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ORIGINAL ARTICLE

Lipid classes and fatty acid profile of selected Indian fresh water fishes

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Abstract Lipid extracts from meat, head and viscera of Indian fresh water fishes, viz.,catla, rohu, mrigal, common carp and tilapia were analyzed for lipid class distribution and fatty acid profile. The yield of meat ranged from 66.0–79.5% and total lipid content in meat was 0.8–3.8%. The total lipid content was higher (>4.0%) in head and viscera. Neutral lipids constituted 71.5–93.3% of the total lipid extract. Higher glycolipid content of 25.2% was observed in lipid extract from meat of common carp and higher phospholipid content (13.7%) was observed in lipid extract from meat of mrigal. Hydrocarbons, sterolesters and triacylglycerol were the major fractions of neutral lipids. Unsaturated fatty acids dominated in all the samples. Palmitic and oleic acids were the major fatty acids found in all the lipid extracts. Docosahexaenoic acid content was higher than 3% in lipid extract from meat of all the fishes. However, in most of the fishes, the content of eicosapentaenoic acid and docosahexaenoic acid were higher in visceral lipids.

Keywords Carps · Tilapia · Fatty acid · Lipid class · Lipase · Acid value

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Introduction

Fish is a good source of highly nutritive proteins, vitamins, minerals and lipids that have beneficial health effects. The world fish production (FAO 2006) has almost stagnated and presently stands at 132 million metric tons. Global fresh water fish production is mainly dependent on carps. In India, fresh water fishery is one of the major contributors to the animal proteins for the population. Indian major carps (catla, rohu, mrigal), common carp and tilapia are the major fresh water food fishes of India. Considerable information is available on the nutritional quality of marine fishes of India (Sen 2005). Reports are available on nutritional quality particularly fatty acid composition of some fresh water and marine food fishes of India (Sen et al. 1976, Nair and Gopalakumar 1978). Most of the studies on lipids are based on fish muscle, which forms a part of a staple diet (Ghosh and Dua 1997, Ackman et al. 2002). Many reports on fatty acid profile of fresh water fish are concerned with those from temperate waters (Aggelousis and Lazos 1991) and very few from tropical waters (Rahman et al 1995). Temperature of the water in which fish habitats influences the fatty acid composition of muscles, and fish needs polyunsaturated fatty acids (PUFA) to provide tolerance to low temperature, thus, fishes from tropical waters are expected to be low in PUFA compared to their temperate counterparts (Rasoarahona et al. 2004).

The major lipids storage sites in fish vary depending on species, they are primarily located in the subcutaneous tissue, belly flap, muscle tissue, liver, mesenteric tissue, and the head (Ackman 1994). Saturated fatty acids (SFA) in fish lipids are dominated by palmitic (C16:0) and myristic (C14:0) acids followed by stearic acid, whereas the major monounsaturated fatty acids (MUFA) are oleic and palmitoleic acids (Kolakowska et al. 2002). Fish oils have been considered as important sources of omega-3 fatty acids (Gbogouri et al. 2006), especially docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) which reduce

the risk of coronary heart diseases (Bhaskar et al. 2006). Both EPA and DHA lower blood pressure and prevent the development of hypertension (Prisco et al. 1998, Mori et al. 1999, Frenoux et al. 2001) which is one of the critical factors resulting in cardiovascular pathologies like atherosclerosis or stroke (Tapiero et al. 2002). These fatty acids are the major constituents of phospholipids, which in turn are major molecules in most biological membranes.

Processing of fish for consumption involves removal of head and viscera. These byproducts of fish are expected to be rich in lipids and proteins. Fish head can be a good source of PUFA. Turon et al. (2005) observed that oil recovered from Nile perch head contained more than 16% n-3 fatty acids. Sathivel et al. (2002) found that unsaturated fatty acid content in viscera of cat fish was equivalent to that in the muscles and suggested that oil from such viscera could be recovered and converted into edible oil.

