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Proximate and Total Fatty Acid Compositions of the Reproductive Organs of Male and Female Common Squid *Todarodes pacificus*

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We analyzed the compositions of proximate and total fatty acids in the reproductive organs of male (testis, vas deferens, seminal vesicle, and spermatophore sac) and female (ovary, oviduct, oviducal gland, and nidamental gland) common squid. The protein contents were 12.1-22.7 and 13.2-19.4% for males and females, respectively, and the lipid contents were 1.0-2.7 and 2.1-8.0%, respectively. The prominent fatty acids in all reproductive organs were 22:6n-3, 20:5n-3, 16:0, 20:1n-9, 18:0, 18:1n-9, and 20:4n-6. Females had 28.6-32.0% of 22:6n-3 and 11.3-22.6% of 20:5n-3, while males had 20.8-26.8% of 22:6n-3 and 14.4-28.7% of 20:5n-3. These results indicate that the reproductive organs of both male and female squid are potential sources of n-3 polyunsaturated fatty acid.

Key words: Common squid, Gonadosomatic index, n-3 Polyunsaturated fatty acid, Ovary, Proximate composition, Reproductive organ, Testis

Introduction

Common squid (*Todarodes pacificus*), a commercially important cepalopod in the Pacific Ocean, occurs in the margins of the northwest Pacific from 20°N to 60°N (Boyle and Rodhouse, 2005). The global catch of common squid in 2004 was about 450,000 tons (FAO, 2005), while in Korea, the catch that year was about 210,000 tons (MOMAF, 2005), accounting for 47% of the world catch. This represented the largest proportion of any harvested species by Korea, making the common squid the country's most commercially important fished species. In general, only the muscle portions of squid, such as the mantle, arms, and head, are used as food, while the remainder of the animal (e.g., reproductive organs) are discarded and/or used as animal feed. Recent studies have analyzed the lipid component of muscle and viscera of squid to evaluate their potential use as nourishment (Kim et al., 2006; Moon et al., 2006). Muscles are composed of more than 50% n-3 polyunsaturated fatty acids (n-3 PUFA) such a docosahexaenoic acid (DHA, 22:6n-3) and eicosapentaenoic acid (EPA, 20:5n-3). The viscera, including the reproductive organs, also have a large proportion of n-3 PUFA (36-49%), and although slightly lower than that of muscles, the viscera in fact have more total lipid content and therefore more total n-3 PUFA. The physiological functions of n-3 PUFAs such as DHA and EPA are well understood (Kinsella, 1988; Hirayama, 1990; Yazawa and Kageyama, 1991; Breslow, 2006; Johnson and Schaefer, 2006; Hibbeln et al., 2007). The reproductive organs comprise about 49% (male) and 54% (female) of the viscera (21-27% body weight) of mature squid (Moon et al., 2006) and may thus be an important source of n-3 PUFA. However, the distribution of n-3 PUFA in the reproductive organs differs between the sexes (Surai et al., 1999; 2000; Jeong et al., 2002). For example, Jeong et al. (2002) demonstrated that DHA and EPA preferentially accumulated in the testis and ovary, respectively, of sweet smelt (*Plecoglossus altivelis*), and had different physiological functions.

Common squid achieve fertilization by direct mating (Boyle and Rodhouse, 2005). Male reproducetive organs include the testis, vas differens, seminal vesicle, and spermatophore sac, while those of

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females include the ovary, oviduct, oviducal gland, and nidamental gland. To date, most studies on squid reproductive organs have considered biological parameters only, and not their chemical components, and although a few studies have analyzed the compositions of the testes and ovaries of squid and cuttlefish (Blanchier and Boucaud-Camou, 1984; de Moreno et al., 1998), no chemical data are available for other reproductive organs such as the vas differens, seminal vesicle, spermatophore sac, oviduct, oviducal gland, and nidamental gland. Therefore, we analyzed and compared the proximate and fatty acid composition of all reproductive organs of both sexes. Our results provide chemical data on all of the reproductive organs of common squid, which should help in future biological studies on this animal, and suggest the potential utilization of these organs as food.

Materials and Methods

Sample

Live, mature common squid were purchased from a local fish market in Tongyeong, Korea, in July 2005. Each squid was dissected along the ventral side to confirm its sex, based on the shape of its reproductive organs and following the methods of Baek et al. (2006). The reproductive organs of both sexes were removed and stored at -70°C until analyzed. The gonadosomatic index (GSI) was calculated as follows: [gonad weight / (body weight - gonad weight)]×100 (Boyle and Rodhouse, 2005; Baek et al., 2006), where the gonad is the testis in males and the ovary in females.

