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Report on the distribution of essential and non essential fatty acids in common edible fishes of Porto-Novo coastal waters, southeast coast of India

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ABSTRACT

Objective: The objective of the study was to evaluate the essential and non essential fatty acids and the distribution of Omega-3 and Omega-6 fatty acids in twenty commonly consumed edible fishes of parangipettai coastal waters. **Methods:** For fatty acid analysis, each fish specimens were beheaded, eviscerated and filleted manually. The tissue samples were oven dried at 67℃ for 24hrs.After that the samples ware grounded finely with pestle and mortar. The saponified samples were cooled at room temperature for 25 min, they were acidified and methylated by adding 2 ml 54% 6 N Hcl in 46% aqueous methanol and incubated at 80℃ for 10 min in water bath. Following the base wash step, the FAMEs were cleaned in anhydrous sodium sulphate and then transferred in to GC sample vial for analysis. FAMEs were separated by gas chromatograph. **Results:** The results of the present study revealed that the most abundant individual FAs were Palmitic acid, Oleic acid, Arachidonic acid (AA), Docosahexaenoic acid (DHA) in most the tissues. The total Arachidonic acid (C20:4 ω-6) was found to be higher proportion (0.17-4.86%), when compared with other Omega-6 fatty acids. The values found for Linoleic acid (C18:2 ω-6) ranging from 0-7.23%. *Siganus javus* has 7.23% of Linoleic acid. **Conclusion:** Fatty acids are the principle components in lipids. The nutritional importance of fish consumption is in great extent associated with the content of omega-3 fatty acids. Sea food is an important dietary food for human beings. It constitute higher amount of protein, lipids, vitamins and essential and nonessential metals and low concentration of carbohydrates.

1. Introduction

The nutritive value of fish is determined by the content of fatty acids that are beneficial to health [57]. Fish is an excellent and relatively a cheaper source of animal protein of high biological value. Therefore its use may help bridge the protein gap because of its multifarious economic advantages and nutritional significance [67]. Fish lipids are well known to be rich in long-chain (LC) n-3 polyunsaturated fatty acids (LC n-3 PUFA), especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) [1]. Earlier research on fish proteins [2-5], has shown that they have bioactive properties and beneficial health effects which make them a very interesting alternative for the food industry. Muscle [6, 7] and waste of fish, such as the head [8] are the main source of very-long-chain polyunsaturated fatty acids which have beneficial and even therapeutic effects on human health. Long chain, n-3 PUFA cannot be synthesized by humans and must be obtained from the diet. It is known that polyunsaturated fatty acids can regulate prostaglandin synthesis and hence induce wound healing, These fatty acids have particular importance in fish since their consumption contributes in the reduction of appearance of cardiovascular diseases [9], anti-inflammatory and antithrombotic effects, reduction of blood cholesterol levels and cancer prevention. The significance of long chain polyunsaturated fatty acids such as n-3 PUFA has gained attention because of their prevention of human cardiovascular diseases [56]. The influence of dietary omega-3 fatty acids on health outcomes is widely recognized. The adequate intake of omega-3 fatty acids docasahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) in particular can increase gestation length and improve infant cognitive and visual performance. Adequate levels of omega-3 fatty acids have also been shown to

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reduce the incidence of preterm birth in some populations [10]. Fatty fish is a rich dietary source of essential fatty acids and vitamin D, both of which could be implicated in the development of schizophrenia [61]. The anti-inflammatory actions of DHA and EPA also involve their ability to suppress the expression of a wide variety of inflammatory genes [62,63]. Omega-3 FAs may be of benefit to a subset of depressed individuals specifically those with a relatively low omega-3 status.[64]. DHA has recently been shown to play a larger role in neurogenic inflammation [65, 66].

Researchers have recently intensified interest in the relationships between the fatty acid composition of fish and that of the diet [11-14]. The lipid content of diet is important as a source of dietary energy, but is also fundamental for supplying adequate amount of essential fatty acids (EFA). The efficiencies of the various alternative animal protein sources as replacements for fish meal have been evaluated in fish diets, e.g. poultry by-product meal [15], gambusia meal [16] tuna liver meal [17] and sand smelt meal [14]. Although the usage of alternative terrestrial or aquatic protein sources as replacement of fish meal in fish diets is expanding [18]. The fatty acid composition is a characteristic of the species or tissue involved, and indeed it is relatively independent from the diet [19, 20, 14].

Many sources emphasize that marine fish have a higher nutritive value than do freshwater fish [21, 22]. Fish fats are characterized by an advantageous composition of fatty acids with a large percentage of unsaturated essential fatty acids (LC-PUFA), including eicosapentaenoic (EPA) and docosahexaenoic (DHA) acids. These acids may be synthesized by animals or humans only to a limited extent and must be supplemented by the diet [23]. These fatty acids from the n-3 family occur in fish in large amounts. This is why both consumers and scientists alike are interested in conditions such as asthma, arteriosclerosis, and joint inflammation as well as delaying the development of cancers [24].