Even though reports are available on the lipid profile of number of marine fishes such reports are scanty on fresh water fishes. Further, efforts have not been made for recovery of oil from fresh water fish wastes. The information on lipid profile of fresh water fish wastes would provide an opportunity for their exploitation. Against this background, this study was carried out to evaluate the lipid content and lipid classes in different body components (meat, head and viscera) of commercially important fresh water fishes from Indian waters.

Materials and methods

Five species of fresh water fishes viz., rohu (*Labeo rohita),* mrigal (C*irrhinus mrigala*), catla (*Catla catla*), tilapia (*Oreochromis mossambicus*) and common carp (*Cyprinus carpio*) were used in this study. They were obtained from the local market and transported to laboratory in ice. All the solvents and chemicals used were of analytical grade.

Preparation of lipid extracts: Head, meat and viscera portions of fish were separately analyzed for the lipid content, lipid classes and sub classes. Lipid extraction was carried out according to the method of Bligh and Dyer (1959). Different portions of fish were separately minced and homogenized using a homogenizer (Polytron PT3100, Kinematica AG, Switzerland) in a solvent mixture of chloroform: methanol (2:1), kept overnight and filtered. The lipid extract was dried over anhydrous sodium sulphate to remove traces of moisture to get total lipid extract and evaporated to dryness using rotary flash evaporator (Superfit, Bangalore, India).

Isolation of lipid classes and sub classes: Lipid classes were separated by silica gel (1:30 w/w of lipid) open column chromatography by successive elution with chloroform (1:100 of w/v lipid), acetone-methanol (9:1 w/v: 1:150 w/v of lipid) and methanol (1:100 of w/v lipid) to get neutral lipid, glycolipid and phospholipids respectively. The neutral lipid obtained was subjected to column chromatography to obtain hydrocarbons, sterolesters, triacyl glycerol (TAG), free fatty acids (FFA), diacyl glycerol (DAG) and monoacyl glycerol (MAG) using hexane and diethyl ether in different ratios (1: 30 w/v, 1:60 w/v; 1:99v/v, 1:50w/v; 5:95v/v, 1:50 w/v; 8:92v/v, 1:80 w/v; 15:85v/v, 1:50 w/v for respective subclasses).

Acid value: Acid value of the extracted lipids was estimated by AOAC (2000) method which was expressed as mg KOH necessary to neutralize the free acids in 1 g sample.

Lipase assay: Lipase activity was assayed based on measurement of free fatty acid release due to enzymatic hydrolysis of triglycerides in stabilized emulsion of vegetable oil (Borlongan 1990). Stabilized emulsion was prepared by homogenizing 50 ml of sunflower oil with 50 ml of 2% bovine serum albumin and 3.5 ml of Tween 80. Assay was carried out by addition of 1 ml of crude enzyme to 1 ml of stabilized lipase substrate in 1.5 ml of 0.1 M Tris –HCl buffer at pH 8. Mixture was incubated for 6 h at 37°C, after which hydrolysis was stopped by addition of 3 ml of 95% ethyl alcohol. The mixture was then titrated with 0.01 N NaOH using 1% phenolphthalein in ethanol as indicator. Blank determination was conducted in a similar manner except the crude enzyme extract was introduced into the assay system after addition of ethyl alcohol at the end of incubation period. A unit of lipase activity was defined as the microgram of NaOH required to neutralize the FFA formed on hydrolysis of oil per mg of protein in extract. Protein content of the enzyme was determined by the method of Lowry et al. (1951) using BSA as standard.

Fatty acid composition of lipid extract: For determination of fatty acid composition, in order to have more representative samples, lipid extracts from 2 samples were pooled together for preparation of fatty acid methyl esters (FAME), and two such pooled samples were analyzed. The lipids were transmethyalated using 2 M methanolic sodium hydroxide followed by 2M methanolic hydrochloric acid to obtain FAME. FAMEs were analysed by gas chromatography (Shimadzu GC 2014, Japan) for identifying the individual fatty acids. FAME dissolved in hexane was analyzed using Omegawax™ 320 fused silica capillary column (30 m × 0.32 mm × 0.25 μm). The conditions used for GC analysis was injection temperature of 250°C, detector (FID) temperature of 260°C and column temperature of 200°C for 60 min. The peaks were identified by comparing with authentic standards. Peak areas above 1% of total were only considered for calculation of % composition of fatty acids. The data was presented as mean of two analyses.

