Food Sci. Biotechnol. Vol. 16, No. 3, pp. 367 ~ 373 (2007)

Food Science and Biotechnology

Food Component Characteristics of Tuna Livers

Kyung Tae Kang, Min Soo Heu, Seung Joon Jee, Jae Hyoung Lee, Hye-Suk Kim, and Jin-Soo Kim*

Division of Marine Life Science/Institute of Marine Industry, Gyeongsang National University, Tongyeong, Gyeongnam 650-160, Korea

Abstract Livers of skipjack tuna (*Katsuwonus pelamis*) and yellowfin tuna (*Thunnus albacares*) were investigated on the food compositional characteristics and also compared to that of Alaska pollack (*Theragra chalcogramma*). The proximate compositions of skipjack tuna and yellowfin tuna livers were high in crude protein, carbohydrate, and crude ash, while were low in crude lipid when compared to that of Alaska pollack liver. The results of heavy metal suggested that tuna livers appeared safe as a food resource. The total amino acid contents of skipjack tuna and yellowfin tuna livers were 17.7 and 17.1 g/100 g, respectively, and the major amino acids in both livers were aspartic acid, glutamic acid, alanine, valine, leucine, and lysine. Tuna livers were good sources of iron and zinc, while have low lipid content. The extractive nitrogen contents of skipjack tuna and yellowfin tuna livers were 526.5 and 468.2 mg/100 g, respectively, and their major free amino acids were taurine, glutamic acid, and alanine. From the results of taste value, the major taste active compounds among free amino acids were glutamic acid and aspartic acid.

Key words: skipjack tuna, yellowfin tuna, fish liver, seafood by-product

Introduction

The annual catch of skipjack tuna and yellowfin tuna, both commercially important fish species, increased from 137,015 and 49,461 M/T, respectively, in 2000 to 171,641 and 52,474 M/T, respectively, in 2005 (1). The increase is probably because both tuna species are mainly used as raw materials for canned tuna production, which is a consumer-friendly seafood products (2). Solid byproducts, such as head, skin, bone, roe, and viscera, were produced in large quantities during the preparation of canned tunas. Among the canned tuna processing byproducts, the use of viscera including the livers, for food has not yet been well studied. Most livers from skipjack tuna and yellowfin tuna have been conventionally used to produce fish meal and fertilizer or directly discharged into estuaries, resulting in environmental pollution and offensive odors (2). However, fish livers are generally rich source of valuable nutrient since they have high protein and lipid content. Therefore, attention must be paid to greater utilization of the tuna livers in order to address such concerns.

Numerous efforts have been made toward the food component characteristics of roes (3) and bone (4), and the preparations of calcium powder from bone (5), natural flavorants from cooking drip (6), gelatin from skin (7, 8), and sauce from scrap (9) for the effective use of byproducts from canned tuna, such as roes, bone, skin, and cooking drip. Less work has, however, been done on the basic investigation of the food compositional characteristics as well as methods for the effective use of tuna livers as a food resource.

The objectives of this study were to examine the food compositional characteristics of livers from skipjack tuna and yellowfin tuna, byproducts of canned tuna, as food resources and also to compare with Alaska pollack liver.

Materials and Methods

Materials Skipjack tuna, *Katsuwonus pelamis*, liver (weight, 53.7±2.5 g; length, 13.4±0.5 cm) and yellowfin tuna, *Thunnus albacares*, liver (weight, 59.7±6.6 g; length, 13.5±1.5 cm) were obtained from a commercial canned tuna processing plant located in Changwon, South Korea in December 2005. Alaska pollack, *Theragra chalcogramma*, liver (weight, 53.7±2.5 g; length, 13.4±0.5 cm) was obtained from a commercial fish market located in Tongyeong, South Korea in December 2005.

Proximate composition According to the AOAC (10) methods, moisture was quantified by oven-drying at 105°C, crude protein by the Kjeldahl procedure, total lipid by Soxhlet extraction and ash by incineration in a muffle furnace at 550°C. In addition, the amount of carbohydrate was calculated by subtracting contents (g) of moisture, lipid, ash, and crude protein from 100 g.

Heavy metal and mineral The mercury content was determined by the combustion gold amalgamation method (11) using a mercury analyzer (Model SP-3A; Nippon Instrument Co., Tokyo, Japan). Other heavy metals, such as lead, cadmium, and chrome, and minerals, such as calcium, iron, zinc, and phosphorus, were determined by the wet ash method (12, 13) using an inductively coupled plasma spectrophotometer (ICP, Atomscan 25; Thermo Electron Co., Waltham, MA, USA).