Researchers have identified and reported specific peptides from animal and fish proteins responsible for ACE inhibition [44-46]. The other reported bioactivities include antihypertensive, immunomodulatory, neuroactive, antimicrobial, mineral and hormonal regulating properties [47-49]. Fish lipids are well known to be rich in long-chain (LC) n-3 polyunsaturated fatty acids (LC n-3 PUFA), especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) [55]. Researchers have identified and reported specific peptides from animal and fish proteins responsible for ACE inhibition [54]. The other reported bioactivities include antihypertensive, immunomodulatory, neuroactive, antimicrobial, mineral and hormonal regulating properties [47], Several studies have indicated that peptides derived from fish by product proteins have antioxidative properties in different oxidative systems [50-52]. The influence of dietary omega-3 fatty acids on health outcomes is widely recognized. The adequate intake of omega-3 fatty acids docasahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) in particular can increase gestation length and improve infant cognitive and visual performance. Adequate levels of omega-3 fatty acids have also been shown to reduce the incidence of preterm birth in some populations [53] Nutritional studies have shown that fish protein concentrate can be added to weaning food growing infants and nursing mothers [44]. Low maternal fish and seafood consumption during pregnancy is reported to increase the risk for a low IQ and suboptimal neuro-developmental outcomes in childhood [58], factors that in turn are associated with an increased risk for adult mental disorders like schizophrenia [59]. A recent meta-analysis found a latitude related increase in schizophrenia prevalence that was greater for groups with low fish consumption [60]. The PUFA are important for maintaining the integrity of membranes of all living cells; for making prostaglandins which regulate many body processes such as inflammation and blood clotting.[68]. A substantial number of experiments have indicated that consumption of fish oils rich in n-3 PUFA has different health benefits including cardiovascular health improving, proper fetal development, anti-inflammatory effects and chronic disease alleviation [69-73]. The natural sources of n-3 PUFA are foremost fish lipids, especially those of marine origin. EPA and DHA have been largely investigated and their positive biological effects have been demonstrated from feeding studies with fish or fish oil supplements [74]. These findings have created a new market for fish oil as a source of healthy components. Many products based on fish oil fatty acids such as dietary supplements and pharmaceuticals as well as other products with technical and cosmetic applications based on fish oil fatty acids have been developed and produced commercially [74-76]. Reviewing the scientific evidence that forms the basis of dietary and public health advice on how to balance the benefits and risks associated with fish consumption is therefore needed [77].

2. Materials and methods

For fatty acid analysis, each fish specimens were beheaded, eviscerated and filleted manually. The tissue samples were oven dried at 67℃ for 24hrs.After that the samples ware grounded finely with pestle and mortar. The preparation and analysis of fatty acid methyl esters (FAMEs) from these fish tissues ware performed according to the method described by Anon *et al*., [25]. 50 mg of tissue samples were added to 1 ml of 1.2M Na OH in 50% aqueous methanol with glass beads (3mm dia) in a screw-cap tube and then incubated at 100 ℃for 30 min in a water bath. The saponified samples were cooled at room temperature for 25 min, they were acidified and methylated by adding 2 ml 54% 6 N Hcl in 46% aqueous methanol and incubated at 80℃ for 10 min in water bath. After rapid cooling, methylated FAs were extracted with 1.25 ml 50% methyl-tert butyl ether (MTBE) in hexane. Each sample was mixed for 10 min and the bottom phase removed with a Pasteur pipette. Top phase was washed with 3 ml 0.3M NaOH. After mixing for 5 min, the top phase was removed for analysis. Following the base wash step, the FAMEs were cleaned in anhydrous sodium sulphate and then transferred in to GC sample vial for analysis. FAMEs were separated by gas chromatograph (HP 6890 N, Agilent Technologies, USA). FAMEs profiles of the tissues were identified by comparing the commercial Eucary data base with MIS Software package (MIS Ver. No. 3.8, Microbial ID. Inc., Newark, Delaware).

3. Results

The results of fatty acid analysis of the twenty different marine fish tissues are presented table1- table 10. There was a significant amount of Palmitic acid (C16:0) in all of the fish tissues compared with other Saturated Fatty Acids (SFAs) like Lauric acid (C12:0), Myristic acid (C14:0), Stearic acid (C18:0) and Arachidonic acid (C20:0).Fatty acid composition of these fish species were found to be 40.03-55.93% Saturated (SFA) (Figure 1), 7.86-30.04% Monounsaturated (MUFA)(Figure 2) and 23.52-56.75% Polyunsaturated fatty acids (PUFA)(Figure 3). The distribution of percentage compositions of Branched & Unknown Fatty acids is shown in Figure 4. Among those, those occurring in the highest proportions of this fish species were Palmitic acid (C16:0, 28.80-31.98%), Myristic acid (C14:0, 0-11.61%), Stearic acid (C18:0, 3.67-10.61%), Palmitoleic (C16:1, 0-11.89%) and Oleic acid (C18:1n9,0-16.82%). These results are in agreement with previous studies on FAs of other species [26-28]. The content of Arachidonic acid (AA), Eicosapentaenoic acid (EPA) and Docasahexaenoic acid (DHA) of these fishes analyzed, ranged from 0.21-4.86%; 5.43-12.35% and 5.92-12.56%,

Table 1.
List of saturated and mono unsaturated fatty acids in fishes.

Fatty acid	*Congresox talabon*	*Arius dussumieri*	*Dussumieria acuta*	*Opisthopterus tardoore*
C10:0	0.06	0.13	0.18	–
C11:0	0.08	–	–	–
C12:0	0.68	1.11	1.10	2.71
C13:0	0.21	0.24	0.23	0.32
C14:0	11.61	10.45	8.55	10.70
C15:0	1.22	1.73	1.91	1.24
C16:0	22.80	27.71	28.99	27.64
C17:0	0.87	1.72	1.61	1.32
C18:0	6.05	8.70	7.90	8.30
C19:0	0.19	0.26	0.22	0.18
C20:0	0.31	0.49	0.49	0.46
C21:0	–	–	0.17	0.14
C22:0	0.16	0.29	0.46	0.36
C23:0	–	0.35	–	–
C24:0	0.10	0.22	0.19	0.13
Σ Of SFAs	44.34	54.4	52.4	53.5
C14:1 ω-3	0.05	–	–	–
C14:1 ω-5	0.32	5.72	–	1.34
C14:1 ω-7	0.21	0.44	0.51	–
C15:1 ω-6	–	0.20	0.80	0.29
C16:1 ω-5	0.24	0.80	0.29	0.26
C16:1 ω-6	0.73	–	0.41	0.49
C16:1 ω-7	11.89	10.41	8.49	7.51
C16:1 ω-9	–	–	–	–
C17:1 ω-7	0.35	2.33	2.33	1.95
C17:1 ω-8	0.61	0.11	0.79	0.43
C18:1 ω-5	0.13	0.19	0.12	–
C18:1 ω-7	0.22	0.23	0.14	–
C18:1 ω-9	9.54	8.81	7.01	8.33
C19:1 ω-8	0.08	0.34	–	–
C20:1 ω-5	0.20	0.56	–	–
C20:1 ω-7	0.29	0.81	–	–
C20:1 ω-9	–	0.14	–	0.72
C20:1 ω-11	1.02	0.53	0.17	0.45
C22:1 ω-7	–	0.13	–	–
C23:1 ω-9	–	–	–	0.72
C24:1 ω-3	0.31	0.52	0.01	–
C24:1 ω-6	–	0.19	–	–
C24:1 ω-9	0.16	0.11	0.45	0.17
Σ Of MUFAs	26.35	32.13	21.52	22.66

Table 2.
List of Polyunsaturated and branched fatty acids in fishes.