Statistical analysis: All determinations except fatty acid analysis were done in triplicates. Yield of different portions and total lipid content in different portions were compared by ANOVA using the software STATISTICA (Statsoft 1999).

Results and discussion

The yield of meat ranged from 66.0 to 79.5% of the total fish weight, highest being from common carp (Table 1). The

yield of head and visceral mass ranged from 15.2 to 28.6% and 4.0 to 12.4%, respectively. The total lipid content (wet weight basis) varied from 0.8–3.8% in meat, 4.5–17.8 % in head and 4.3–27.8% in viscera (Table 1) indicating that head and visceral mass are rich in lipids. Viscera of all the fishes except tilapia showed fat content more than 9.0%. In all the fishes, the fat content was high in head and viscera compared to meat and differed significantly between fishes ($p < 0.05$) and different body portions ($p < 0.001$). The results indicated that with yield of head and viscera in fresh water fish being in the range of 30–35% and with high fat content they could be good source of lipids that can be recovered. The fishes analyzed in this study were collected over a period of 6 months (May–October 2008) and not much variation was found in lipid content due to the season.

Ackman et al. (1994) observed higher lipid content in livers of carps compared to lipid content in muscle. In the present study as the visceral mass contained liver also, the lipid content in viscera was higher than that in the meat. Based on the lipid content in the muscle, fishes can be classified into the following 4 categories according to their lipid content: very low fat (<2% fat), low fat (2–4% fat), medium fat (4–8% fat), and high fat (>8% fat) fishes (Ackman 1994). According to this classification rohu and common carp can be categorized as low fat fishes, while, tilapia, mrigal and catla as very low fat fishes. Sen (2005) also categorized carps under low fat fishes.

The extracted lipid was separated into different lipid classes (neutral-, glyco- and phospholipid) by silica gel column chromatography where the neutral lipid was further separated into subclasses. Neutral lipids constituted the major portion (71.5–93.3%) of the total lipids (Table 1). The glycolipid content in meat ranged from 3.5 to 25.2%, while phospholipid content was in the range of 2.6–13.7%. Similar observation of high neutral lipid content is reported in liver oil of the ray, *Himantura bleekeri* (Sandrine et al. 2007) and muscle lipids of *Diplodus vulgaris* and *Conger conger* (Varljen et al. 2003). In head (4.7–18.8%) and viscera also the glycolipid (10.2–18.8%) content was higher than phospholipids. Only in the lipid from meat of mrigal, phospholipids content was higher than glycolipids. Ghosh and Dua (1997) have reported higher phospholipids content in meat of *Callichrous parda* which was similar to composition of lipid classes in meat of mrigal (Table 1). Hydrocarbons, sterol esters and triacylglecerol were the major components of neutral lipids from different fishes and constituted more than 80% of total neutral lipids (Table 2). Hydrocarbons content ranged from 24.6 to 57.6% of neutral lipids and differed significantly between different fishes ($p < 0.001$) and body portions ($p < 0.01$). However, sterolesters and FFA/FA content did not differ between different body portions and content of triacylglycerols did not differ between different fishes. Acid value (Table 3) was found to be lower in case of lipid extract from head, which ranged from 3.2–4.6% whereas higher in case of viscera (11.0–46.1%) and meat (8.1–23.4%). Acid value was highest in lipid extracted from viscera of tilapia (46.6%) which also correlated with lipase activity. Past studies on lipase in different species of aquatic origins like whale (Isihara 1960), skate (Brokerhoff and Hoyle 1965), Amazon fish (Reimer 1982), turbot (Koven et al. 1997) and intestinal lipase of rohu (Nayak et al 2004) have reported the properties of this enzyme. Lipase activity was found to be higher in meat of catla followed by mrigal and tilapia (Table 3). In general, there was no correlation between lipase activity and acid value of the lipids from