Analysis of proximate composition

Moisture, protein (N×6.25), and ash contents were determined according to the Association of Official Analytical Chemists (AOAC, 1990). Total lipids (TL) were extracted and purified using the methods of Bligh and Dyer (1959), and the content was determined gravimetrically. The phospholipid (PL) content of the TL was determined following Bartlett (1959), and the nonpolar lipid (NL) content of the TL was calculated from the difference between the TL and PL.

Analysis of lipid class and fatty acid composition

The lipid class compositions of PL and NL were determined as described in Jeong et al. (1990). The fatty acids were determined after methylation according to the American Oil Chemists' Society (AOCS, 1990). The fatty acid composition of the TL was analyzed using a gas-liquid chromatograph (GC 17A; Shimadzu Seisakusho Co. Ltd., Kyoto, Japan) fitted with an Omegawax 320 fused silica capillary column (30 m×0.32 mm ID; Supelco, Bellefonte, PA, USA). The injector and flame-ionization detector were maintained at 250°C, the column oven temperature was increased from 180°C (initial time 8 min) to 230°C in 3°C/minimal intervals, and the final temperature was maintained for 15 min. Helium was used as a carrier gas at the constant column inlet pressure of 1.0 kg/cm^2 with a split ratio of 1:50. Fatty acids were identified by comparing them to authentic standards (Sigma Chemical Co., St. Louis, MO, USA) and oyster fatty acids, which were analyzed by Koizumi et al. (1990). Methyl tricosanoate (99%; Aldrich Chemical Co., Milwaukee, WI, USA) was used as an internal standard.

Statistical analysis

Each analysis of each sample included four determinations (two groups×two determinations), and the data were presented as means ± SD. Statistical analyses were performed using SPSS (version 10.0; SPSS Inc., Chicago, IL). Significant differences among samples ($p<0.05$) were identified by analysis of variance (ANOVA) and ranked by Duncan's multiple range test.

Results

Biological profiles

Table 1 shows the biological profiles of the squid. In females, the proportions of the ovary, oviduct, oviducal gland, and nidamental gland were 24.6, 10.0, 2.5, and 15.4% of total viscera, respectively. In males, the proportions of the testis, vas deferens, seminal vesicle, and spermatophore sac were 25.6, 2.8, 13.6,

Table 1. Biological profiles of reproductive organ from male and female common squid. GSI, Gonadosomatic index

	Male (n=30)	Female (n=20)
Body length (cm)	43.2±2.2	46.2±2.8
Mantle length (cm)	23.3±1.2	26.3±1.6
Body weight (g)	239.2±26.6	309.4±50.2
Reproductive organs (g)		
Testis (T)	12.6	-
Spermatophoric sac (Ss)	7.5	-
Seminal vesicle (Sv)	6.7	-
Vas deferens (Vd)	1.4	-
GSI (%)*	5.6	-
Ovary (O)	-	20.6
Nidamental gland (Ndg)	-	12.9
Oviduct (Od)	-	8.4
Oviducal gland (Odg)	-	2.1
GSI (%)	-	7.1

Table 2. Proximate composition of each reproductive organ from male and female common squid (wt %). Data are presented as mean ± SD of four determinations (two groups×two determinations) and different superscript letters indicate statistically significant difference ($p<0.05$)

Component	Male				Female			
	Testis	Vas deferens	Seminal vesicle	Spermatophoric sac	Ovary	Oviduct	Oviducal gland	Nidamental gland
Moisture	76.7±0.2^{b}	69.9±0.52^{a}	80.4±0.05^{d}	78.1±0.1^{c}	71.0±0.09^{b}	65.7±0.1^{a}	76.3±0.1^{d}	74.0±0.1^{c}
Protein	17.1±0.6^{c}	22.7±0.11^{d}	12.1±0.40^{a}	14.0±0.2^{b}	18.3±0.15^{c}	19.4±0.3^{d}	13.2±0.3^{a}	15.7±0.3^{b}
Lipid	2.7±0.2^{c}	2.2±0.09^{b}	2.5±0.12^{c}	1.0±0.2^{a}	5.9±0.16^{b}	8.0±0.1^{c}	2.1±0.0^{a}	2.1±0.2^{a}
Ash	2.2±0.0^{a}	2.9±0.07^{b}	2.1±0.07^{a}	3.3±0.1^{c}	2.0±0.03^{c}	1.4±0.0^{a}	1.7±0.0^{b,c}	1.8±0.0^{b,c}

and 15.2% of total viscera, respectively. In terms of total reproductive organ weight, the testis and ovary comprised 44.7 and 46.8%, respectively. The GSI of males and females was 5.6 and 7.1%, respectively. Note that some spermatophores were scattered throughout the mantle cavity of males.