Fatty acid	*Congresox talabon*	*Arius dussumieri*	*Dussumieria acuta*	*Opisthopterus tardoore*
C16:2 ω -6	-	0.01	0.13	-
C18:2 ω -3	-	0.12	0.14	0.39
C18:2 ω -6	1.27	1.91	2.0	1.19
C18:3 ω -3	5.37	5.01	5.91	6.12
C18:3 ω -6	0.31	0.59	0.52	0.23
C18:4 ω -3	-	0.12	-	0.84
C19:2 ω -6	-	-	0.11	-
C20:2 ω -6	-	0.11	-	-
C20:3 ω -6	0.44	0.19	-	-
C20:4 ω -6	3.81	2.13	2.33	2.92
C20:5 ω -3	7.12	6.12	5.91	5.87
C20:5 ω -6	0.31	0.19	0.09	0.09
C22:3 ω -3	0.82	0.79	-	0.29
C22:4 ω -6	4.16	0.64	0.14	0.71
C22:5 ω -3	3.21	0.53	0.11	0.34
C22:6 ω -3	6.12	5.92	6.13	6.23
Σ Of PUFAs	32.94	24.25	23.52	25.29
C14:0 Iso	0.07	0.12	-	-
C15:0 Iso	0.37	-	0.42	0.20
C15:0 Anteiso	0.19	-	0.44	0.20
C16:0 Iso	0.17	-	-	0.11
C17:0 Iso	0.40	0.11	0.34	0.18
C17:0 Anteiso	0.26	0.14	-	-
C19:0 Iso	-	-	0.11	-
C20:0 Iso	-	0.17	-	0.42
C20:0 Anteiso	0.39	0.32	-	-
Σ Of Branched	1.48	0.86	1.31	1.11
Unknown& Others	0.91	0.17	0.51	0.11

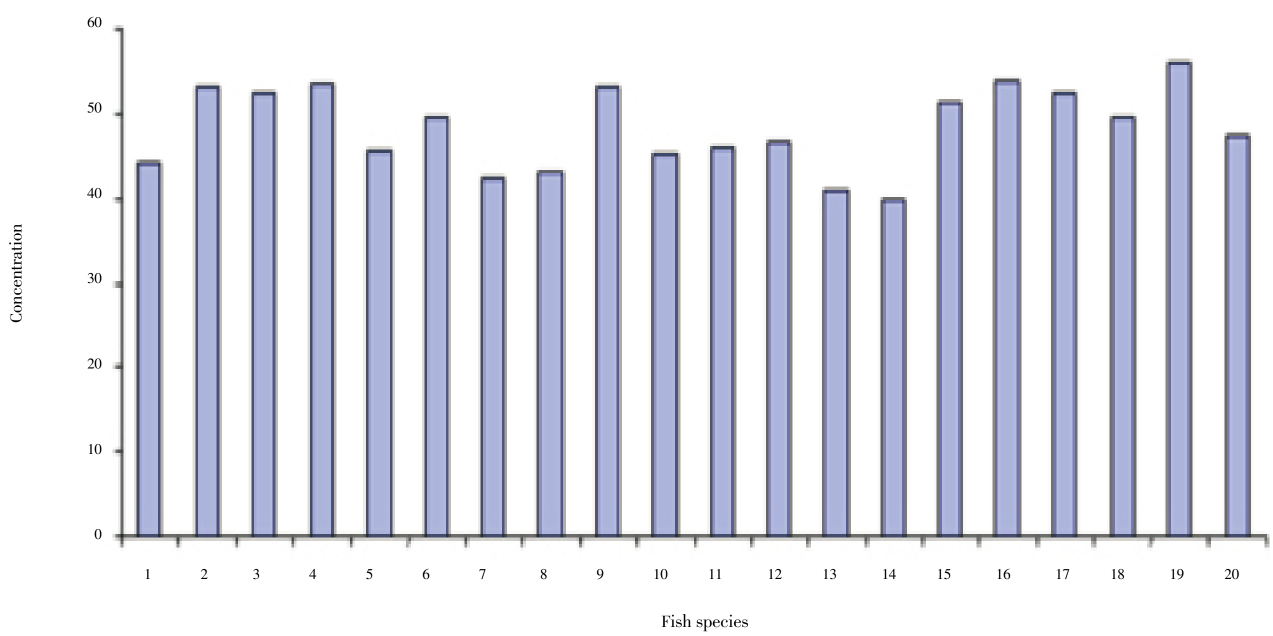

Figure 1. Percentage composition of saturated fatty acids in fishes

Table 3.
List of saturated and mono unsaturated fatty acids in fishes.