Total amino acid composition Total amino acid composition was determined with an amino acid analyzer (Biochrom 20; Pharmacia Biotech, Buckinghamshire, England). Samples were hydrolyzed in 6 N HCl in evacuated sealed tubes at 110°C for 24 hr. The hydrolysates were evaporated to dryness in a vacuum

---

*Corresponding author: Tel: 82-55-640-3118; Fax: 82-55-640-3111
E-mail: jinsukim@gaechuk.gsnu.ac.kr
Received September 27, 2006; accepted February 5, 2007

evaporator at 40°C and then diluted with sodium citrate buffer for analyzing amino acid.

Lipid extraction and separation Total lipid (TL) was extracted with chloroform/methanol mixture solution acccording to the method of Bligh and Dyer (14). The TL was separated into polar lipid (PL) and neutral lipid (NL) using a sep-pak silica cartridge (Waters Asso., Milford, MA, USA) according to the method of Juaneda and Rocquelin (15).

Lipid class composition and fatty acid composition Lipid class composition of phospholipid and NL were determined according to the method described by Jeong *et al.* (16) using Chromarod S-III and Iatroscan MK-5 TLC/FID analyzer (Iatron Lab. Inc., Tokyo, Japan). An aliquot of the chloroform solution of TL was spotted on the Chromarods with a single spotting action, using Drummond Microcap disposable pipets (1 μL, Drummond Scientific Co., Broomail, PA, USA). The Chromarods were placed in a constant humidity tank over saturated sodium chloride solution for 10 min and then immediately transferred to the developing tank. The solvent system for NL was a mixture of *n*-hexane/diethyl ether/formic acid (97:3:1, v/v/v). In the case of phospholipid, acetone and a mixture of chloroform/methanol/water (65:35:4, v/v/v) were used as the solvent system. The Chromarods were heated for 2 min in an oven at 115°C and were scanned using an Iatroscan MK-5. The air and hydrogen flow rates for the Iatroscan analyzer were 2,000 and 160 mL/min, respectively, and the scan speed was set at 30 sec/scan.

TL and NL were methylated according to the AOCS (17) method. Their fatty acid composition were analyzed using a gas-liquid chromatography (Shimadzu GC 14A; Shimadzu Seisakusho, Co., Ltd., Kyoto, Japan) equipped with a Supelcowax-10 fused silica-wall-coated open tubular column (30 m × 0.32 mm i.d., Supelco, Inc., Bellefonte, PA, USA). The injector and the flame-ionizaton detector were held at 250°C and the column was programmed from 180 to 230°C at 1°C/min. Helium was used as a carrier gas at the constant inlet pressure of 1.0 kg/cm^2 with a split ratio of 1:50. Fatty acids were identified by comparison of their retention times with those of standards (Aldrich Chem. Co., Milwaukee, WI, USA).

Extractive nitrogen and free amino acid The sample (10 g) was homogenized with 30 mL of 20% trichloroacetic acid (TCA). The homogenate was centrifuged at 1,000×g for 10 min. The precipitate was re-extracted with 10 mL of 10% TCA and centrifuged. Both supernatants were combined and made up to 100 mL before used as a sample for analyzing extractive nitrogen (Ex-N) and free amino acid (FAA) composition.

Ex-N was determined according to the Kjeldahl method and FAA composition was also analyzed using an amino acid analyzer (Biochrom 20; Pharmacia Biotech.).

Results and Discussion

Proximate composition and heavy metal content The proximate compositions and heavy metal contents of Alaska pollack, skipjack tuna, and yellowfin tuna livers are shown in Table 1. The results of proximate composition indicated that the tuna livers had higher in crude protein, carbohydrate, and crude ash, while lower in crude lipid than Alaska pollock liver. Higher crude lipid and lower moisture and carbohydrate were observed in skipjack tuna liver compared to yellowfin tuna liver. There was, however, no significant difference in crude protein and crude ash contents between livers from skipjack tuna and yellowfin tuna. The results of proximate composition suggested that tuna livers could be used as a potential protein resource.