Proximate composition

Table 2 lists the proximate compositions of the reproductive organs. The moisture content of males was 69.9-80.4% (mean 76.3%): highest in the vas deferens and lowest in the seminal vesicle. The moisture content of females was 65.7-76.3% (mean 71.7%): highest in the nidamental gland and lowest in the oviduct ($p<0.05$). The protein content of males was 12.1-22.7% (mean 16.5%): highest in the vas deferens, lowest in the seminal vesicle, and intermediate in the testis and spermatophore sac. In females, the protein content was 13.2-19.4% (mean 16.7%): highest in the oviduct, lowest in the oviducal gland, and intermediate in the ovary and the nidamental gland ($p<0.05$). The lipid content of males was 1.0-2.7% (mean 2.1%): highest in the seminal vesicle and lowest in the spermatophore sac. The lipid content of females was 2.1-8.0% (mean 4.5%): highest in the oviduct, lowest in the oviducal and nidamental glands, and intermediate in the ovary ($p<0.05$). The ash content of males and females were 2.1-3.3 and 1.4-2.0%, respectively, and was highest in the spermatophore sac (3.3%) and lowest in the oviduct (1.4%). Male squid had about 1.5-fold more ash content than females. Table 3 shows the t-value difference in proximate composition between the testis and ovary. The testis had more moisture ($p<0.001$) and ash ($p<0.01$), while the ovary had more lipids ($p<0.001$) and protein ($p<0.01$).

Fatty acid composition

The total fatty acid compositions of the male reproductive organs are shown in Table 4. The prominent fatty acids were DHA, EPA, 16:0, 20:1n-9, 18:0, 20:4n-6, and 18:1n-9 (only in the testis). PUFAs dominated (42.2-61.1%), while monounsaturated fatty

Table 3. Comparison of proximate composition of testis and ovary from common squid (wt %). Data are presented as mean ± SD of four determinations (two groups×two determinations). $^{*}p<0.01$, $^{**}p<0.001$

Component	Testis	Ovary	t-value
Moisture	76.7±0.2	71.0±0.1	53.24**
Protein	17.1±0.6	18.3±0.2	7.54*
Lipid	2.7±0.2	5.9±0.2	19.69**
Ash	2.2±0.0	2.0±0.0	4.87*

acids (MUFAs) made up the lowest proportion (15.2-22.8%) and saturated fatty acids (SFAs) were at intermediate levels (21.4-35.0%). PUFA levels were highest in the vas deferens (61.1%), lowest in the testis (42.2%), and intermediate in the seminal vesicle (53.5%) and spermatophore sac (52.8%). In contrast, SFA levels were highest in the testis (35.0 %), lowest in the vas deferens (21.4 %), and intermediate in the spermatophore sac (31.7%) and seminal vesicle (28.4%). Of the total SFAs, the proportion of 16:0 was highest in the testis (21.0%), lowest in the vas deferens (7.6%), and intermediate in the seminal vesicle (18.1%) and spermatophore sac (19.1%). The proportion of 18:0 was higher in the vas deferens (8.7%) and the testis (7.3%) and lower in the spermatophore sac (6.8%) and seminal vesicle (5.9%) ($p<0.05$). Of the total MUFAs, the proportion of 20:1 n-9 was higher in the vas deferens (10.2%) and seminal vesicle (10.0%) and lower in the testis (8.5%) and spermatophore sac (7.2%) ($p<0.05$). The 18:1 n-9 was a prominent fatty acid only in the testis (5.2%). Of the total PUFAs, the proportion of DHA was highest in the spermatophore sac (26.8%), and showed no significant differences ($p<0.05$) in other reproductive organs (20.8-22.2%). The level of EPA was highest in the vas deferens (28.7%), followed by the seminal vesicle (26.9%), spermatophore sac (17.9%), and the testis (14.4%) ($p<0.05$). Therefore, the level of n-3 PUFAs, such as DHA and EPA, was highest in the vas deferens (50.9%), followed by the seminal vesicle (47.8%), spermatophore sac (44.7%), and finally the testis (35.2%). The 20:4 n-6 (arachidonic acid, AA) was highest in the vas deferens (9.0%), followed by the spermatophore sac (6.0%), testis

Table 4. Fatty acid composition of total lipid of each reproductive organ from male squid (wt %). Data are presented as mean ± SD of four determinations (two groups×two determinations), fatty acid components present at <0.5% in all the values of each lane were removed and different superscript letters indicate statistically siginificant difference ($p<0.05$). [2]DMA, dimethyl acetals. [3]Others include 15:0 and 17:0 anteiso. [4]Others include 18:1 DMA and 22:1n-9. [5]Others include 17:2n-8, 18:2n-6, 18:4n-3, 20:2n-6, 20:3n-3, 20:4n-3, 22:3n-6, 22:4n-6, 22:5n-6 and 22:5n-3. [6]ND, not detected.