Table 1 Yield (% whole fish) of body parts in different fresh water fishes and composition of total lipids (% wwb) and neutral lipid, glycolipid and phospholipid (% of total lipids)

Fish	Tissue	Yield	Total lipid	Neutral Lipid	Glycolipid	Phospholipid
Rohu	Meat	68.5 ± 0.68	2.9 ± 0.57	74.7 ± 1.63	16.9 ± 0.30	8.4 ± 1.82
	Head	16.3 ± 2.98	17.8 ± 1.00	93.3 ± 2.22	4.7 ± 1.72	2.0 ± 0.79
	Viscera	12.4 ± 0.7	27.8 ± 1.67	84.2 ± 0.72	13.4 ± 1.17	2.4 ± 0.33
Catla	Meat	66.0 ± 1.68	1.2 ± 0.19	71.5 ± 0.73	21.4 ± 1.18	7.2 ± 1.01
	Head	28.6 ± 1.35	8.9 ± 1.48	87.4 ± 1.31	10.2 ± 0.53	2.4 ± 0.88
	Viscera	5.4 ± 0.48	9.8 ± 2.21	87.5 ± 1.24	10.6 ± 0.72	2.0 ± 0.58
Mrigal	Meat	75.6 ± 0.73	1.8 ± 0.34	82.7 ± 1.38	3.5 ± 0.12	13.7 ± 0.82
	Head	15.3 ± 2.08	4.5 ± 0.82	82.5 ± 1.27	14.7 ± 0.75	2.8 ± 0.50
	Viscera	7.5 ± 0.92	12.0 ± 0.40	83.6 ± 1.96	13.3 ± 1.48	3.1 ± 0.54
Tilapia	Meat	66.2 ± 4.57	0.8 ± 0.10	76.2 ± 0.82	14.8 ± 0.96	9.1 ± 0.28
	Head	27.4 ± 3.92	5.7 ± 0.77	82.6 ± 0.94	14.4 ± 0.78	3 ± 1.19
	Viscera	6.1 ± 0.72	4.3 ± 0.73	84.3 ± 1.15	10.8 ± 0.67	4.7 ± 1.52
Carp	Meat	79.5 ± 2.67	3.8 ± 0.22	72.2 ± 2.53	25.2 ± 2.19	2.6 ± 0.52
	Head	15.2 ± 0.47	10.4 ± 0.60	78.4 ± 1.32	18.1 ± 1.51	3.7 ± 0.25
(n=3)	Viscera	4.0 ± 1.29	9.4 ± 0.82	77.4 ± 5.55	18.8 ± 4.71	3.8 ± 0.91

Table 2 Subclasses of neutral lipids (% of total neutral lipids) of different parts of different fresh water fishes

