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Fatty acid composition of important aquatic animals in Southern Thailand

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Abstract: Aquatic animals are important to health-conscious consumers due to their high content of polyunsaturated fatty acids (PUFA) particularly omega-3 FA. This paper reports the fat contents and fatty acid profiles of 20 species of marine fish and 6 species of squid and shrimp (obtained in the fishing port of Pattani, Thailand), in addition to 7 types of Thai freshwater fish to create a fatty acid database. Among this, some of them have few reports. The aquatic animals in this study had 1.08–3.36% fat, and contained a high fraction of unsaturated fatty acids; some had a PUFA fraction >40% of total fatty acids. This was the case, among others, for *Megalaspis cordyla* (hardtail scad) and *Selar crumenophthalmus* (bigeye scad) in marine fish, *Channa striata* (snakehead fish) in freshwater fish, and *Photololigo duvauceli* (Indian squid). Of the 33 aquatic animals in this study, 27 had more PUFA-n3 (omega-3) than PUFA-n6 (omega-6); and 10 species had more than 0.5 g of docosahexanoic acid (DHA) and eicosapentaenoic acid (EPA) per 100 g of meat. In particular, *Euthynnus affinis* (Eastern little tuna) had more than 1 g of DHA and EPA per 100 g of meat. For freshwater fish, *Clarias batrachus* (catfish) had PUFA 40.1% of total fatty acid, and 0.69 g of DHA and EPA per 100 g of meat, making it a potential source of PUFA-n3 in freshwater fish.

Keywords: Fatty acid, aquatic animal, marine fish, freshwater fish, omega-3

Introduction

Southern Thailand is an important area for producing and exporting fishery products. There are 12 fishing ports, namely: Songkla, Pattani, Chumporn, Surat Thani, Nakorn Sri Thammarat, Narathiwat, Ranong, Phuket, Pang Nga, Krabi, Trang, and Satoon. Among these, Pattani is the second largest fishing port; it is located relatively far south, and has an estimated marine culture volume of 110,000 tons/yr, with more than 30 types of aquatic animals.

Aquatic animal fats are good sources of essential fatty acids that are not synthesized in the human body. Fatty acids in fish oil have a very distinctive character compared to fatty acids from other sources. They consist not only of essential fatty acids, but are also a significant source of omega-3 fatty acids – especially eicosapentaenoic acid (EPA, C20:5n3) and docosahexanoic acid (DHA, C22:6n3). These fatty acids play a vital role in human nutrition, disease prevention, and health promotion. There are reports that EPA can help prevent heart disease (Uauy *et al*., 2001) since it decreases triglycerides and VLDL (very low-density lipoprotein) cholesterol (Frenoux *et al*., 2001); whereas DHA is a primary component of membranes in the brain, and possibly delays the onset of Alzheimer's disease (Cunnane *et al*., 2009). The best natural sources of omega-3 fatty acids are cold-water fish such as salmon, mackerel, tuna and sardine, depending on genotype, regional and climate factors. However, warm-water fishes, both marine and freshwater, are also a significant source of omega fatty acids. Even so, there is not much existing information on the fatty acid profiles of different types of commonly consumed marine animals and freshwater fish from warm-water areas.

The objective of this study was to investigate the quantity of fatty acids in some important and commonly consumed aquatic animals and freshwater fish, in terms of individual fatty acids, saturated fatty acids (SFA), unsaturated fatty acids (UFA) and PUFA-n3 fatty acids, in order to create a nutritional database. Samples were collected every month for 10 months, and carefully analyzed by a 100 m GC capillary column to ensure accuracy.

Materials and Methods

Chemicals

Standard fatty acid methyl ester mixtures were purchased from Sigma Chemical Co. (St. Louis, MO) and stored at -20°C. All chemicals and solvents were reagent grade and purchased from Sigma Chemical Co. and Fisher Scientific, Inc. (Pittsburgh, PA).

Sample preparation

Twenty species of economically important marine fish and 6 types of squid and shrimp (Table 1) were collected from the fishing port of Pattani, Thailand. Seven species of freshwater fish were purchased

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from local markets. The samples of each species were selected randomly, and collected every month for 10 months, from March through December. Samples were put in plastic bags, kept in an icebox until turned in to the laboratory within 1 h, and then kept at -20°C in a freezer for not more than 24 h prior to further analysis. Only edible muscle was used to determine fat content and fatty acid composition. Each lot of samples collected was analyzed in 3 replicates.