Fatty acid	*Scomberoides commersonianus*	*Megalopsis cardyla*	*Carangoides chrysophrys*	*Caranx para*
C10:0	–	0.06	–	–
C11:0	–	–	–	0.11
C12:0	0.82	0.76	0.33	0.32
C13:0	0.26	–	–	0.15
C14:0	8.67	7.95	4.44	3.53
C15:0	1.43	1.33	1.57	1.91
C16:0	26.18	28.72	25.91	28.53
C17:0	1.77	1.96	1.36	0.94
C18:0	5.23	6.02	6.0	5.81
C19:0	0.31	0.39	0.67	0.47
C20:0	0.51	0.70	0.72	0.46
C21:0	–	0.51	–	0.13
C22:0	0.22	0.40	0.38	0.67
C23:0	–	0.30	0.20	0.29
C24:0	0.25	0.43	0.55	0.98
Σ Of SFAs	45.65	49.53	42.13	43.32
C14:1 ω-3	–	–	–	–
C14:1 ω-5	–	0.40	–	–
C14:1 ω-7	–	0.13	–	0.17
C15:1 ω-6	0.26	–	0.24	0.27
C16:1 ω-5	–	0.24	0.22	0.13
C16:1 ω-6	0.31	0.79	0.80	0.14
C16:1 ω-7	7.79	6.80	7.81	6.18
C16:1 ω-9	0.26	–	0.27	0.23
C17:1 ω-7	8.52	3.26	2.23	1.19
C17:1 ω-8	0.66	0.95	0.68	0.73
C18:1 ω-5	–	0.19	–	0.11
C18:1 ω-7	–	0.21	0.17	0.13
C18:1 ω-9	7.79	8.77	8.91	5.84
C19:1 ω-8	–	0.13	0.19	0.11
C20:1 ω-5	–	–	–	–
C20:1 ω-7	–	–	0.61	–
C20:1 ω-9	–	0.71	0.42	–
C20:1 ω-11	–	0.55	–	0.59
C22:1 ω-7	–	–	0.21	–
C23:1 ω-9	–	–	–	–
C24:1 ω-3	–	0.67	0.09	0.14
C24:1 ω-6	–	–	–	–
C24:1 ω-9	0.28	0.56	0.74	–
Σ Of MUFAs	25.87	24.36	23.59	15.96

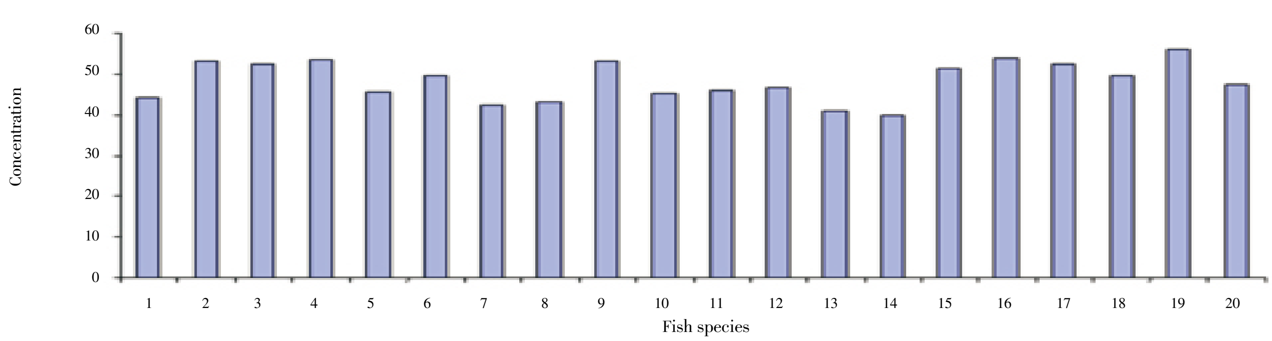

Figure 2. Percentage compositions of Mono Unsaturated Fatty acids in fishes

Table 4.
List of Polyunsaturated and branched fatty acids in fishes.

Fatty acid	*Scomberoides commersonianus*	*Megalopsis cardyla*	*Carangoides chrysophrys*	*Caranx para*
C16:2 ω -6	–	0.19	–	–
C18:2 ω -3	0.15	0.74	0.57	0.41
C18:2 ω -6	1.89	1.35	2.38	0.91
C18:3 ω -3	6.93	6.32	6.01	5.91
C18:3 ω -6	0.45	0.51	0.46	0.45
C18:4 ω -3	–	–	–	–
C19:2 ω -6	–	1.15	–	0.91
C20:2 ω -6	0.01	0.52	–	0.93
C20:3 ω -6	0.36	–	0.31	0.78
C20:4 ω -6	3.44	3.79	3.76	2.97
C20:5 ω -3	5.43	8.16	9.15	8.13
C20:5 ω -6	0.14	0.11	0.17	0.41
C22:3 ω -3	0.41	0.51	1.65	1.01
C22:4 ω -6	0.32	0.16	0.19	0.81
C22:5 ω -3	0.16	0.12	0.05	0.16
C22:6 ω -3	6.13	6.14	6.14	6.13
Σ of PUFAs	25.82	29.76	30.84	29.92
C14:0 Iso	–	–	–	–
C15:0 Iso	0.29	0.44	0.35	0.11
C15:0 Anteiso	0.39	0.31	0.31	0.19
C16:0 Iso	–	–	0.26	–
C17:0 Iso	0.58	0.23	0.27–	0.19
C17:0 Anteiso	–	–	–	–
C19:0 Iso	0.17	–	–	–
C20:0 Iso	0.99	–	–	1.07
C20:0 Anteiso	–	–	–	–
Σ Of Branched	2.42	0.98	1.19	1.56
Unknown& Others	0.57	0.36	0.39	0.17

