N = 3$); $*p < 0.05$, $**p < 0.01$ significantly different as compared to J-mackerel.

3.4. Heavy metals concentrations

Monitoring the content of metals in fish is important in order to evaluate the possible risk of fish and other organism consumption for human health. As shown in Table 3, the order of the metal concentrations was significantly Zn>Cu>Cr>As and Hg. P-mackerel had higher content of As, Cd, Cr, Cu, Hg, Pb, and Zn compared to those of J-mackerel. The differences between J- and P-mackerel were statistically significant for Cd, Cr, Cu, Hg and Zn ($p < 0.05$). In general, contents of Zn and Cu are higher than Pb and Cd in fish muscle. The essential metals, such as Zn and Cu, are regulated to maintain a certain homeostatic status in fish. On the contrary, the non essential metals, such as mercury and lead, have no biological function or requirement and their contents in fish muscles are generally low [18]. The Food Code of Korea specifies that, for this type of food, the contents of Hg and Pb should be less than 0.5 mg/kg wet weight [19]. Even though there is consistent evidence for beneficial effects of modest fish consumption, there are possible risks and adverse effects associated with fish. The main concern has been the presence of environmental contaminants. The greatest public and scientific attention has been on methyl mercury, a component that represents a permanent threat to human health. There are health advisories in place to limit consumption of particular types of seafood, and some researchers have discussed that the levels of environmental contaminants in some species may offset the benefits of several compounds such as n–3 PUFA and selenium [20, 21]. Interestingly, Ouedraogo and Amyot [22] investigated effect of dietary habits such as cooking methods and food components on fish mercury bioavailability. They found that mercury bioaccessibility from mackerel can be reduced by cooking and by the co-ingestion of tea and coffee.

As fish is staple food for human, the accumulation of metals exceeding the permissible limits is a serious health concern. The present study thus highlighted the heavy metal concentrations of chub mackerel caught at two different areas in order to evaluate their nutritional value. Among non-essential metals, Hg concentrations of P-mackerel were determined to be the highest levels in this study. The metals contents of both P- and J-mackerel were less than maximum levels in the Korea Food Code. The present study may be useful for possible health risks of fish consumption in Korea. Of cause, it is just first step so that fish contamination levels should be carefully monitored on a regular basis.

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