Fat extraction

For accurate results, three fat extraction methods were compared: 1) Bligh and Dyer (1959), referred by Manirakiza *et al*. (2000); 2) Folch *et al*. (1957) and 3) AOAC (1990). The comparison showed that solvent extraction according to Bligh and Dyer (1959) exhibited the highest extraction yield. The details of the extraction are as follows.

Edible muscle tissue samples (5 g each) were ground and mixed with 60 ml of solvent (chloroform/methanol/water, 2:1:0.5) and 25 µl of 10% BHA, then homogenized for 4 min and filtered through filter paper. Each mixture was centrifuged at 2000 x g for 10 min. The lower layer was transferred to an evaporation flask with a Pasteur pipette. Evaporation was performed with a Rotavapor® R-210 (BÜCHI, Switzerland) at 45ºC; then the residue was further dried for 15 min.

Preparation of fatty acid methyl ester (FAME)

Approximately 50 mg of the fat extracts was mixed with 2 ml of solvent (methanol/hexane, 4:1). Two hundred µl of acetyl chloride was gradually added. The aliquot was heated at 100°C in a heating box for 1 h. Five ml of 6% potassium carbonate and 2 ml of hexane were added. The solution was centrifuged at 3000 x g for 15 min; the hexane layer was then collected and dried with sodium sulfate.

Fatty acid analysis

Fatty acid methyl esters were analyzed using a 6890N gas chromatograph (Agilent Technologies, Santa Clara, CA) with an autosampler equipped with a SP-2560 fused silica capillary column, 100 m x 0.25 mm (Sigma-Aldrich/Supelco, St. Louis, MO). This long column provided a great separation between each fatty acid including their cis/trans isomers. Injector temperature was set at 240°C. The oven temperature was 75°C, held for 1 min; then increased at 20°C /min to 185 °C and held for 15 min; then raised at 4°C /min to 220°C and held for 30 min. The flame ionization detector (FID) temperature was set at 280°C. Fatty acid peaks were identified from standard fatty acid mixtures. The percent of individual fatty acids was calculated and the results expressed as mean ± SD.

Results and Discussion

Fat contents of marine fish, freshwater fish, squid and shrimp

Fat analysis was conducted for the fleshy part of each species. Twenty types of marine fish in this study (collected from Pattani fishing port) were obtained from fishing grounds along the east coast of the Gulf of Thailand. These samples contained 1.89–3.36% fat (Table 1), categorized as lean fish. Similar results have been reported by Özogul *et al*. (2007), 1.01–3.02%. Among the marine fish in this analysis, *Euthynnus affinis* (Eastern little tuna) had the highest fat content. This fish is a sustainable pelagic fish that is significant for domestic consumption in Thailand, and important for the fishery industry. The second high fat content was *Selar crumenophthalmus* (Bigeye scad). It contained 3.31% fat and had high in unsaturated fatty acid (Table 2). It was an important commonly consumed fish but had only few reports presented. Most of the freshwater fish consumed in Thailand are *Channa* sp., *Clarias* sp., *Helostoma* sp., and *Puntius* sp. Fat contents of these freshwater species were between 1.08% for *Helostoma temmincki* to 2.77% for *Clarias batrachus*. Most of these had fat contents similar to those reported in earlier studies (Özogul *et al.,* 2007; Karapanagiotidis *et al.,* 2010); but some fish, e.g. the Channidae family, had a lower fat content than previously reported from a study in Malaysia (Zuraini *et al*., 2006). Generally, diet and environmental factors affect the chemical composition of animals, together with their species. A similar type of *Channa* sp. from rice-fish farming in northeast Thailand had only 0.99% fat (Karapanagiotidis *et al.,* 2010) but the present work found 1.47% fat content.

The fat content of the fillets of squid and shrimp collected from Pattani fishing port are presented in Table 1. They were in a narrow range, from 1.38% fat for *Penaeus monodon* Fabricius (giant tiger prawn) to 1.87% for *Sepia pharaonis* (rainbow cuttlefish). Similar results were reported by Passi *et al.* (2002), who found the fat content of squid and shrimp in Italy to be 1.42% and 1.84%, for *Sepia officinalis* and *Squilla mantis* (common cuttlefish and mantis shrimp) respectively.