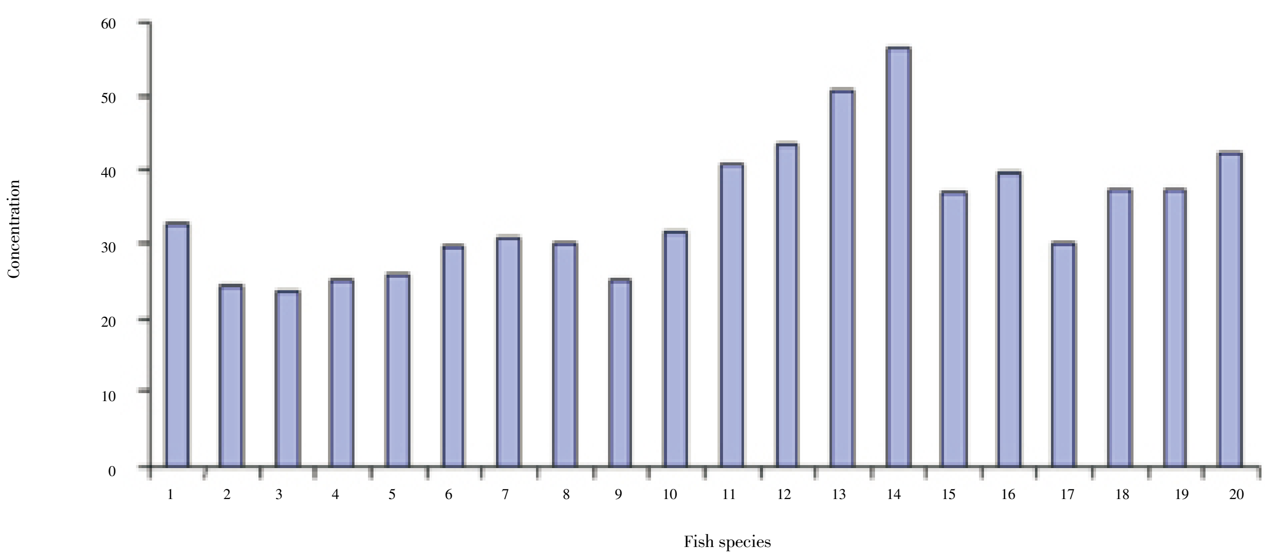

Figure 3. Percentage composition of Poly Unsaturated Fatty acids in fishes

Table 5.
List of Saturated and mono unsaturated fatty acids in fishes.

Fatty acid	*Secutor incidiator*	*Sardinella longiceps*	*Tenulosa ilisha*	*Elutherenema tetradactylum*
C10:0	0.05	0.13	–	–
C11:0	–	–	–	–
C12:0	1.06	0.29	0.22	0.11
C13:0	0.22	–	0.23	0.13
C14:0	9.94	5.22	10.65	3.65
C15:0	1.65	1.25	1.0	1.69
C16:0	29.17	30.98	28.72	31.98
C17:0	2.11	1.29	0.74	0.16
C18:0	6.18	5.09	3.67	8.45
C19:0	0.42	0.20	0.10	0.52
C20:0	0.92	0.43	0.12	0.11
C21:0	0.19	–	0.04	–
C22:0	0.57	0.23	0.13	–
C23:0	0.25	0.11	0.09	–
C24:0	0.59	0.14	0.15	–
$\sum$ Of SFAs	53.32	45.36	45.86	46.8
C14:1 ω –3	–	0.02	–	0.11
C14:1 ω –5	0.72	0.09	–	0.63
C14:1 ω –7	0.19	0.10	–	–
C15:1 ω –6	0.26	0.14	–	–
C16:1 ω –5	0.25	0.22	0.29	–
C16:1 ω –6	0.52	–	1.20	–
C16:1 ω –7	8.52	9.44	8.79	5.85
C16:1 ω –9	–	–	–	–
C17:1 ω –7	3.07	–	–	–
C17:1 ω –8	0.72	0.65	0.24	–
C18:1 ω –5	–	–	0.08	–
C18:1 ω –7	–	–	–	–
C18:1 ω –9	6.22	16.82	2.85	10.39
C19:1 ω –8	0.72	–	–	–
C20:1 ω –5	0.26	–	–	–
C20:1 ω –7	0.43	–	–	0.12
C20:1 ω –9	0.32	–	–	0.63
C20:1 ω –11	0.41	–	–	0.11
C22:1 ω –7	–	–	0.94	–
C23:1 ω –9	0.37	0.29	–	–
C24:1 ω –3	–	0.14	–	0.11
C24:1 ω –6	0.14	–	–	–
C24:1 ω –9	0.71	–	0.05	–
$\sum$ Of MUFAs	23.51	27.91	14.44	17.95

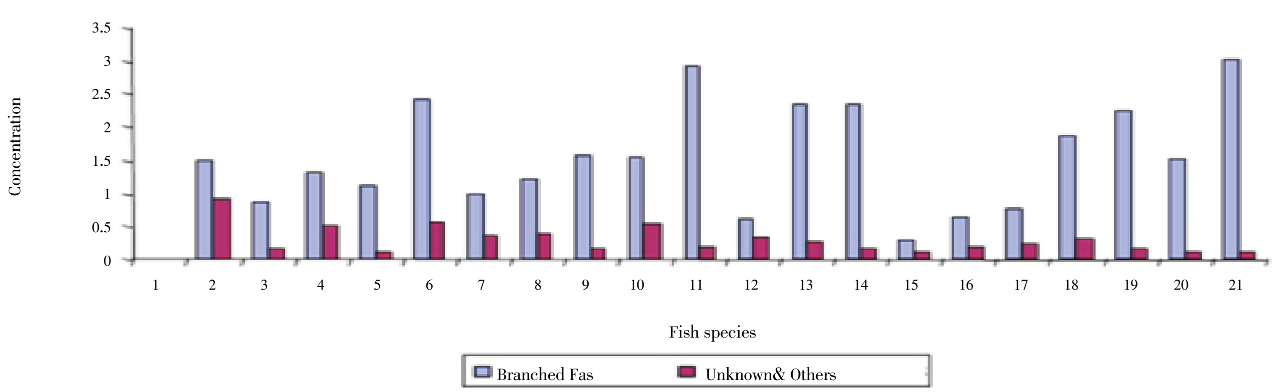

Figure 4. Percentage compositions of Branched & Unknown Fatty acids

Table 6.
List of Polyunsaturated and branched fatty acids in fishes.