Fish	Tissue	HC	Ster/FAME	TAG/C	FFA/FA	DAG/Chol	MAG
Rohu	Meat	31.3 ± 1.21	15.4 ± 1.70	33.5 ± 1.60	11.0 ± 1.63	3.6 ± 0.52	4.5 ± 1.12
	Head	38.7 ± 1.14	14.7 ± 0.84	26.0 ± 0.81	9.8 ± 1.14	3.6 ± 0.58	4.8 ± 0.92
	Viscera	46.4 ± 0.53	14.7 ± 1.70	26.8 ± 0.65	5.8 ± 0.68	4.9 ± 0.40	3.3 ± 1.12
Catla	Meat	28.9 ± 2.36	14.9 ± 0.60	36.9 ± 1.69	8.5 ± 1.38	2.2 ± 0.41	4.5 ± 0.23
	Head	24.6 ± 2.58	14.6 ± 1.14	27.2 ± 0.75	13.3 ± 2.19	3.3 ± 0.82	1.5 ± 0.40
	Viscera	39.1 ± 7.02	14.4 ± 2.64	33.5 ± 1.17	9.8 ± 1.48	3.3 ± 0.64	2.9 ± 0.27
Mrigal	Meat	35.8 ± 2.27	10.2 ± 1.32	35.3 ± 0.96	11.7 ± 1.38	3 ± 0.42	7 ± 0.64
	Head	53.2 ± 7.04	11.5 ± 2.65	22.9 ± 1.18	8.5 ± 1.43	2.9 ± 0.65	1.9 ± 0.29
	Viscera	43.6 ± 5.44	14.5 ± 3.58	25.1 ± 4.22	9.7 ± 1.68	5.6 ± 0.71	5.7 ± 0.43
Tilapia	Meat	28.3 ± 5.07	15.8 ± 1.13	27.2 ± 2.42	10.7 ± 0.58	2.9 ± 0.45	5.2 ± 0.47
	Head	34.1 ± 2.90	15.6 ± 1.56	28.5 ± 3.52	9.8 ± 0.51	4.5 ± 1.08	2 ± 0.79
	Viscera	34.5 ± 1.23	16.2 ± 3.69	22.9 ± 0.52	9.8 ± 1.64	7.9 ± 1.57	5.6 ± 1.12
C carp	Meat	29.9 ± 1.84	12.6 ± 2.67	42.8 ± 1.83	9.6 ± 2.39	4.9 ± 1.86	5.5 ± 0.52
	Head	57.6 ± 5.73	8.5 ± 0.80	23.8 ± 2.23	4.3 ± 0.35	1.4 ± 0.17	1.2 ± 0.24
(n=3)	Viscera	45.7 ± 2.11	13.9 ± 0.48	19.3 ± 1.18	7.7 ± 0.26	10.8 ± 1.04	2.5 ± 0.26

HC: Hydrocarbons, FAME: Fatty acid methylesters, FFA: Free fatty acids, DAG: Diacyl glycerol, MAG: Monoacyl glycerol

Table 3 Acid value of the oil and lipase activity in different parts of different fresh water fishes

Fish	Tissue	Acid value	Lipase activity*
Rohu	Head	4.0±0.25	16.8±2.01
	Meat	8.1±0.50	88.2±3.21
	Viscera	12.8±0.34	74.6±2.41
Catla	Head	3.2±0.21	51.7±1.77
	Meat	23.4±0.51	26.4±0.02
	Viscera	22.5±0.64	169.4±0.04
Common carp	Head	3.9±0.26	62.1±0.02
	Meat	8.5±0.34	76.3±2.41
	Viscera	10.9±0.44	95.7±0.05
Mrigal	Head	4.6±0.24	14.5±2.34
	Meat	9.8±0.43	43.7±2.43
	Viscera	11.1±0.66	149.1±3.28
Tilapia	Head	4.5±0.35	58.6±4.64
	Meat	11.1±0.58	43.4±5.55
	Viscera	46.1±1.52	298.1±1.83

*μg of NaOH required to neutralize the FFA formed on hydrolysis of oil per mg of protein in extract (n=3)

other parts. Many factors such as active swimming (Jonas and Bilinski 1964) and specificity of lipase for fatty acid (Bilinski and Lau 1969) influence lipase activity in tissues. Lipase activity was found to be higher in viscera of different fishes being highest in tilapia which can be due to the intestinal lipases as well as lipase from intestinal micro flora. It also differs significantly among different fishes which may be due to the difference in feeding habits of fish (Ghosh and Saigal 1981).