Fatty acid	Testis	Vas deferens	Seminal vesicle	Spermatophoric sac
14:0	2.6±0.6^{c}	1.0±0.2^{a}	1.8±0.1^{b}	1.4±0.1^{a,b}
16:0 DMA[2]	0.4±0.0^{a}	0.7±0.3^{b}	0.2±0.0^{a}	1.0±0.6^{c}
16:0	21.0±2.2^{c}	7.6±0.6^{a}	18.1±0.4^{a,b}	19.1±0.6^{b}
17:0	1.2±0.2^{c}	1.1±0.1^{a,b}	1.1±0.0^{b,c}	1.0±0.0^{a}
18:0 DMA	1.4±0.0^{b}	1.7±0.9^{b}	0.6±0.1^{a}	1.5±0.1^{b}
18:0	7.3±0.3^{c}	8.7±0.2^{d}	5.9±0.0^{a}	6.8±0.0^{b}
20:0 DMA	0.5±0.0	0.6±0.3	0.2±0.0	0.5±0.1
Others[3]	0.6	0	0.5	0.4
∑Saturates	35.0	21.4	28.4	31.7
16:1n-9	1.7±0.1^{d}	0.2±0.0^{a}	0.5±0.0^{b}	0.6±0.1^{c}
16:1n-7	0.2±0.0	0.9±0.4	0.1±0.0	0.2±0.0
18:1n-11	1.8±0.0^{b}	3.1±0.6^{c}	0.6±0.0^{a}	0.8±0.6^{a}
18:1n-9	5.2±0.3^{c}	0.8±0.1^{a}	2.5±0.0^{b}	2.7±0.3^{b}
18:1n-7	2.2±0.1^{b}	1.2±0.1^{a}	1.2±0.0^{a}	1.2±0.1^{a}
18:1n-5	0.5±0.0	0.6±0.1	0.3±0.0	0.3±0.0
20:1n-11	0.6±0.7^{b}	ND[6]	1.7±0.1^{d}	1.2±0.0^{c}
20:1n-9	8.5±0.8^{a,b}	10.0±2.1^{b,c}	10.2±0.2^{c}	7.2±0.1^{a}
22:1n-11	1.5±0.3^{c}	ND	0.2±0.6^{a}	0.4±0.1^{b}
Others[4]	0.6	0.5	0.3	0.6
∑Monoenes	22.8	17.3	17.6	15.2
20:4n-6	5.2±0.3^{b}	9.0±0.4^{d}	4.2±0.0^{a}	6.0±0.0^{c}
20:5n-3	14.4±1.0^{a}	28.7±0.8^{d}	26.9±0.1^{c}	17.9±0.1^{b}
22:6n-3	20.8±2.1^{a}	22.2±0.6^{a}	20.9±0.3^{a}	26.8±0.5^{b}
Others[5]	1.8	1.2	1.5	2.1
∑Polyenes	42.2	61.1	53.5	52.8
Unknown	ND	0.2±0.0	0.5±0.0	0.3±0.0

(5.2%), and seminal vesicle (4.2%) ($p<0.05$). Table 5 shows the total fatty acid compositions in the reproductive organs of female squid. The prominent fatty acids were similar to those of males, except for AA. The PUFAs also dominated, and were highest in the nidamental gland (58.6%) and oviducal gland (56.3%) and lowest in the ovary (47.0%) and oviduct (46.6%). SFA was the second most abundant class of fatty acid, and was highest in the oviduct (34.8%) and ovary (33.9%) and lowest in the oviducal gland (29.8%) and nidamental gland (29.0%). The MUFA was the least abundant class of fatty acid, and was highest in the ovary (18.2%) and oviduct (17.6%) and lowest the oviducal gland (13.3%) and nidamental gland (11.7%). The 16:0, the most abundant SFA fatty acid, was highest in the oviduct (26.3%), followed by the ovary (24.6%); no significant differences were observed in any other organs (19.5-20.2%). The proportion of 18:0 was slightly higher in the oviducal gland (6.3%) and ovary (5.8%) than in the oviduct (5.0%) and nidamental gland (5.0%) ($p<0.05$). Of the total MUFAs, the proportion of 20:1n-9 was about the same in all female reproductive organs, but the proportion of 18:1 n-9 was about two to three times higher in the ovary (4.8%) and oviduct (4.3%) than in the oviducal gland (1.2%) and nidamental gland (2.1%) ($p<0.05$). Of total FUFA, the proportion of DHA was the highest in the oviduct (32.0%), followed by the ovary (30.8%), oviducal gland (28.9%), and nidamental gland (28.6%) ($p<0.05$). The proportion of EPA was higher in the nidamental gland (22.6%) and oviducal gland (21.5%) than in the ovary (12.8%) and oviduct (11.3%) ($p<0.05$). Therefore, the levels of n-3 PUFAs such as DHA and EPA were higher in the nidamental gland (51.4%) and oviducal gland (50.4%) than in the oviduct (43.3%) and ovary (43.6%). AA was a minor fatty acid, only prominent in the male reproductive organs, although both the oviducal and nidamental glands had about 3% AA. As shown in Table 6, the testis contained the highest levels of EPA, AA, and 20:1 n-9, while the ovary contained the highest levels of DHA and 16:0.