Fatty acid	*Secutor incidiator*	*Sardinella longiceps*	*Tenulosa ilisha*	*Elutherenema tetradactylum*
C16:2 ω –6	–	0.31	0.11	0.02
C18:2 ω –3	0.11	–	2.05	0.15
C18:2 ω –6	1.81	1.38	1.73	2.59
C18:3 ω –3	5.31	6.30	6.36	9.69
C18:3 ω –6	0.65	0.28	0.69	1.65
C18:4 ω –3	–	1.69	2.12	1.02
C19:2 ω –6	–	1.24	0.17	1.69
C20:2 ω –6	–	0.12	1.12	0.11
C20:3 ω –6	–	0.38	2.36	0.01
C20:4 ω –6	4.04	2.69	3.15	4.86
C20:5 ω –3	6.05	5.90	10.05	10.13
C20:5 ω –6	0.65	0.11	1.65	0.13
C22:3 ω –3	0.26	0.29	2.30	2.12
C22:4 ω –6	0.35	1.35	0.12	0.19
C22:5 ω –3	0.05	0.36	0.12	0.39
C22:6 ω –3	6.11	9.12	6.56	12.56
Σ Of PUFAs	25.38	31.52	40.66	43.31
C14:0 Iso	0.16	–	–	–
–C15:0 Iso	0.43	1.25	0.16	–
C15:0 Anteiso	0.41	–	–	–
C16:0 Iso	0.18	–	–	–
C17:0 Iso	0.36	0.60	0.12	–
C17:0 Anteiso	–	–	0.20	2.34
C19:0 Iso	–	–	–	–
C20:0 Iso	–	1.07	0.11	–
C20:0 Anteiso	–	–	–	–
Σ Of Branched	1.54	2.92	0.59	2.34
Unknown& Others	0.54	0.19	0.34	0.27

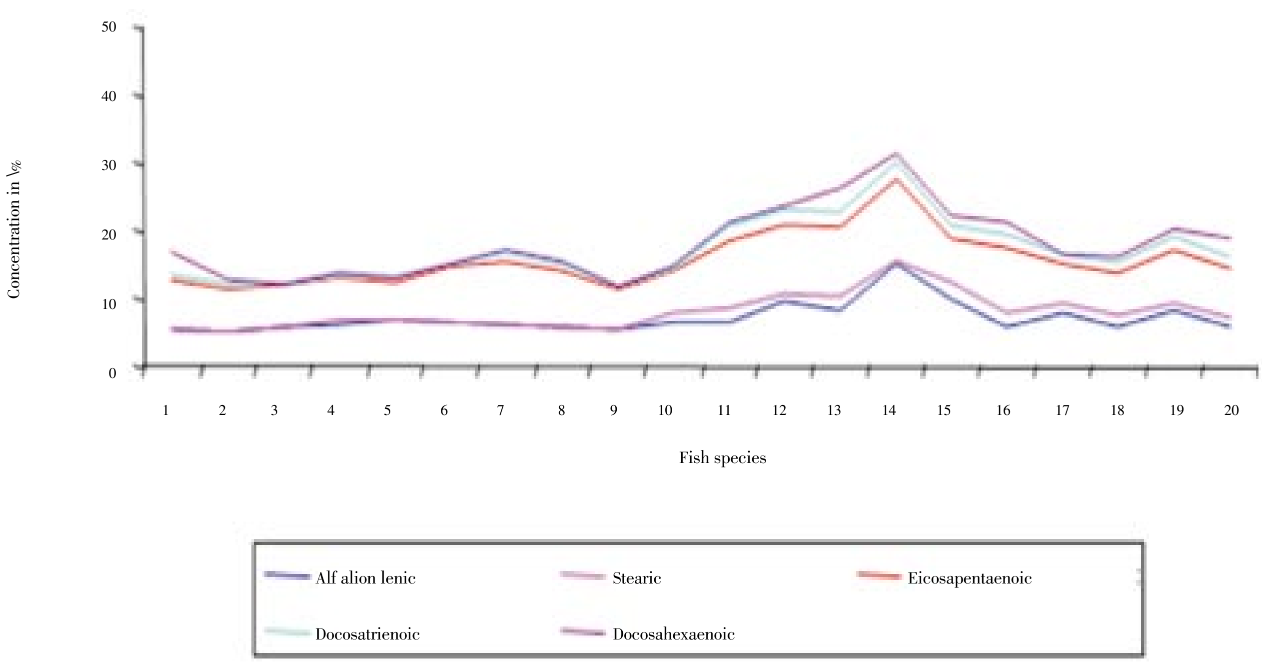

Figure 5. Distribution of Omega–3 fatty acids

Table 7.
List of Saturated and mono unsaturated fatty acids in fishes.

Fatty acid	*Sphyraena obtusa*	*Siganus javus*	*Carangoides malabaricus*	*Rastrilliger kanagurta*
C10:0	0.10	–	–	–
C11:0	0.05	–	–	–
C12:0	0.88	1.17	0.72	1.0
C13:0	–	0.12	–	0.11
C14:0	–	2.65	6.03	6.07
C15:0	–	0.69	1.49	1.42
C16:0	30.53	30.66	29.78	30.11
C17:0	1.01	0.64	1.92	2.07
C18:0	6.45	4.09	10.18	10.61
C19:0	1.03	–	0.42	0.13
C20:0	–	–	0.46	0.62
C21:0	–	–	0.10	0.53
C22:0	–	–	0.16	0.57
C23:0	–	–	–	0.54
C24:0	0.69	0.01	0.36	0.11
$\sum$ Of SFAs	40.84	40.03	51.62	53.89
C14:1 ω –3	0.15	–	–	0.17
C14:1 ω –5	0.17	–	–	0.12
C14:1 ω –7	0.20	–	–	1.13
C15:1 ω –6	–	1.21	–	–
C16:1 ω –5	–	0.46	–	–
C16:1 ω –6	–	–	0.10	–
C16:1 ω –7	11.15	–	5.97	8.12
C16:1 ω –9	–	3.10	0.69	–
C17:1 ω –7	–	0.21	–	–
C17:1 ω –8	–	–	–	0.65
C18:1 ω –5	–	–	–	0.12
C18:1 ω –7	–	–	–	–
C18:1 ω –9	1.65	4.04	–	6.97
C19:1 ω –8	–	–	–	0.42
C20:1 ω –5	–	–	–	0.12
C20:1 ω –7	–	–	–	–
C20:1 ω –9	–	–	–	–
C20:1 ω –11	–	–	–	0.51
C22:1 ω –7	2.87	–	–	1.69
C23:1 ω –9	–	–	0.22	–
C24:1 ω –3	–	–	–	–
C24:1 ω –6	–	–	0.57	–
C24:1 ω –9	1.51	–	0.31	1.69
$\sum$ Of MUFAs	17.70	9.02	7.86	21.71