Heavy metals (cadmium, lead, and chrome) were not detected except for mercury, which ranged from 0.009 to 0.063 mg/kg in all fish livers. According to KFAD (11), the limits for heavy metal safety were 2.0 mg/kg for cadmium and lead, and 0.5 mg/kg for mercury. Based on the guideline tuna livers appears to be safe in terms of

Table 1. Proximate composition and heavy metal contents of livers from Alaska pollack, skipjack tuna, and yellowfin tuna[1)]

Components		Fish livers		
		Alaska pollack	Skipjack tuna	Yellowfin tuna
Proximate composition (g/100 g)	Moisture	50.3±0.3	66.7±0.2	71.3±0.2
	Crude protein	6.0±0.0 (12.1)[2)]	18.1±0.2 (54.4)	18.1±0.2 (63.1)
	Crude lipid	39.0±0.6 (78.4)	6.3±0.2 (18.9)	2.6±0.1 (9.1)
	Crude ash	0.7±0.1 (1.4)	1.6±0.1 (4.8)	1.5±0.0 (5.2)
	Carbohydrate[3)]	4.0	7.3	6.5
Heavy metal (mg/kg)	Hg	0.009±0.003	0.044±0.010	0.063±0.012
	Pb	ND[4)]	ND	ND
	Cd	ND	ND	ND
	Cr	ND	ND	ND

[1)] Values are the means±SD of 3 determinations.
[2)] The values in the parentheses are based on dry weight.
[3)] Carbohydrate = 100 - (moisture + protein + lipid + ash).
[4)] ND: Not detected.

Table 2. Total amino acid compositions (TAA) of livers from skipjack tuna and yellowfin tuna

Amino acid	Skipjack tuna liver		Yellowfin tuna liver	
	mg/100 g liver	g/100 g amino acid	mg/100 g liver	g/100 g amino acid
Aspartic acid	1,619.8	9.2	1,274.7	7.5
Threonine1)	342.2	1.9	377.1	2.2
Serine	964.4	5.5	895.1	5.2
Glutamic acid	2,429.9	13.7	2,574.8	15.1
Proline	793.8	4.5	1,006.5	5.9
Glycine	846.9	4.8	456.0	2.7
Alanine	1,138.4	6.4	1,145.7	6.7
Cystine	456.9	2.6	689.8	4.0
Valine1)	1,108.2	6.3	1,151.1	6.7
Methionine1)	201.8	1.1	370.1	2.2
Isoleucine1)	919.2	5.2	978.8	5.7
Leucine1)	1,582.1	8.9	1,420.1	8.3
Tyrosine	858.3	4.9	881.2	5.2
Phenylalanine1)	1,092.3	6.2	947.9	5.5
Histidine	704.9	4.0	616.4	3.6
Lysine1)	1,649.5	9.3	1,422.5	8.3
Arginine	971.5	5.5	883.4	5.2
Total	17,680.1	100.0	17,091.3	100.0

1)Essential amino acid.

heavy metal content.

Total amino acid composition Total amino acid compositions of skipjack tuna and yellowfin tuna livers are shown in Table 2. There was no difference in total amino acid contents between skipjack tuna (17,680 mg/100 g) and yellowfin tuna livers (17,091 mg/100 g). The major amino acids for skipjack tuna and yellowfin tuna livers were aspartic acid (9.2 and 7.5%, respectively), glutamic acid (13.7 and 15.1%, respectively), alanine (6.4 and 6.7%, respectively), valine (6.3 and 6.7%, respectively), leucine (8.9 and 8.3%, respectively), and lysine (9.3 and 8.3%, respectively). As except for tryptophan, the essential amino acid composition of both tuna livers was 38.9%. The high amounts of lysine, a limiting amino acid (18) in grains such as rice, the staple food for Koreans, in both tuna livers may act a nutritional supplement.

Comparison of amino acid composition, expressed as mg/g of protein, of skipjack tuna liver, yellowfin tuna liver, and protein foods (egg, milk, and beef) are shown in Table 3. Cereal proteins, Asian main foods, are often low in lysine, and in some instances they lack threonine. Those essential amino acids in greatest deficit with respect to requirements are designated limiting amino acids (19). When the dietary pattern of amino acids differs greatly from the ideal pattern, this situation is referred as amino acid imbalance (20). It can lead to reduced efficiency of amino acid utilization, depressed growth, increased susceptibility to diseases, and/or permanent impairment of mental capabilities in children (19).