Fatty acid profile of marine fish

The fatty acid compositions of the marine fish studied are listed in Table 2. During the 10 months of the study, the fat content of each animal differed slightly, but not the fatty acid profile. The major fatty acids found were 16:0, 18:0, 18:1 n-9, 18:2 n-6,

Table 1. Aquatic animal types

Type	Type of aquatic animal		Fat content (%)
	Scientific name	Common name	
Marine fish	*Caesio erythrogaster*	Yellowtail fusilier	2.42±0.38
	Sillago sihama	Silver sillago	2.43±0.34
	Parastromateus niger	Black pomfret	2.58±0.51
	Atule mate	Yellowtail scad	2.13±0.27
	Nemipterus hexodon	Ornate threadfin bream	1.89±0.35
	Rastrelliger kanaguria	Indian mackerel	3.26±0.21
	Euthynnus affinis	Eastern little tuna	3.36±0.34
	Megalaspis cordyla	Hardtail scads	2.39±0.28
	Sardinella albella	Sardine	2.54±0.38
	Amblygaster leiogaster	Smooth-belly sardinella	3.04±0.17
	Otolithes ruber	Tiger-toothed croaker	2.57±0.27
	Scatophagus argus	Scat	2.46±0.27
	Mugil cephalus	Flathead mullet	2.62±0.19
	Selar crumenophthalmus	Bigeye scad	3.31±0.25
	Carangoides gymnostethus	Bludger	2.12±0.35
	Anodontostoma chacunda	Chacunda gizzard-shad	2.40±0.23
	Lutjanus johnii	John's snapper	2.52±0.39
	Eleutheronema tetradactylum	Fourfinger threadfin	2.68±0.21
	Pampus argenteus	Silver pomfret	3.22±0.67
	Elagatis bipinnulata	Rainbow runner	2.74±0.74
Fresh water fish	*Hoplolatilus sp.*	Malacanthus	2.56±0.24
	Arius truncatus	Asian redtail catfish	2.61±0.28
	Clarias batrachus	Catfish	2.77±0.28
	Helostoma temmincki	Kissing gourami	1.08±0.21
	Notopterus notopterus	Bronze featherback	1.49±0.28
	Channa striata	Snakehead fish	1.47±0.18
	Puntius gonionotus	Common silver barb	1.63±0.40
Squid and shrimp	*Sepia pharaonis*	Rainbow cuttlefish	1.87±0.19
	Photololigo duvaucelii	Indian squid	1.59±0.23
	Penaeus merguiensis	Banana prawn	1.48±0.28
	Litopenaeus vannamei	Whiteleg shrimp	1.62±0.20
	Penaeus monodon Fabricius	Giant tiger prawn	1.38±0.25
	Macrobrachium rosenbergii	Giant freshwater prawn	1.66±0.31

20:5 n3 and 22:6 n3. Palmitic acid was the dominant saturated fatty acid, contributing approximately 50–70% of total saturated fatty acids. It occurs naturally in fish, being a source of metabolic energy for their growth (Sargent *et al.,* 2002). A comparison of UFA and SFA for all 20 species of marine fish in this study found higher UFA (range 50.4–68.9%) than SFA (range 31.1–49.6%). Some marine fish from Pattani fishing port were found to have more than 67% UFA, such as *Megalaspis cordyla* (hardtail scad) and *Parastromateus niger* (black pomfret).

The fraction of PUFA in marine fish in this study ranged from 25.3% of total fat for *Amblygaster leiogaster* (smooth-belly sardinella) to 53.1% for *Atule mate* (yellowtail scad). Yellowtail scad is one of the main fish species available in Pattani and Songkla fishing ports; this work confirmed that it is also a healthy choice for human consumption. In addition, inexpensive fish eg. *M. cordyla* and *S. crumenophthalmus* had high PUFA content as well.

PUFA-n3 have been shown to be highly relevant in primary and secondary cardiovascular prevention (*Din et al.,* 2007), as well as in modulation of inflammatory and immune responses (Calder and Zurier, 2001). PUFA may also interfere with the carcinogenic process, and may play a significant role in the prevention of malignancies (Terry *et al.,* 2003). Several other chronic disorders have been reported to be associated with low intake of PUFA-n3 fatty acids, such as obesity and some neuropsychiatric disorders (Browne *et al.,* 2006). The content of PUFA-n3 (omega-3) in the study samples, ranging from 10.1–38.1%, was higher than that of PUFA-n6 (omega-6), 4.9–26.1%. *Nemipterus hexodon* (ornate threadfin bream) had the highest PUFA-n3 of marine fish at 38.1% of total fatty acids. The most abundant PUFA was docosahexanoic acid (DHA, 5.9–28.1%), while eicosapentaenoic acid (EPA) was present in a range of 0.3–9.2%. The generally recommended daily intake of DHA/EPA is 0.5 g for infants and 1 g for adults (Kris-Etherton *et al*., 2002). Therefore, consumption of *Euthynnus affinis* (Eastern little tuna), with approximately 1.0 g DHA+EPA per 100 g meat, would be a good choice from a nutritional standpoint.