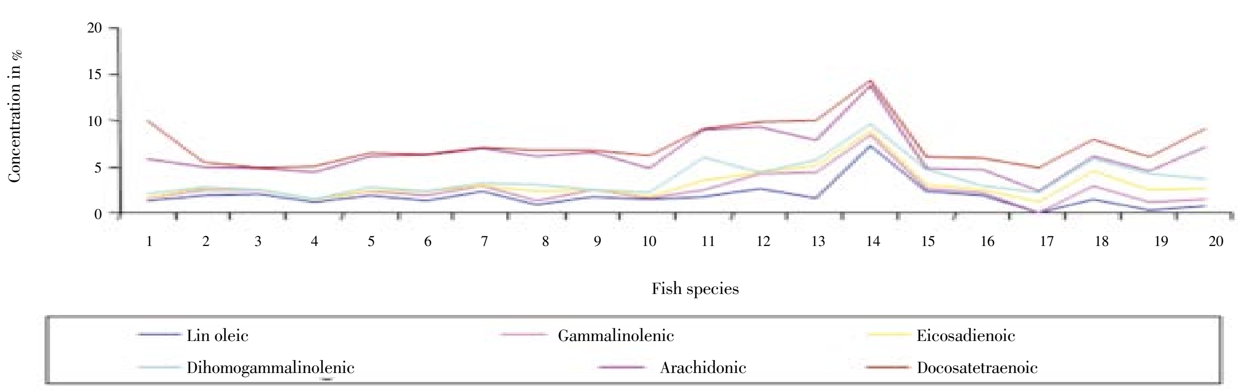

Figure 6. Distribution of Omega – 6 fatty acids

Table 8.
List of Polyunsaturated and branched fatty acids in fishes.

Fatty acid	*Sphyraena obtusa*	*Siganus javus*	*Carangoides malabaricus*	*Rastrilliger kanagurta*
C16:2 ω -6	1.31	1.04	0.57	1.13
C18:2 ω -3	2.36	-	0.12	2.31
C18:2 ω -6	1.65	7.23	2.29	1.82
C18:3 ω -3	8.14	15.07	10.01	5.91
C18:3 ω -6	2.65	1.14	0.36	0.39
C18:4 ω -3	2.13	0.19	2.1	1.91
C19:2 ω -6	1.21	0.5	0.79	1.01
C20:2 ω -6	0.72	0.51	0.4	0.19
C20:3 ω -6	0.69	1.62	1.57	0.54
C20:4 ω -6	2.13	4.32	0.21	1.65
C20:5 ω -3	10.02	12.35	6.51	9.54
C20:5 ω -6	0.15	0.14	0.11	0.13
C22:3 ω -3	2.65	2.56	2.13	2.15
C22:4 ω -6	2.18	0.57	1.32	1.36
C22:5 ω -3	3.17	1.29	1.51	1.42
C22:6 ω -3	9.59	8.12	7.11	8.12
Σ Of PUFAs	50.75	56.65	37.11	39.58
C14:0 Iso	-	-	0.57	0.12
-C15:0 Iso	-	-	-	0.11
C15:0 Anteiso	-	-	-	0.54
C16:0 Iso	-	-	-	-
C17:0 Iso	-	0.12	0.42	-
C17:0 Anteiso	2.22	0.16	0.12	-
C19:0 Iso	0.12	-	0.10	-
C20:0 Iso	-	-	-	-
C20:0 Anteiso	-	-	-	-
Σ Of Branched	2.34	0.28	0.64	0.77
Unknown& Others	0.15	0.11	0.19	0.24

Table 9.
List of Saturated and mono unsaturated fatty acids in fishes.

Fatty acid	*Uppenus sulphureus*	*Liza partia*	*Ilisha melastoma*	*Johinus borneensis*
C10:0	-	-	-	-
C11:0	-	-	-	-
C12:0	0.78	0.51	0.53	0.51
C13:0	0.19	-	0.18	-
C14:0	6.32	9.24	8.72	4.98
C15:0	1.10	3.27	2.97	0.95
C16:0	30.10	29.07	30.14	30.67
C17:0	1.58	1.42	1.97	1.27
C18:0	10.18	5.73	8.47	7.79
C19:0	0.35	-	0.92	-
C20:0	0.63	-	0.39	0.43
C21:0	0.29	0.15	0.25	-
C22:0	0.17	0.19	0.41	-
C23:0	0.36	0.10	0.29	0.04
C24:0	0.22	0.26	0.69	0.71
Σ Of SFAs	52.27	49.79	55.93	47.35
C14:1 ω -3	-	-	0.16	-
C14:1 ω -5	-	-	0.13	-
C14:1 ω -7	0.11	-	-	-
C15:1 ω -6	-	-	-	-
C16:1 ω -5	0.36	0.12	0.17	-
C16:1 ω -6	-	0.12	-	-
C16:1 ω -7	-	1.19	-	10.88
C16:1 ω -9	-	1.17	-	0.53
C17:1 ω -7	-	0.35	0.23	1.24
C17:1 ω -8	-	0.12	0.18	0.51
C18:1 ω -5	0.11	0.99	0.09	0.13
C18:1 ω -7	0.15	0.16	0.14	0.18
C18:1 ω -9	7.67	10.86	9.84	10.64
C19:1 ω -8	0.16	0.15	0.63	0.54
C20:1 ω -5	-	0.11	0.18	0.79
C20:1 ω -7	-	-	0.36	0.42
C20:1 ω -9	-	-	1.22	0.55
C20:1 ω -11	-	0.62	-	1.14
C22:1 ω -7	-	-	-	1.32
C23:1 ω -9	-	0.15	-	0.04
C24:1 ω -3	0.17	-	0.14	0.07
C24:1 ω -6	1.31	0.08	0.19	0.16
C24:1 ω -9	0.68	0.26	0.11	0.90
Σ Of MUFAs	10.72	16.45	13.77	30.04

Table 10.
List of Polyunsaturated and branched fatty acids in fishes.