The amino acid compositions of tuna livers were similar or high, while threonine was low when compared to the amino acid requirement composition in children (histidine, 19 mg/g; isoleucine, 28 mg/g; leucine and lysine, 44 mg/g; methionine + cystine and phenylalanine + tyrocine, 22 mg/g; threonine, 28 mg/g; tryptophan, 9 mg/g; valine, 25 mg/g) and the amino acid compositions of other protein sources, such as egg, milk, and beef. However, the compositions of all amino acids including threonine were also higher than the amino acid requirement for adults (histidine, 11 mg/g; isoleucine, 13 mg/g; leucine 19 mg/g; lysine, 16 mg/g; methionine + cystine, 17 mg/g; phenyl-

Table 3. Total amino acid content of fish livers compared to the amino acid requirement in children and adult

Amino acid	Amino acid requirement composition1) (mg/g protein)		Amino composition (mg/g of protein)				
	Children1)	Adult1)	Egg1)	Milk1)	Beef1)	Skipjack tuna liver	Yellowfin tuna liver
Histidine	19	11	22	27	34	39	34
Isoleucine	28	13	54	47	48	51	54
Leucine	44	19	86	95	81	87	78
Lysine	44	16	70	78	89	91	79
Methionine + cystine	22	17	57	33	40	36	59
Phenylalanine + tyrosine	22	19	93	02	80	108	101
Threonine	28	9	47	44	46	19	21
Tryptophan	9	5	17	14	12	ND2)	ND
Valine	25	13	66	64	50	61	64
Total sum except for histidine	222	111	490	477	445	455	456

1)The data were quoted by The Korean Nutrition Society (18).
2)ND: Not determined.

Table 4. Mineral contents of livers from Alaska pollack, skipjack tuna, and yellowfin tuna[1] (mg/100 g)

Mineral	Egg[2]	Milk[2]	Beef[2]	Fish livers		
				Alaska pollack	Skipjack tuna	Yellowfin tuna
Ca	47.0	100.0	6.0	31.1±0.2	26.3±0.2	18.2.±0.2
Fe	1.8	0.2	2.1	0.7±0.0	16.5±0.4	18.5±0.5
Zn	0.9	0.4	3.0	ND[3]	2.2±0.1	5.2±0.1
P	168.0	90.0	138.0	132.8±1.2	344.0±3.8	299.4±2.4

[1] Values are the means±SD of 3 determinations.
[2] The data were quoted by The Korean Nutrition Society (18).
[3] ND: Not detected.

alanine + tyrosine, 19 mg/g; threonine, 9 mg/g; tryptophan, 5 mg/g; valine, 13 mg/g). The result above suggested that skipjack tuna and yellowfin tuna livers could be used as a potential protein source.

Mineral composition Mineral composition of skipjack tuna, yellowfin tuna, and Alaska pollack livers are shown in Table 4. The calcium and phosphorus composition were 26.3 and 132.8 mg/100 g, respectively, for skipjack tuna liver, and 18.2 and 299.4 mg/100 g, respectively, for yellowfin tuna liver. Tuna livers were high in phosphorus, iron, and zinc, while was low in calcium compared to Alaska pollack liver. The calcium and phosphorus contents of skipjack tuna was high compared to those of yellowfin tuna liver. Tuna livers were also high in calcium, phosphorus, iron, and zinc contents compared to egg, milk, and beef except for calcium composition of egg and milk. The Korean Institute for Health and Social Affairs recommends a daily intake of 700 mg of both calcium and phsphorus, and 12 mg of both iron and zinc for adults (21). Based on the results of experiment and the recommendations of the Korean Institute for Health and Social Affairs on mineral, tuna livers might be considered as a good source for iron enhancement, while not for other minerals, such as calcium, zinc, and phosphorus.

Lipid class composition and fatty acid composition The total lipid (TL), neutral lipid (NL), and polar lipid (PL) composition of Alaska pollack, skipjack tuna, and yellowfin tuna livers are shown in Table 5. The NL composition was the highest in Alaska pollack liver (39.0%), followed by skipjack tuna liver (6.3%), and yellowfin tuna liver (2.6%). For the reason, Alaska pollack liver is now being used as a resource for extracting functional lipids. The NL and PL compositions in TL were 95.8 and 4.2%, respectively, for Alaska pollack liver, 96.7 and 3.3%, respectively, for skipjack tuna liver, and 97.3 and 2.7%, respectively, for yellowfin tuna liver. The results indicated that no significant difference was observed in NL and PL compositions among TLs of Alaska pollack, skipjack tuna, and yellowfin tuna livers. The results revealed that the livers of the 3 fish species studied could be a good source for extracting lipids due to the low PL content. Phospholipids are usually removed by degumming process for preventing Maillard reaction and reducing fish odor (22). Bosund and Granrot (23) reported that generally the PL composition of TL of source for extracting lipid was approximately 10%.