Fatty acid profile of freshwater fish

The main fatty acids of freshwater fish for all 7 species were C16:0, C18:0, C18:1n-9, and 18:2n6, and some species had high C22:6n3. Fatty acid profiles showed UFA and SFA in the ranges of 50.6–75.9% and 24.1–49.4%, respectively, of total fatty acid. Among these, *Puntius gonionotus* (common silver barb) and *Clarias batrachus* (catfish) had the highest UFA content.

The fraction of PUFA in freshwater fish ranged from 25.6–41.2%. The fractions of PUFA-n3 (ranging from 7.7–28.0%) were higher than those of PUFA-n6 (ranging from 8.1–20.8%). *Clarias batrachus* had the highest PUFA-n3 among freshwater fish at 28.0% of total fatty acids. The most abundant PUFA-n3 were DHA (2.9–23.3%) and EPA (0.5–5.0%). Compared to marine fish, freshwater fish had significantly lower DHA and EPA contents. However, *Clarias batrachus* (catfish) was a significant source of DHA at 23.3%. This study found that catfish, with an EPA fraction of 1.5%, was a good source of PUFA-n3, and therefore should be recommended to consumers. We could not find any data to compare the DHA content of the catfish in this study to those caught in other parts of Thailand. Some data is available for *Channa striatus* in eastern Thailand, where study results have shown

Table 2. Fatty acid composition of marine fish

Fatty acid	Type of marine fish				
	O. ruber	*S. argus*	*M. cephalus*	*S. crumenophthalmus*	*C. gymnostethus*
Saturated fatty acid					
C8:0	0.0±0.0	0.0±0.0	0.0±0.0	0.3±0.0	0.2±0.1
C10:0	0.1±0.0	0.4±0.0	0.1±0.1	0.2±0.0	0.2±0.1
C11:0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
C12:0	0.3±0.1	0.7±0.0	0.5±0.0	0.1±0.0	0.4±0.1
C14:0	1.8±0.3	2.4±0.0	5.8±0.3	2.5±0.2	2.6±0.1
C15:0	0.0±0.0	0.0±0.0	0.0±0.0	1.6±0.1	0.0±0.0
C16:0	19.8±1.4	28.2±0.4	22.4±1.4	19.3±1.1	29.1±1.4
C18:0	7.8±0.4	7.1±0.2	7.3±0.6	10.9±0.6	12.2±0.3
C20:0	0.3±0.0	2.0±0.2	0.5±0.1	0.6±0.1	0.8±0.2
C21:0	0.0±0.0	0.0±0.0	0.3±0.0	0.3±0.1	0.6±0.1
C22:0	0.0±0.0	1.3±0.1	0.9±0.1	0.5±0.0	0.3±0.1
C23:0	0.0±0.0	0.0±0.0	0.7±0.1	0.1±0.0	0.0±0.0
C24:0	2.5±0.3	2.3±0.0	1.3±0.0	3.7±0.1	1.8±0.0
Monounsaturated FA					
C14:1	1.9±0.1	2.3±0.0	4.9±0.5	0.4±0.0	0.6±0.1
C16:1	3.7±0.4	4.1±0.0	6.8±0.6	2.7±0.3	3.8±0.0
C18:1n9t	2.6±0.1	1.9±0.1	1.3±0.0	1.9±0.5	3.0±0.0
C18:1n9c	14.2±0.8	12.7±1.1	12.2±0.6	8.0±0.3	12.5±0.6
C20:1	0.0±0.0	0.0±0.0	1.7±0.1	0.0±0.0	0.0±0.0
C22:1n9	0.0±0.0	0.1±0.4	0.5±0.1	0.0±0.0	0.3±0.0
C24:1	0.9±0.0	0.0±0.0	0.7±0.1	1.3±0.0	1.4±0.1
Polyunsaturated FA					
C18:2n6t	2.8±0.2	3.3±0.1	0.7±0.0	1.9±0.1	1.3±0.4
C18:2n6c	6.8±0.1	11.4±0.5	3.9±0.5	2.6±0.2	5.5±0.3
C18:3n3	1.4±0.1	1.7±0.0	1.2±0.0	1.1±0.0	1.1±0.0
C18:3n6	2.7±0.2	2.3±0.0	0.5±0.1	3.1±0.1	2.1±0.1
C20:2	1.7±0.1	1.5±0.1	1.0±0.1	0.7±0.0	0.4±0.1
C20:3n3	3.9±0.5	3.7±0.0	5.9±0.5	3.4±0.3	5.5±0.2
C20:3n6	1.2±0.0	1.4±0.1	0.6±0.1	3.3±0.1	0.4±0.1
C20:4n6	1.7±0.0	1.9±0.1	0.8±0.1	1.0±0.1	1.5±0.1
C20:5n3	8.5±0.3	0.8±0.0	0.8±0.1	2.6±0.1	1.2±0.1
C22:2	2.0±0.1	0.4±0.0	0.5±0.0	3.3±0.1	0.6±0.1
C22:6n3	11.4±0.2	6.0±0.4	16.2±0.8	22.9±1.2	10.3±0.7
SFA	32.7	44.5	39.7	39.9	48.4
UFA	67.3	55.5	60.3	60.0	51.6
MUFA	23.3	21.0	28.2	14.3	21.7
PUFA	44.0	34.6	32.2	45.8	29.9
PUFAs-n3	25.1	12.3	24.2	29.9	18.1
PUFAs-n6	15.2	20.3	6.5	11.8	10.9