Discussion

We found that the lipid content of the testis was about half that of the ovary, similar to previous re-

Table 5. Fatty acid composition of total lipid of each reproductive organ from female squid (wt %). Data are presented as mean ± SD of four determinations (two groups×two determinations), fatty acid components present at <0.5% in all the values of each lane were removed and different superscript letters indicate statistically siginificant difference ($p<0.05$). [2]DMA, dimethyl acetals. [3]Others include 15:0, 16:0 DMA and 17:0 anteiso and 20:0 DMA. [4]Others include 16:1n-7, 18:1 DMA, 18:1n-5, 22:1n-11 and 22:1n-9. [5]Others include 17:2n-8, 18:2n-6, 18:4n-3, 20:3n-3, 20:4n-3 and 22:3n-6.

Fatty acid	Ovary	Oviduct	Oviducal gland	Nidamental gland
14:0	1.8±0.1^{c}	2.0±0.0^{d}	1.5±0.0^{b}	1.2±0.1^{a}
16:0	24.6±1.0^{b}	26.3±0.1^{c}	19.5±0.3^{a}	20.2±0.9^{a}
17:0	0.7±0.0^{b}	0.6±0.0^{a}	1.1±0.0^{c}	1.0±0.0^{c}
18:0 DMA[2]	0.5±0.0^{a}	0.4±0.0^{a}	0.8±0.1^{b}	0.9±0.1^{c}
18:0	5.8±0.0^{b}	5.0±0.0^{a}	6.3±0.1^{c}	5.0±0.2^{a}
Others[3]	0.5	0.5	0.6	0.7
∑Saturates	33.9	34.8	29.8	29.0
16:1n-9	0.5±0.0^{a,b}	0.5±0.0^{a}	0.5±0.1^{a}	0.4±0.1^{a}
18:1n-11	0.6±0.0^{b,c}	0.7±0.0^{c}	0.4±0.1^{a}	0.4±0.0^{a}
18:1n-9	4.8±0.1^{d}	4.3±0.0^{c}	2.1±0.2^{b}	1.2±0.1^{a}
18:1n-7	1.3±0.0^{b}	1.2±0.0^{b}	1.1±0.0^{a}	1.1±0.0^{a}
20:1n-11	3.6±0.1^{c}	3.8±0.1^{d}	1.8±0.0^{b}	1.4±0.0^{a}
20:1n-9	6.5±0.1^{b}	6.2±0.0^{a}	6.4±0.1^{b}	6.4±0.3^{a,b}
Others[4]	0.5	0.9	1	0.8
∑Monoenes	18.2	17.6	13.3	11.7
20:2n-6	0.2±0.0	0.2±0.0	0.8±0.0	0.7±0.0
20:4n-6	1.5±0.0^{b}	1.3±0.0^{a}	3.1±0.0^{c}	3.3±0.1^{d}
20:5n-3	12.8±0.2^{b}	11.3±0.1^{a}	21.5±0.2^{c}	22.6±0.8^{d}
22:4n-6	0.1±0.0	0.1±0.0	0.4±0.0	0.7±0.8
22:5n-6	0.3±0.0	0.4±0.0	0.3±0.0	1.1±1.6
22:5n-3	0.7±0.0^{a}	0.6±0.0^{a}	0.7±0.0^{a}	1.0±0.9^{a}
22:6n-3	30.8±0.9^{b}	32.0±0.1^{c}	28.9±0.4^{a}	28.6±0.8^{a}
Others[5]	0.6	0.7	0.6	0.6
∑Polyenes	47.0	46.6	56.3	58.6
Unknown	0.8±0.0	1.0±0.0	0.6±0	0.6±0.0