Fatty acids in fishes are derived from 2 main sources, namely, biosynthesis and diet (Hearn et al. 1987, Morris et al. 1995, Kamler et al. 2001). The chain length varies from C_{14}–C_{24} of varying degree of unsaturation, from saturated to polyunsaturated. Fatty acid composition of the total lipid extract of different parts of five different fresh water fishes as shown in Tables 4–6 indicates the dominance of unsaturated fatty acids in all the samples analysed. The dominant fatty acids in the lipid extract from meat of different fishes were palmitic (C16:0) (maximum 26.5%) and oleic acid (C18:1) (maximum 27.1%). However, in lipids from tilapia meat the oleic acid content was low (2.7%) but linolenic acid (C18:3) content was high (12.2%). High amount of linolenic acid was observed in common carp meat as well (Table 4). EPA content was low in the lipid extracted from meat of rohu (1.6%) and mrigal (2.1%), but was higher than 5.0% in lipid extracted from meat of other fishes. High levels of DHA (upto 7.6%) was observed in all fishes except the lipid extract from meat of mrigal. Gopakumar (1975) also reported similar observations of fatty acid profile of some of the fresh water fishes of India. Ackman et al. (1994) also observed dominance of palmitic, oleic, linoleic, DHA in the lipid extracts from different species of rohu. Unsaturated fatty acids accounted 40.8–57.7% in total lipid extract of meat of different fishes, with the highest being in rohu meat, due to high oleic acid content. Even though rohu meat contained higher amount of oleic acid, it had lower concentration of EPA compared to other fishes (Table 4). EPA and DHA were found to be higher in meat of catla, tilapia and common carp. Mrigal meat had low EPA (2.1%) and DHA (3.1%) content compared to other fishes.

In case of head and viscera, unsaturated fatty acid content varied from 35.51–56.36% and 36.6–48.3%,

Table 4 Fatty acid composition (% of total lipid extract) of meat from fresh water fishes

Fatty acids	Catla	Tilapia	Rohu	Mrigal	Common carp
C14:0	3.6	4.0	2.1	4.9	ND
C15:0	4.7	ND	1.1	3.8	ND
C16:0	24.1	26.5	24.2	25.5	16.1
C18:0	6.1	4.5	5.4	3.7	7.1
C20:0	ND	ND	1.8	1.5	ND
Σ Saturates	38.5	35.0	34.6	39.4	23.2
C16:1	7.3	14.3	4.3	12.4	2.7
C18:1n-9	12.8	2.7	27.1	15.9	12.8
C18:1n-7	2.8	3.0	2.2	6.4	3.1
Σ Mono-unsaturates	22.9	20.0	33.6	34.7	18.6
C18:2 n-6	4.3	4.8	14.2	2.4	9.7
C18:3 n-3	5.6	12.2	2.9	3.2	12.9
C20:5 n-3	5.3	5.1	1.6	2.1	5.1
C22:5 n-3	2.0	6.4	1.0	1.3	2.9
C22:6 n-3	6.3	7.0	5.4	3.1	7.6
Σ Poly-unsaturates	23.5	35.5	25.1	12.1	38.2
n3/n6	4.5	6.4	0.8	4.0	2.9

ND: not detected (n=2)

Table 5 Fatty acid composition (% of total lipid extract) of head from fresh water fishes (n=2)

Fatty acids	Catla	Tilapia	Rohu	Mrigal	Common Carp
C14:0	4.2	5.8	2.9	5.7	1.0
C15:0	4.7	1.1	1.2	4.0	ND
C16:0	25.3	34.1	26.7	27.3	14.2
C18:0	6.0	3.4	4.3	2.8	7.8
C20:0	ND	ND	2.0	1.4	ND
Σ Saturates	40.2	44.4	37.1	41.2	23.0
C16:1	8.1	19.4	5.4	13.4	3.3
C18:1n-9	11.7	3.0	29.7	15.0	18.5
C18:1n-7	3.2	2.7	2.1	6.4	3.0
Σ Mono-unsaturates	23.0	25.1	37.2	34.8	24.8
C18:2 n-6	4.5	6.6	14.8	2.4	10.0
C18:3 n-3	6.0	14.4	3.4	3.8	24.2
C20:5 n-3	5.0	1.5	1.0	1.5	3.1
C22:5 n-3	1.8	1.5	1.0	ND	2.1
C22:6 n-3	5.2	1.0	1.2	1.2	5.7
Σ Poly-unsaturates	22.5	25.0	21.4	8.9	45.1
n3/n6	4.0	2.8	0.4	2.7	3.5