Table 5. Total lipid (TL), neutral lipid (NL), and polar lipid (PL) compositions of livers from Alaska pollack, skipjack tuna, and yellowfin tuna[1]

	Fish livers		
	Alaska pollack	Skipjack tuna	Yellowfin tuna
TL (g/100 g liver)	39.0	6.3	2.6
NL (g/100 g TL)	(95.8±3.9)[2]	(96.7±5.1)	(97.3±4.7)
Free sterol	20.1±2.1	26.1±3.3	22.3±2.3
Free fatty acid	6.4±1.2	11.2±2.3	15.4±2.0
Triglyceride	55.2±5.4	48.8±4.9	48.3±4.8
Sterol ester	18.3±1.6	13.9±1.4	14.0±1.6
PL (g/100 g TL)	(4.2±0.4)	(3.3±0.3)	(2.7±0.3)

[1] Values are the means±SD of 3 determinations.
[2] The value in parenthesis means (g/100 g total lipid).

NL in fish livers were found to be free sterol (FS), free fatty acid (FFA), triglyceride (TG), and sterol ester (SE). The percentages of NL in skipjack tuna and yellowfin tuna livers were the highest for TG, followed FS, SE, and FFA. There was, however, no significant difference in the percentage between NLs of tuna livers. Comparing with NL of Alaska pollack liver, the percentages of FS and FFA of neutral lipid in tuna livers were higher level, while those of TG and SE were lower. Kim *et al.* (24) reported that the lipid extracted from seafood byproducts, such as squid and fish livers, should be refined with alkali solution for removing FFA.

Fatty acid compositions of TL and NL of Alaska pollack, skipjack tuna, and yellowfin tuna livers are shown in Table 6. Regardless of TL and NL, 28 kinds of fatty acids were detected in Alaska pollack liver and 26 kinds for both tuna livers. The carbon number of fatty acids in all samples ranged from 14 to 22. The fatty acid compositions of TL and NL were the highest in monoenes (TL, 44.5%; NL, 47.7%) for Alaska pollack liver, in saturates (TL, 39.1%; NL, 39.4%) for skipjack tuna liver, and in polyenes (TL, 41.4%; NL, 40.6%) for yellowfin tuna liver. The major fatty acids of TL were 16:0 (15.8%), 16:1n-7 (13.5%), 18:1n-9 (16.9%), and 20:5n-3 (17.1%) in Alaska pollack liver, while for skipjack tuna and yellowfin tuna livers were 16:0 (26.8 and 25.8%, respectively), 18:1n-9 (17.9 and 14.8%, respectively), and 22:6n-3 (21.7 and 25.5%, respectively). These results indicated an observed

Table 6. Fatty acid compositions of total lipid (TL) and neutral lipid (NL) of livers from Alaska pollack, skipjack tuna, and yellowfin tuna