Table 6. Comparison of prominent fatty acid composition of testis and ovary (wt %). Data are presented as mean ± SD of four determinations (two group× two determinations), fatty acid components present at <0.5% in all the values of each lane were removed. $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$

Fatty acid	Testis	Ovary	t-value
16:0	21.0±2.2	24.6±1.0	2.97*
18:0	7.3±0.3	5.8±0.0	11.85**
18:1n-9	5.2±0.3	4.8±0.1	2.47
20:1n-11	0.6±0.7	3.6±0.1	8.99**
20:1n-9	8.5±0.8	6.5±0.1	5.12*
20:4n-6	5.2±0.3	1.5±0.0	29.11***
20:5n-3	14.4±1.0	12.8±0.2	3.22*
22:6n-3	20.8±2.1	30.8±0.9	8.92**

ports on cuttlefish (*Sepia officina*, Blanchier and Boucaud-Camou, 1984), Argentine shortfin squid (*Illex argentinus*, de Moreno et al., 1998), sweet smelt (Jeong et al., 2000), and tuna (Hiratsuka et al., 2004). This may occur because the lipids may be reserved only for sperm production, development, and motility, while ovaries may need more lipid as a major energy reserve for egg production and development. Moreover, the higher lipid content of the oviduct (8.0%) may serve as temporary storage of lipid before fertilization and transfer of lipid to the eggs. A negative correlation was observed between the moisture and protein content of male (r=-0.99) and female (r=-0.94) reproductive organs and also between the moisture and lipid content of female (r=-0.96) organs. In particular, the oviducal and nidamental glands contained lower levels of four proximate (moisture, protein, lipid and ash) compositions compared to the other female reproductive organs. This means that the glands contain more carbohydrate from glycoprotein than the other organs, although no determination of carbohydrate was made in this study. However, previous studies have shown that these glands, which are accessory organs of the reproductive system, secrete mucosubstances when egg masses are spawned. The oviducal gland secretes a viscous substance that envelops the eggs, and the nidamental gland secretes an albuminous substance that forms the egg mass surface layer (Hamabe, 1962). Major components of these mucosubstances are glucose, galactose, and fucose for neutral sugar; *N*-acetylglucosamine and *N*-acetylgalactosamine for amino sugar; and threonine, praline, and isoleucine for amino acid (Kimura et al., 2004). A high ash

content was observed in all male reproductive organs, particularly in the spermatophore sac. This may have been due to minerals such as calcium and phosphorus required by a cement body located between the sperm mass and ejaculatory apparatus within a club-like spermatophore with a hard outer shell. This arrow-head-like structure is presumably used to penetrate the tissue of the female (Takahama et al., 1991). The lower level of lipid in the spermatophore sac may be attributable to this higher level of ash. We found that the fatty acid profiles of the reproductive organs of squid were similar to those of muscle and viscera (Kim et al., 2006; Moon et al., 2006), but different in their proportions. In general, squid muscle (Kim et al., 2006) and viscera (except the liver) (Moon et al., 2006) contain PUFA>SFA>MUFA, while the liver contains PUFA>MUFA>SFA. Our results on the proportions of fatty acid groups were similar to those of Moon et al. (2006). Muscle and viscera contain more DHA than EPA (Kim et al., 2006; Moon et al., 2006), but in spite of the same origin, each reproductive organ was not the same. The testis and spermatophore sac in males, and all reproductive organs in females had more DHA, while the vas deferens and seminal vesicle contained a higher level of EPA. The reason for this difference is unclear, and thus further study is necessary, especially with respect to the fatty acid composition of PL classes such as PC and PE, which are the major PL classes in most tissues. We also found that the percentage of n-3 PUFA was 35.2-50.9% in males and 43.3-51.2% in females. These results are slightly less than those of squid muscle (approximately 50%) but similar to those of squid viscera (36-49%). Although the percentage of n-3 PUFA in the reproductive organs, with respect to total lipid content, is lower than that in squid muscle, more n-3 PUFA is present in the reproductive organs because far more total lipid exists. Therefore, we conclude that the gonad of the common squid, particularly the ovary, could be a good source of n-3 PUFA. However, the distribution of n-3 PUFA in the reproductive organs (mainly the gonads) differs between the sexes, and DHA and EPA preferentially accumulate in the testis and ovary, respectively, and serve different physiological functions (Surai et al., 1999; 2000; Jeong et al., 2002). Jeong et al. (2002) studied the total fatty acid composition of the gonads of wild and cultured sweet smelt, a freshwater fish, and reported that the testes contained more DHA and EPA than the ovaries and that the proportion of DHA in both gonads was higher than that of EPA. In contrast, the ovary of skipjack tuna contains more DHA and EPA than the testis (Hiratsuka et al., 2004), and the proportion of DHA in both gonads is also higher than that of EPA. We also found that the proportion of DHA was higher in the ovary than the testis, but that EPA was higher in the testis than in the ovary. Therefore, these results suggest that DHA and EPA are rich in the testis and ovary of fishes, but their proportions vary among fish species. We also found that the proportion of AA was higher in all male reproductive organs, including the testis, than in all female organs, including the ovary.