Fatty acid	Type of marine fish				
	A. chacunda	*L. johnii*	*E. tetradactylum*	*P. argenteus*	*E. bipinnulata*
Saturated fatty acid					
C8:0	0.2±0.1	0.1±0.0	0.0±0.0	0.3±0.3	0.4±0.0
C10:0	0.2±0.1	0.4±0.0	0.0±0.0	0.2±0.1	0.4±0.0
C11:0	0.0±0.0	0.0±0.0	0.0±0.0	0.1±0.1	0.0±0.0
C12:0	0.5±0.0	1.9±0.2	0.2±0.1	0.3±0.2	0.4±0.1
C14:0	5.0±0.4	1.4±0.1	2.0±0.0	0.3±0.1	1.3±0.1
C15:0	1.9±0.1	0.0±0.0	1.3±0.1	0.0±0.0	0.0±0.0
C16:0	14.4±0.6	21.5±0.3	18.6±1.0	23.8±1.3	20.0±0.3
C18:0	10.5±0.5	7.2±0.6	11.0±0.6	6.3±0.4	4.4±0.1
C20:0	0.4±0.1	2.7±0.1	0.4±0.0	0.3±0.0	0.5±0.1
C21:0	0.6±0.1	0.0±0.0	0.5±0.1	1.0±0.1	0.6±0.0
C22:0	0.3±0.0	0.0±0.0	0.4±0.0	1.4±0.3	0.8±0.1
C23:0	0.6±0.1	0.0±0.0	0.0±0.0	0.2±0.1	0.4±0.0
C24:0	1.5±0.1	1.7±0.1	3.7±0.2	0.7±0.1	2.9±0.0
Monounsaturated FA					
C14:1	0.7±0.1	0.7±0.1	0.6±0.0	0.0±0.0	0.5±0.0
C16:1	11.5±0.5	2.6±0.3	2.9±0.1	3.8±0.2	3.9±0.1
C18:1n9t	1.7±0.0	1.8±0.1	3.3±0.2	1.5±0.0	4.6±0.1
C18:1n9c	12.5±0.5	16.2±0.6	13.4±0.3	13.1±0.5	19.7±0.6
C20:1	0.0±0.0	0.8±0.1	0.0±0.0	10.1±0.9	0.5±0.0
C22:1n9	0.6±0.1	0.0±0.0	0.0±0.0	0.6±0.0	0.0±0.0
C24:1	2.0±0.2	2.1±0.1	1.6±0.1	0.5±0.1	1.6±0.1
Polyunsaturated FA					
C18:2n6t	1.0±0.1	2.3±0.1	1.6±0.1	0.2±0.0	0.3±0.0
C18:2n6c	4.8±0.2	7.4±0.1	6.3±0.2	3.2±0.2	7.3±0.2
C18:3n3	1.1±0.1	1.3±0.0	0.8±0.1	2.0±0.4	8.5±0.1
C18:3n6	1.5±0.1	2.8±0.1	3.7±0.1	5.9±0.4	0.4±0.0
C20:2	0.5±0.0	2.6±0.5	1.9±0.1	0.4±0.1	0.3±0.0
C20:3n3	8.0±0.3	3.8±0.1	5.4±0.3	2.0±0.0	2.0±0.0
C20:3n6	0.6±0.1	2.1±0.2	1.6±0.0	0.0±0.0	0.8±0.0
C20:4n6	0.9±0.2	3.0±0.1	1.5±0.0	3.4±0.1	0.9±0.0
C20:5n3	0.3±0.1	3.7±0.3	0.7±0.1	0.4±0.1	0.4±0.0
C22:2	0.4±0.1	0.8±0.1	1.3±0.0	0.6±0.0	0.0±0.0
C22:6n3	15.7±0.6	9.2±0.5	15.6±0.3	17.6±0.9	16.4±0.2
SFA	36.0	37.0	37.9	35.1	32.0
UFA	64.0	63.0	62.1	64.9	68.0
MUFA	29.1	24.1	21.7	29.5	30.8
PUFA	35.0	38.9	40.4	35.4	37.2
PUFAs-n3	25.2	18.0	22.6	22.1	27.3
PUFAs-n6	8.8	17.6	14.6	12.3	9.6