Fatty acid	Fish livers (area%)					
	Alaska pollack		Skipjack tuna		Yellowfin tuna	
	TL	NL	TL	NL	TL	NL
14:0	5.7	5.4	0.7	0.8	0.8	0.7
15:0	0.3	0.3	0.6	0.6	0.7	0.7
16:0	15.8	16.0	26.8	27.2	25.8	25.8
17:0	1.1	1.4	2.2	2.1	2.1	2.2
18:0	2.6	2.6	8.0	8.0	7.4	7.4
20:0	0.4	0.4	0.8	0.7	0.8	1.5
Saturates	25.9	26.1	39.1	39.4	37.6	38.3
16:1n-7	13.5	12.8	3.0	2.7	2.6	2.9
16:1n-5	0.3	0.3	0.1	0.2	0.2	0.1
18:1n-9	16.9	18.2	17.9	18.0	14.8	14.7
18:1n-7	7.1	7.5	2.8	2.9	2.6	2.6
18:1n-5	0.4	0.3	0.1	0.1	0.1	0.1
20:1n-9	2.2	2.8	0.9	0.9	0.8	0.8
20:1n-9	0.5	0.5	0.1	0.1	-	-
22:1n-11	3.0	4.3	-	-	-	-
22:1n-9	0.7	0.9	-	-	-	-
Monoenes	44.5	47.7	24.8	24.8	21.0	21.1
18:2n-6	0.7	0.7	0.8	0.8	0.9	0.9
18:3n-3	0.4	0.4	0.2	0.2	0.2	0.2
18:4n-3	1.6	1.4	0.1	0.1	0.1	0.1
20:2n-6	0.2	0.1	0.2	0.2	0.2	0.2
20:3n-3	0.1	0.1	0.1	0.1	0.1	0.1
20:4n-6	0.4	0.4	3.7	3.6	4.0	4.0
20:4n-3	0.4	0.4	0.4	0.4	0.4	0.4
20:5n-3	17.1	14.6	4.2	4.2	4.9	4.7
21:5n-6	0.6	0.5	0.1	0.1	0.1	0.1
22:4n-6	0.1	0.1	1.0	1.1	1.1	1.1
22:5n-6	0.1	0.1	2.1	2.0	2.2	2.2
22:5n-3	0.9	0.9	1.5	1.5	1.7	1.6
22:6n-3	7.0	6.6	21.7	21.4	25.5	25.1
Polyenes	29.6	26.1	36.0	35.7	41.4	40.6

difference in the major fatty acids, such as 16:1n-7, 20:5n-3, and 22:6n-3, between TLs from Alaska pollack and tuna livers. However, there was no significant difference in the major fatty acids between TL and NL in the same fish livers, which was probably because TL is mostly consisted of NL. The fatty acid compositions in fish livers were also observed to be typical of fish lipids, containing substantial quantities of some highly unsaturated long chain fatty acids, such as 20:5 and 22:6 (25). However, the deterioration of a marine lipid is greatly influenced by its degree of unsaturation (26). The relatively large amount of polyunsaturated acids, especially 22:6n-3, in tuna livers must therefore be considered in the preservation of quality during handling for lipid extraction and refining process, and frozen storage.

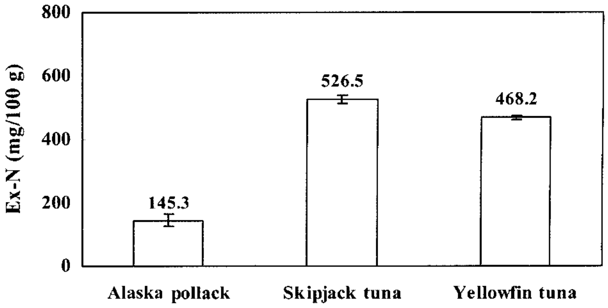

Fig. 1. Extractive-nitrogen (Ex-N) of livers from Alaska pollack, skipjack tuna, and yellowfin tuna. Values are the means±SD of 3 determinations.

Extractive nitrogen and free amino acid composition The compositions of extractive nitrogen (Ex-N) in Alaska pollack, skipjack tuna, and yellowfin tuna are shown in Fig. 1. The Ex-N content was the highest in skipjack tuna liver (526.5 mg/100 g), followed by yellowfin tuna liver (468.2 mg/100 g) and Alaska pollack liver (435.8 mg/100 g). The ratio of the Ex-N composition to total nitrogen (2,896.0 mg/100 g) in skipjack tuna liver was 18.1%, which was high compared to those of Alaska pollack liver (15.1%) and yellowfin tuna liver (16.2%), while was lower than the bivalves, such as pen shell (21.3%), abalone (22.2%), and oriental hard clam (22.4%) (27).

The free amino acid compositions and the taste values of skipjack tuna, yellowfin tuna, and Alaska pollack livers are shown in Table 7. Twenty five kinds of free amino acids were identified in both tuna livers. The total free amino acid contents of skipjack tuna liver was 954.8 mg/100 g, which is high compared to that of the yellowfin tuna liver (871.8 mg/100 g). The major free amino acids in skipjack tuna liver were taurine (8.1%), glutamic acid (10.8%), and alanine (6.9%), which comprised 25.8% of the total free amino acid content. The same kinds and the similar compositions of major free amino acids were observed for yellowfin tuna liver. The taste threshold among free amino acids was the lowest in aspartic acid (3 mg/100 g), followed by glutamic acid (5 mg/100 g), lysine (20 mg/100 g), and methionine (30 mg/100 g). The total taste value in skipjack tuna liver was 47.45, which was high compared to that of yellowfin tuna liver (40.87). The major amino acids in taste value in the skipjack tuna liver were aspartic acid (18.66) and glutamic acid (20.62), which is the same observation for yellowfin tuna liver. Based on the results of free amino acid and taste value, glutamic acid and aspartic acid acts as the major taste-active components of tuna livers.