DHA is rich in the sperm of humans (Conquer et al., 1999) and ducks (Surai et al., 2000) as well as the testes of fish (Jeong et al., 2002). DHA concentration may be positively correlated with sperm density, the number of motile sperm, and sperm motility (Nissen and Kreysel, 1983; Conquer et al., 1999). In the testis of common squid, DHA was also rich but lower than that in the ovary, suggesting that DHA in common squid may be needed much more in females than in males for normal physiological function of their reproductive systems. In fact, female common squid may need a large amount of DHA not only for the development of eggs but also for nourishment after hatching. In fish, developing eggs and larval stages probably have a greater need for n-3 PUFA (Bell et al., 1995). In contrast to DHA, the percentages of EPA and AA were significantly higher in the testis than in the ovary. EPA and AA, and n-3 and n-6 fatty acids play very important roles in the reproductive function of males and females, respectively, although EPA competitively inhibits the formation of PGE2 from AA (Weber, 1990). Wade et al. (1994) demonstrated opposing effects of n-3 and n-6 series fatty acids on testicular steroid production in goldfish. That is, they found that the n-6 fatty acid AA stimulated testosterone production, whereas n-3 fatty acids, particularly EPA, functioned as an inhibitory regulator of steroid production.

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References

AOAC. 1990. Official Methods of Analysis (15th ed.). Association of Official Analytical Chemists, Arlington, VA, USA.

AOCS. 1998. AOCS Official Method. Ce 1b-89. In: Official Methods and Recommended Practice of the AOCS (5th ed.). Firestone, D. ed. AOCS, Champaign,

USA.

Baek, H.J., J.W. Kim, Y.J. Cho and S. Kim. 2006. Sexual maturity and reproductive cycle of the common squid *Todarodes pacificus* in the East Sea of Korea. J. Kor. Fish. Soc., 39, 472-479.

Bartlett, G.R. 1959. Phosphorus assay in column chromato-graphy. J. Biol. Chem., 234, 466-468.

Bell, M.V., R.S. Batty, J.R. Dick, K. Fretwell, J.C. Navarro and J.R. Sargent. 1995. Dietary deficiency of docosahexaenoic acid impairs vision at low light intensities in juvenile herring (*Clupea harengus*). Lipids, 30, 443-449.

Blanchier, B. and E. Boucaud-Camou. 1984. Lipids in the digestive gland and the gonad of immature and mature *Sepia officinalis* (Mollusca: Cephalopoda). Mar. Biol., 80, 39-43.

Bligh, E.G. and W.J. Dyer. 1959. A rapid method of total lipid extraction and purification. Can. J. Biochem. Physiol., 37, 911-917.

Boyle, P. and P. Rodhouse. 2005. Cephalopods: Ecology and Fisheries. Blackwell Science, Oxford, UK.

Breslow, J.L. 2006. n-3 Fatty acids and cardiovascular disease. Am, J. Clin. Nutr., 83, 1477S-1482S.

Conquer, J.A., J.B. Martin, I. Tummon, L. Watson and F. Tekpetey. 1999. Fatty acid analysis of blood serum, seminal plasma and spermatozoa of normozoospermic vs. asthenozoospermic males. Lipids, 34, 793-799.

De Moreno, J.E.A., V.J. Moreno, L. Ricci, M. Roldan and M. Gerpe. 1998. Variations in the biochemical composition of the squid *Illex argentinus* from the South Atlantic Ocean. Comp. Biochem. Physiol., 119B, 631-637.

FAO. 2005. Yearbooks of Fisheries Statistics. Electronic Publishing Policy and Support Branch Communication Division, FAO, Rome, Italy.

Hamabe, M. 1962. Embryological studies on the common squid, *Ommastrephes sloani pacificus* Steenstrup, in the southwestern waters of the Sea of Japan. Bull. Japan Sea Reg. Fish. Res. Lab., 10, 1-45.

Hibbeln, J.R., J.M. Davis, C. Steer, P. Emmett, I. Roger, C. Williams and J. Golding. 2007. Maternal seafood comsumption in pregnancy and neurodevelopmental outcomes in childhood (ALSPAC study): an observational cohort study. Lancet, 369, 578-585.