Table 3. Fatty acid composition of freshwater fish

Fatty acid	Type of freshwater fish			
	Hoplolatilus sp.	*A. truncatus*	*C. batrachus*	*H. temmincki*
Saturated fatty acid				
C8:0	0.0±0.0	0.0±0.0	0.0±0.0	0.5±0.0
C10:0	0.5±0.0	0.0±0.0	0.4±0.0	0.7±0.0
C11:0	0.0±0.0	0.0±0.1	0.0±0.0	0.5±0.1
C12:0	0.3±0.0	0.6±0.0	0.3±0.0	0.3±0.1
C14:0	1.7±0.1	7.4±0.4	1.1±0.1	1.1±0.1
C15:0	1.3±0.1	1.0±0.2	1.2±0.2	0.0±0.0
C16:0	24.2±0.6	26.9±1.7	23.1±1.3	29.1±1.0
C18:0	13.4±1.3	8.6±0.6	3.7±0.3	4.9±0.2
C20:0	0.6±0.0	0.0±0.0	0.6±0.1	4.2±0.2
C21:0	0.0±0.0	0.0±0.0	0.0±0.0	1.5±0.1
C22:0	0.3±0.1	0.0±0.0	1.0±0.1	0.4±0.0
C23:0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
C24:0	0.0±0.0	0.0±0.0	1.8±0.2	2.3±0.1
Monounsaturated FA				
C14:1	0.0±0.0	3.2±0.5	1.0±0.1	0.4±0.0
C16:1	4.2±0.0	5.8±0.5	1.6±0.2	0.8±0.0
C18:1n9t	4.4±0.3	3.8±0.6	2.6±0.2	0.5±0.0
C18:1n9c	23.3±1.3	9.2±0.9	20.2±1.7	6.0±0.1
C20:1	0.1±0.0	0.0±0.0	0.0±0.0	12.9±1.1
C22:1n9	0.1±0.2	0.2±0.0	1.5±0.1	1.0±0.1
C24:1	0.0±0.0	0.0±0.0	0.0±0.0	1.3±0.1
Polyunsaturated FA				
C18:2n6t	1.4±0.1	0.1±0.0	0.0±0.0	0.2±0.1
C18:2n6c	9.1±0.2	12.1±0.5	1.5±0.5	1.2±0.1
C18:3n3	2.1±0.0	4.1±0.3	3.1±0.1	2.1±0.1
C18:3n6	1.7±0.1	1.7±0.1	3.5±0.1	2.1±0.1
C20:2	0.3±0.0	0.2±0.1	2.1±0.0	1.3±0.0
C20:3n3	0.3±0.1	2.6±0.1	0.0±0.0	0.9±0.4
C20:3n6	4.3±0.4	5.7±0.5	4.4±0.6	5.5±0.5
C20:4n6	1.2±0.1	1.2±0.0	0.6±0.4	0.5±0.0
C20:5n3	2.4±0.4	1.8±0.1	1.5±0.0	5.0±0.1
C22:2	0.0±0.0	0.0±0.0	0.0±0.0	0.3±0.0
C22:6n3	2.9±0.6	3.9±0.9	23.3±1.7	12.6±1.0
SFA	42.2	44.5	33.1	45.3
UFA	57.9	55.5	66.9	54.7
MUFA	32.2	22.3	26.8	22.9
PUFA	25.6	33.3	40.1	31.7
PUFAs-n3	7.7	12.3	28.0	20.5
PUFAs-n6	17.6	20.8	10.1	9.5