The results of food compositional characteristics of tuna livers suggested that livers of skipjack tuna and yellowfin tuna may serve as a useful source for processing food.

Table 7. Free amino acid compositions and taste values of livers from skipjack tuna and yellowfin tuna

Amino acid	Taste threshold (mg/100 g)[1]	Fish livers			
		Skipjack tuna		Yellowfin tuna	
		mg/100 g liver	Taste value	mg/100 g liver	Taste value
Phosphoserine	-	17.4 (1.8)[2]	-	16.7 (1.9)	-
Taurine	-	77.3 (8.1)	-	82.6 (9.5)	-
Aspartic acid	3	56.0 (5.9)	18.66	45.2 (5.2)	15.07
Threonine	260	41.7 (4.4)	0.16	43.9 (5.0)	0.17
Serine	150	39.0 (4.1)	0.26	35.7 (4.1)	0.24
Glutamic acid	5	103.1 (10.8)	20.62	89.9 (10.3)	17.98
Proline	300	55.6 (5.8)	0.19	41.0 (4.7)	0.14
Glycine	130	31.8 (3.3)	0.24	27.3 (3.1)	0.21
Alanine	60	66.1 (6.9)	1.10	62.8 (7.2)	1.05
Valine	140	46.0 (4.8)	0.33	41.8 (4.8)	0.30
Cystine	-	12.5 (1.3)	-	12.0 (1.4)	-
Methionine	30	33.9 (3.6)	1.13	30.9 (3.5)	1.03
Cystathionine-2	-	19.3 (2.0)	-	20.7 (2.4)	-
Isoleucine	90	38.9 (4.1)	0.43	32.9 (3.8)	0.37
Leucine	190	53.5 (5.6)	0.28	49.1 (5.6)	0.26
Tyrosine	-	40.5 (4.2)	-	32.6 (3.7)	-
β-Alanine	-	13.6 (1.4)	-	5.2 (0.6)	-
Phenylalanine	90	38.5 (4.0)	0.43	32.2 (3.7)	0.36
Ethanolamine	-	5.6 (0.6)	-	3.3 (0.4)	-
Ornithine	-	31.0 (3.2)	-	26.5 (3.0)	-
Lysine	50	50.6 (5.3)	1.01	47.0 (5.4)	0.94
1-Methylhistidine	-	9.1 (1.0)	-	5.7 (0.7)	-
Histidine	20	41.5 (4.4)	2.08	44.9 (5.1)	2.24
Anserine	-	5.4 (0.6)	-	16.0 (1.8)	-
Arginine	50	26.9 (2.8)	0.54	25.9 (3.0)	0.52
Total		1,027.9 (100.0)	47.45	945.9 (100.0)	40.87

[1] The data were quoted from Kato *et al.* (28).

[2] The value in parenthsis means (g/100 g anmino acid).