ND: not detected (n=2)

Table 6 Fatty acid composition (% of total lipid extract) of viscera from fresh water fishes (n=2)

Fatty acids	Catla	Tilapia	Rohu	Mrigal	Common Carp
C14:0	3.6	2.4	4.4	6.1	4.1
C15:0	1.2	0.0	0.0	4.1	1.3
C16:0	29.4	30.4	27.5	27.4	32.4
C18:0	6.9	9.6	4.0	3.2	7.6
C20:0	1.5	ND	ND	1.5	ND
Σ Saturates	42.6	42.4	35.9	42.3	45.4
C16:1	7.3	9.2	14.3	13.7	8.4
C18:1n-9	20.2	3.0	7.8	14.9	23.8
C18:1n-7	2.9	2.5	3.8	6.6	3.3
Σ Mono-unsaturates	30.4	14.7	25.9	35.2	35.5
C18:2 n-6	3.6	5.4	8.4	2.4	3.8
C18:3 n-3	3.8	12.6	16.0	3.9	3.6
C20:5 n-3	2.8	2.5	1.9	1.3	2.3
C22:5 n-3	1.6	5.2	1.0	1.0	1.1
C22:6 n-3	5.4	8.9	1.5	1.0	5.3
Σ Poly-unsaturates	17.2	34.6	28.8	9.6	16.1
n3/n6	3.8	5.4	2.4	3.0	3.2

ND: not detected (n=2)

respectively (Tables 5 and 6). Palmitic acid was the dominant fatty acid in the lipid extract from viscera of all fishes. Sen et al. (1976) reported that palmitic acid content is high in visceral lipids than lipids from other tissues of fresh water fishes. Oleic acid was also found to be higher in head of rohu which is accompanied with an increased concentration of the unsaturated fatty acid (56.4%). Palmitoleic acid was found higher in case of meat of mrigal (12.4%) and tilapia (14.3%) whereas linolenic acid was found to be higher in different parts of rohu, and head of common carp. In case of lipid extract from head, palmitic acid accounted 60% of all saturated fatty acid content, which was similar as in case of oil from Nile pearch head (Turon et al. 2005). EPA and DHA were found higher in common carp and tilapia. DHA content was above 3.0% in meat of all the fishes but varied in viscera (1.0–8.9%) with the highest being in tilapia. Lower amounts of EPA and DHA was reported in commercially important fresh water fishes from Brazil (Gutierrez and da Silva 1993).

The characteristic difference between marine fish and fresh water fish has been indicated to be the higher levels of C16:0 and C18:0 acid and lower levels of C20:0 and C22:0 acids in fresh water fishes (Ackman 1967, Nair and Gopakumar 1978). In the present study also C22:0 acid was not detected in any of the fishes analysed. Fresh water fishes are also known to contain high amount of EPA and DHA (Wang et al. 1990). The fatty acid profile of the lipid extracts

indicated the dominance of n-3 fatty acids over n-6 fatty acids except for the lipid extract from meat and head from rohu (Tables 4–6). Physiological effects of n-3 fatty acids in humans are well documented (Bhaskar et al. 2006).

Conclusion

The study indicated that the yield of meat in 5 different fresh water fishes tested was higher than 65%. The lipid content in the meat was lower than in the head and visceral mass. Neutral lipids constituted the major fraction in the total lipid extract from all 3 tissues analyzed. Fatty acid profile of the lipid extract from 3 different tissues indicated the dominance of palmitic and oleic acid and equal distribution of SFA and unsaturated fatty acids. EPA and DHA were also detected in significant quantities in the analyzed samples. Fresh water fish byproducts such as head and viscera were found to be rich in lipids. Health benefits of fish oils are well established. As the study indicated the relatively high content of EPA and DHA in the fresh water fishes particularly from head and viscera, efforts should be made to recover the lipids from these tissues to utilize them.

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