Fatty acid	Type of freshwater fish		
	N. notopterus	*C. striata*	*P. gonionotus*
Saturated fatty acid			
C8:0	0.0±0.0	0.5±0.0	0.5±0.1
C10:0	0.6±0.1	0.8±0.2	0.3±0.1
C11:0	0.0±0.0	0.4±0.0	0.3±0.0
C12:0	0.2±0.0	0.3±0.0	0.2±0.0
C14:0	1.7±0.1	0.3±0.0	3.8±0.6
C15:0	0.0±0.0	0.0±0.0	0.0±0.0
C16:0	30.4±0.8	22.1±0.5	14.6±0.5
C18:0	11.1±0.2	11.2±1.0	0.4±0.0
C20:0	0.5±0.0	0.4±0.0	0.8±0.1
C21:0	1.0±0.0	0.9±0.2	0.8±0.0
C22:0	2.1±0.1	2.3±0.2	1.0±0.3
C23:0	0.0±0.0	0.0±0.0	0.7±0.1
C24:0	1.8±0.2	0.9±0.2	0.8±0.3
Monounsaturated FA			
C14:1	0.0±0.0	0.0±0.0	0.0±0.0
C16:1	0.0±0.0	1.4±0.1	0.6±0.1
C18:1n9t	0.3±0.0	0.8±0.3	0.8±0.0
C20:1	2.2±0.1	2.9±0.2	6.5±0.1
C18:1n9c	20.9±0.6	13.3±0.5	29.8±1.2
C22:1n9	0.4±0.0	0.6±0.1	2.0±0.1
C24:1	0.9±0.0	0.8±0.2	0.7±0.1
Polyunsaturated FA			
C18:2n6t	0.0±0.0	0.0±0.0	0.8±0.1
C18:2n6c	0.8±0.2	1.6±0.2	2.3±0.1
C18:3n3	0.7±0.1	3.4±0.0	3.6±0.0
C18:3n6	1.2±0.0	0.0±0.0	2.3±0.1
C20:2	0.0±0.0	0.8±0.2	0.8±0.0
C20:3n3	2.2±0.1	10.6±0.4	0.0±0.0
C20:3n6	0.0±0.0	0.0±0.0	3.4±0.5
C20:4n6	6.1±0.5	8.2±0.1	3.1±0.2
C20:5n3	0.5±0.0	0.6±0.0	2.6±0.2
C22:2	1.4±0.1	1.9±0.0	0.6±0.0
C22:6n3	13.0±0.6	13.0±0.7	16.0±0.4
SFA	49.4	39.4	24.1
UFA	50.6	60.7	75.9
MUFA	24.7	19.6	40.5
PUFA	25.9	41.2	35.4
PUFAs-n3	16.4	27.6	22.2
PUFAs-n6	8.1	9.8	11.9

Table 4. Fatty acid composition of squid and shrimp

Fatty acid	Type of squid and shrimp					
	S. pharaonis	*P. duvaucelii*	*P. merguiensis*	*L. vannamei*	*P. monodon* Fabricius	*M. rosenbergii*
Saturated FA						
C8:0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
C10:0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
C11:0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
C12:0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
C14:0	1.4±0.1	1.6±0.1	1.3±0.2	2.0±0.5	1.8±0.0	2.1±0.1
C15:0	0.6±0.1	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
C16:0	21.3±1.7	23.7±0.6	26.4±1.5	15.3±1.1	20.9±2.1	30.1±1.3
C18:0	11.5±0.3	7.9±0.1	0.4±0.0	8.9±0.1	9.9±0.4	7.3±0.2
C20:0	0.0±0.0	5.6±0.2	4.4±0.1	9.0±0.2	4.2±0.6	1.0±0.1
C21:0	1.1±0.1	2.4±0.5	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
C22:0	0.0±0.0	0.0±0.0	0.8±0.0	0.0±0.0	1.0±0.0	0.4±0.1
C23:0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
C24:0	3.6±0.5	0.0±0.0	4.5±0.1	4.8±0.0	5.9±0.4	3.5±0.0
Monounsaturated FA						
C14:1	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.1	0.0±0.0
C16:1	2.8±0.1	0.0±0.0	0.1±0.0	3.0±0.0	1.8±0.1	1.2±0.0
C18:1n9t	1.6±0.5	2.4±0.1	2.1±0.4	3.2±0.0	0.0±0.0	0.0±0.0
C18:1n9c	12.7±0.2	11.7±0.9	11.2±0.2	15.0±0.3	13.2±1.1	16.5±0.3
C20:1	0.1±0.0	0.0±0.0	2.3±0.0	3.1±0.4	2.2±0.0	0.0±0.0
C22:1n9	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
C24:1	0.0±0.0	0.0±0.0	4.4±0.0	3.7±0.5	0.0±0.0	4.1±0.1
Polyunsaturated FA						
C18:2n6t	3.1±0.2	0.8±0.1	0.9±0.0	0.0±0.0	0.8±0.1	0.1±0.1
C18:2n6c	8.0±0.2	11.0±0.1	15.6±1.3	11.1±1.0	15.7±1.1	1.8±0.0
C18:3n3	0.0±0.0	1.9±0.1	1.1±0.2	1.4±0.1	1.3±0.1	3.0±0.4
C18:3n6	4.0±0.2	3.0±0.1	0.0±0.0	1.7±0.1	0.0±0.0	2.4±0.1
C20:2	1.6±0.1	1.2±0.0	0.7±0.1	0.0±0.0	0.0±0.0	1.6±0.1
C20:3n3	4.2±0.2	5.4±0.1	4.2±0.7	2.7±0.2	4.0±0.1	3.0±0.1
C20:3n6	1.0±0.0	0.0±0.0	0.0±0.0	3.6±0.1	0.0±0.0	1.3±0.1
C20:4n6	2.2±0.1	2.0±0.5	1.9±0.1	3.0±0.0	2.1±0.1	2.0±0.0
C20:5n3	10.6±0.2	7.5±0.7	3.8±0.1	2.4±0.4	4.1±0.3	2.0±0.0
C22:2	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
C22:6n3	8.9±0.3	11.9±0.8	13.8±0.4	6.2±0.7	11.0±0.2	16.7±0.7
SFA	39.4	41.3	37.9	40.0	43.8	44.4
UFA	60.6	58.8	62.2	60.1	56.3	55.6
MUFA	17.2	14.1	20.1	28.1	17.3	21.7
PUFA	43.5	44.7	42.1	32.0	39.0	33.9
PUFAs-n3	23.7	26.7	22.9	12.6	20.4	24.7
PUFAs-n6	18.2	16.8	18.5	19.4	18.6	7.6