Hiratsuka, S., T. Kitagawa, Y. Matsue, M. Hashidume and S. Wada. 2004. Lipid class and fatty acid composition of phospholipids from the gonads of skipjack tuna. Fish. Sci., 70, 903-909.

Hirayama, T. 1990. Life-style and mortality: A large-scale census-based cohort study in Japan. Contrib. Epidemiol. Biostat., 6, 1-133.

Jeong, B.Y., W.G.. Jeong, S.K. Moon and T. Ohshima. 2002. Preferential accumulation of fatty acid in the testis and ovary of cultured and wild sweet smelt *Plecoglossus altivelis*. Comp. Biochem. Physiol., 131B, 251-259.

Jeong, B.Y., S.K. Moon, W.G. Jeong and T. Ohshima. 2000. Lipid classes and fatty acid compositions of wild and cultured sweet smelt *Plecoglossus altivelis* muscles and eggs in Korea. Fish. Sci., 66, 716-724.

Jeong, B.Y., T. Ohshima, C. Koizumi and Y. Kanou. 1990. Lipid deterioration and its inhibition of Japanese oyster during frozen storage. Nippon Suisan Gakkaishi, 56, 2083-2091.

Johnson, E.J. and E.J. Schaefer, 2006. Potential role of dietary n-3 fatty acids in the prevention of dementia and macular degeneration. Am, J. Clin. Nutr. 83, 1494S-1498S.

Juanico, M. 1983. Squid maturity scales for population analysis. In: Advances in Assessment of World Cephalopod Resources. Caddy, J.F. ed. FAO Fisheries Technical Paper, No. 231, 341-378,

Kim, K.D., J.Y. Kang, S.K. Moon and B.Y. Jeong. 2006. Lipid class and fatty acid composition of muscle portions from male and female common squid *Todarodes pacificus*. J. Kor. Fish. Soc., 39,367-375.

Kimura, S., Y. Higuchi, M. Aminaka, J.R. Bower and Y. Sakurai. 2004. Chemical properties of egg-mass mucin complexes of the ommastrephid squid *Todarodes pacificus*. J. Moll. Stud., 70, 117-121.

Kinsella, J.E., 1988. Food lipids and fatty acids-Importance in food quality, nutrition, and health. Food Technol., 42, 124-145.

Koizumi, C., B.Y. Jeong and T. Ohshima, 1990. Fatty chain compositions of ether and ester glycerophospholipids in the Japanese oyster *Crassostrea gigas* (Thunberg). Lipids, 25, 363-370.

MOMAF. 2005. Statistic Database for Fisheries Production. Retrieved from http://fs.fips.go.kr/main.jsp .

Moon, S.K., K.D. Kim, J.Y. Kang, N.J. Sung and B.Y. Jeong. 2006. Lipid class and fatty acid composition of the viscera from common squid, *Todarodes pacificus*. J. Kor. Fish. Soc., 39, 376-383.

Nissen, H.P. and H.W. Kreysel. 1983. Polyunsaturated acids in relation to sperm motility. Andrologia,15, 264-269.

Surai, P.F., J-P. Brillard, B.K. Speake, E. Blesbois, F. Seigneurin and N.H.C. Sparks. 2000. Phospholipid fatty acid composition, vitamin E content and susceptibility to lipid peroxidation of duck spermatozoa. Theriogenology, 53, 1025-1039.

Surai, P.F., B.K. Speake, R.C. Noble and M. Mezes, 1999. Species-specific differences in the fatty acid profiles of the lipids of the yolk and of the liver of the chick. J. Sci. Food Agric., 79, 733-736.

Takahama, H., T. Kinoshita, M. Sato and F. Sasaki. 1991.

Fine structure of the permatophores and their ejaculated forms, sperm reservoirs, of the Japanese common squid, *Todarodes pacificus*. J. Morphol., 207, 241-252.

Wade, M.G., G. Van Der Kraak, M.F. Gerritis and J.S. Ballantyne. 1994. Release and steroidogenic actions of polyunsaturated fatty acids in the gold fish testis. Biol. Reprod., 51, 131-139.

Weber, P.C. 1990. The modification of the arachidonic acid cascade by n-3 fatty acids. In: Advances in Prostaglandin, Thromboxane and Leukotriene Reserch, Vol. 20. Samuelson, B., S.E. Dahlen, J. Fritsch and P. Hedgvist, eds. Raren Press, New York, 232-240.

Yazawa, K. and H. Kageyama. 1991. Physiological activity of docosahexaenoic acid. Yukagaku, 40, 974-978.

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