References

1. Ministry of Maritime Affairs and Fisheries. Fishery production survey. Available form: http://fs.fips.go.kr/main.jsp. Accessed July 28, 2006.
2. Kim JS, Yeum DM, Kang HG, Kim IS, Kong CS, Lee TG, Heu MS. Fundamentals and Applications for Canned Foods. Hyoil Publishing Co., Seoul, Korea. pp. 45-48, 95, 351-354 (2002)
3. Heu MS, Kim HS, Jung SC, Park CH, Park HJ, Son SW, Park HS, Kim CG, Kim JS. Food component characteristics of tuna roes. J. Korean Fish. Soc. 39: 1-8 (2006)
4. Kim JS, Yang SK, Heu MS. Component characteristics of cooking tuna bone as a food resource. J. Korean Fish. Soc. 33: 38-42 (2000)
5. Kim JS, Cho ML, Heu MS. Preparation of calcium powder from cooking skipjack tuna bone and its characteristics. J. Korean Fish. Soc. 33: 158-163 (2000)
6. Kim SK, Byun HG, Jeon YJ, Joo DS, Kim JB. Development of natural seasoning using desalinated tuna boiled extract. J. Korean Fish. Soc. 32: 75-82 (1999)
7. Cho SM, Gu YS, Kim SB. Extracting optimization and physical properties of yellowfin tuna (*Thunnus albacares*) skin gelatin compared to mammalian gelatins. Food Hydrocolloid 19: 221-229 (2005)
8. Jongjareonrak A, Benjakul S, Visessanguan V, Prodpran T, Tanaka M. Characterization of edible films from skin gelatin of brownstripe red snapper and bigeye snapper. Food Hydrocolloid 20: 492-501 (2006)
9. Lee EH, Lee TH, Kim JS, Ahn CB. Processing and taste compounds of the fish sauce from skipjack scrap. J. Korean Fish. Soc. 22: 25-35 (1989)
10. AOAC. Official Methods of Analysis. 16th ed. Method 69-74. Association of Official Analytical Chemists, Washington, DC, USA (1995)
11. KFDA. Food Code of the Korean Food and Drug Administration. Moon-Young Publishing Co., Seoul, Korea. pp. 70-72 (2006)
12. Tsutagawa Y, Hosogai Y, Kawai H. Comparison of mineral and phosphorus contents of muscle and bone in the wild and cultured horse mackerel. J. Food Hyg. Soc. Jpn. 34: 315-318 (1994)
13. Ham SS, Choi KK, Cui CB, Lee BG, Joo DS, Lee DS. Quality characteristics of soy sauce fermented by *Bacillus licheniformis*

NH20 isolated from traditional *meju* and *Aspargillus oryze*. Food Sci. Biotechnol. 13: 537-543 (2004)

14. Bligh EG, Dyer WJ. A rapid method of lipid extraction and purification. Can. J. Biochem. Phys. 37: 911-917 (1959)
15. Juaneda P, Rocquelin G. Rapid and convient separation of phospholipid and nonphosphorus lipids from rat heart using silica cartridge. Lipids 20: 40-41 (1985)
16. Jeong BY, Moon SK, Jeong WG. Fatty acid compositions of marine invertebrates. J. Korean Soc. Food Nutr. 22: 291-299 (1993)
17. AOCS. Official Methods and Recommended Practive of the AOCS. 4th ed. Method Ce 16-89. American Oil Chemists' Society, Champaign, IL, USA (1990)
18. Kim HS, Park CH, Choi SG, Han BW, Kang KT, Shim NH, Oh HS, Kim JS, Heu MS. Food component characteristics of red-tanner crab (*Chionoecetes japonicus*) paste as food processing source. J. Korean Soc. Food Sci. Nutr. 34: 1077-1081 (2005)
19. Cheftel JC, Cuq JL, Lorient D. Amino acids, peptides, and proteins. pp. 245-369. In: Food Chemistry. Fennema OR (ed). Marcel Dekker Inc., New York and Basel, USA (1985)
20. Lee GH. Food Chemistry. Hyungseol Pubishing Co., Seoul, Korea, pp. 79-83 (1997)
21. The Korean Nutrition Society. Recommended Dietary Allowance for Koreans. Joongang Publishing Co., Seoul, Korea. pp. 57-82 (2000)
22. Zama K. Oxidation of phospholipids of aquatic animals, in symposium on oxidation of marine animal lipids. Bull. Japan Soc. Sci. Fish. 36: 867-868 (1970)
23. Bosund I, Granrot B. Lipid hydrolysis in frozen baltic herring. J. Food Sci. 34: 13-17 (1969)
24. Kim JS, Ha JH, Lee EH. Refining of squid viscera oil. Agric. Chem. Biotechnol. 40: 294-300 (1997)
25. Leu SS, Jhaveri SN, Karakoltsidis PA, Constantinides SN. Atlantic mackerel (*Scomber scombrus L*): Seasonal variation in proximate composition and distribution of chemical nutrients. J. Food Sci. 46: 1635-1638 (1981)
26. Krzeczkowski RA, Stone FE. Amino acid, fatty acid, and proximate composition of snow crab (*Chionoecetes bairdi*). J. Food Sci. 39: 386-388 (1974)
27. Choi JH, Shin TS, Ahn CB. Nutrient components in the siphon of the surf clam Tresus keenae. J. Fish. Sci. Technol. 8: 43-50 (2005)
28. Kato H, Rhue Mr, Nishimura T. Role of free amino acids and peptides in food taste. pp. 158-174. In: Flavor Chemistry: Trends and Development. American Chemical Society. Washington, DC, USA (1989)