a mean DHA of 13.0%; while the DHA fraction of the *Channa* sp. in Malaysia was in a range 15.2–21.8% of total fatty acids (Zuraini *et al*., 2006). Some freshwater fish also have been reported to have a high content of DHA, e.g. 24% (Özogul *et al.,* 2007) and 26.5% (Ahlgren *et al*., 1994). Another significant fatty acid in freshwater fish was arachidonic acid (C20:4). Freshwater snakehead fish (*Channa striatus*) in this study had a high fraction of arachidonic acid (8.2%), similar to the result reported by Zuraini *et al*. (2006), who also noted that this fatty acid is a precursor of prostaglandin and thromboxane biosynthesis, and has been used for centuries in folk medicine to reduce pain and inflammation.

Fatty acid profiles of squid and shrimp

All six types of squid and shrimp in this study – *Sepia pharaonis* (rainbow cuttlefish), *Photololigo duvauceli* (Indian squid), *Penaeus merguiensis* (banana prawn), *Litopenaeus vannamei (*whiteleg shrimp), *Penaeus monodon* Fabricius (giant tiger prawn) and *Macrobrachium rosenbergii* (giant freshwater prawn) – are important economically; especially the most exported item, the giant tiger prawn. Major fatty acids of this group were C16:0, C18:0, C18:1n9, C18:2n6, C20:5n3 and C22:6n3. Similar to the results for marine and freshwater fish, they contained a higher amount of UFA (55.6–62.2%) than SFA (37.9–44.4%). Among these, *Penaeus merguiensis* (banana prawn) had a ratio of UFA/SFA of 1.6, which is beneficial for human health according to the recommendation of the UK Department of Health which gives a minimum value of 0.45 (HMSO, 1994 referred by Özogul *et al*., 2007).

PUFA in squid and shrimp ranged from 32.0–44.7%. These results are in agreement with a previous study of Brazilian fish by Liania *et al.* (2003) who reported PUFA of squid and shrimp in a range of 26.5–34.7%. Among the samples studied, the fraction of PUFA-n3 (ranging from 12.6–26.7%) was higher than that of PUFA-n6 (7.6–19.4%). *Macrobrachium rosenbergii* and *Photololigo duvauceli* had the highest PUFA-n3 among squid and shrimp, while *Litopenaeus vannamei* (whiteleg shrimp) contained PUFA-n3 <10%. The most abundant PUFA was DHA (6.2–16.7%); however EPA also represented a significant fraction (2.0–10.6%).

Conclusions

Fatty acid profiles of 33 species of aquatic animals were compared. Generally the animals contained a high amount of unsaturated fatty acids, which in some of them comprised more than 65% of the total fatty acids. Marine fish had a higher fraction of monounsaturated fatty acid (MUFA) and PUFA than freshwater fish. Marine fish that proved to be good sources of PUFA-n3 are *Nemipterus hexodon* (ornate threadfin bream), *Euthynnus affinis* (Eastern little tuna) and *Megalaspis cordyla* (hardtail scad). *Clarias batrachus* (catfish) is a good source of PUFA-n3 among the freshwater species. Squid and shrimp had less PUFA-n3 than the fish mentioned, but still had a high PUFA-n3 content, in a range of 9.9–21.7%.

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