Fatty acid	*Uppenus sulphureus*	*Liza partia*	*Ilisha melastoma*	*Johinus borneensis*
C16:2 ω-6	–	1.12	1.43	1.47
C18:2 ω-3	–	1.41	0.56	2.35
C18:2 ω-6	–	1.41	0.33	0.74
C18:3 ω-3	7.72	5.72	8.12	5.91
C18:3 ω-6	–	1.53	0.78	0.65
C18:4 ω-3	1.57	1.92	1.01	1.15
C19:2 ω-6	1.72	1.53	1.69	1.32
C20:2 ω-6	1.17	1.54	1.42	1.29
C20:3 ω-6	1.02	1.37	1.62	0.91
C20:4 ω-6	0.17	0.19	0.33	3.58
C20:5 ω-3	5.54	6.12	7.99	7.12
C20:5 ω-6	0.12	0.56	0.89	0.48
C22:3 ω-3	1.36	1.54	1.91	1.68
C22:4 ω-6	2.52	1.92	1.56	1.91
C22:5 ω-3	0.11	0.57	0.93	2.72
C22:6 ω-3	7.13	8.91	6.78	9.11
Σ Of PUFAs	30.15	37.36	37.35	42.39
C14:0 Iso	–	–	0.10	–
-C15:0 Iso	0.46	0.41	0.30	–
C15:0 Anteiso	–	–	0.19	–
C16:0 Iso	0.36	–	–	–
C17:0 Iso	0.72	1.13	–	–
C17:0 Anteiso	0.32	–	–	2.35
C19:0 Iso	–	–	–	–
C20:0 Iso	–	0.68	0.52	0.67
C20:0 Anteiso	–	–	0.41	–
Σ Of Branched	1.86	2.22	1.52	3.02
Unknown& Others	0.31	0.17	0.11	0.12

Table 11.
Ratio of ω-3 and ω-6 in the 20 marine fishes.

S. No	Fish Name	ω-3 / ω-6 ratio	S. No	Fish Name	ω-3 / ω-6 ratio
1	*Congresox talabon*	3.8	11	*Tenulosa ilisha*	2.6
2	*Arius dussumier*	3.2	12	*Elutherenema tetradactylum*	3.2
3	*Dussumieria acuta*	3.4	13	*Sphyraena obtusa*	2.9
4	*Opisthopterus tardoore*	3.9	14	*Siganus javus*	2.3
5	*Scomberoides commersonianus*	2.9	15	*Carangoides malabaricus*	3.8
6	*Megalopsis cardyla*	2.8	16	*Rastrilliger kanagurta*	3.8
7	*Carangoides chrysophrys*	3.2	17	*Uppenus sulphureus*	3.3
8	*Caranx para*	2.6	18	*Liza partia*	2.3
9	*Secutor incidiator*	2.3	19	*Ilisha melastoma*	2.7
10	*Sardinella longiceps*	3.1	20	*Johinus borneensis*	2.4

respectively. The high level of polyunsaturated fatty acids (23.52-56.65%) (Figure 6) . Medically important Omega-6 FAs like γ-linolenic acid (GLA) was in the range of 0.-2.65%, Linoleic acid (LA) 0-7.23%, Arachidonic acid (ARA) 0.21-4.86% and Dihomogammalinolenic acid (DGLA) 0-2.36%. The other Omega-3 FAs like Stearidonic acid (SA) 0-2.13% Docosatrienoic acid (DTA) 0-2.65% and Docasapentaenoic acid (DPA) 0.05-3.21% were also found in these samples (Figure 5).

4. Discussion

The highest amount of Palmitic acid was found in Elutherenema tetradactylum (31.98%) and lowest amount in Congresox talabon (22.80%). Among the Saturated fatty acids,the C16:0 Fatty acid was the dominant one. Palmitic acid was found to be the most abundant in different fish species [29-34]. These results demonstrated that significant part of the fatty acid in the muscle tissue was poly unsaturated fatty acids (PUFAs). The content of PUFA varied from 23.52% to 56.75%. The major classes of unsaturated fatty acids in nature are Omega-6 and Omega-3, represented by Oleic acid, Arachidonic acid, Linoleic acid, Alfa Linoleic acid, Eicosapentaenoic acid and Docasahexaenoic acid respectively [35, 36]. In this present study we investigated the major fatty acids in twenty different fish tissues. Oleic acid (C18:1n9c) was identified as the primary Monounsaturated fatty acid in the ranging from 1.65% in Sphyraena obtusa to 16.82% in Secutor incidiator. The results demonstrated that significant part of the fatty acids in the muscle tissue was polyunsaturated fatty acids (PUFA). The content of PUFA varied from 23.52% to 56.75%. The content of Monounsaturated fatty acids (MUFA) varied from 7.86% in Carangoides malabaricus to 32.13% in Arius dussumieri. The values for MUFA (7.86-32.13%) are lower than the SFA and PUFA. This study has shown that marine fish were richer in ω-3 PUFAs (17.89-39.58%) than ω-6 PUFAs (5.14-17.07%). Wang, Miller, Perren and Addis (1990)[37], reported similar findings, in that marine fish were rich in ω-3, especially DHA and EPA. Bowman and Rand (1980) reported that Arachidonic acid (C20:4 ω-6) is a precursor for prostaglandin and thromboxan which will influence the blood clot and its attachment to the endothelial tissue during wound healing. Apart from that, the acid also plays a role in growth. Compared with fresh water fishes, these marine fishes have lower amount of AA. Based on an earlier study [38], incases the contents of AA in marine fishes lower than fresh water fishes. The ω-3: ω-6 ratio is a better index in comparing relative nutritional value of different fish species. Table.2 shows that ratio of ω-3: ω-6 in different fish tissues studied. However, there is no recommended intake in terms of ω-3: ω-6 ratios but evident in wild animals and estimated nutrient intake during human evolution suggests a diet ratio of 1:1 [39]. Compared with fresh water fish, marine fish contain higher amount levels of PUFAs especially ALA, DHA and EPA as found in this study. However, both sea water and fresh water fish were good sources of EPA and DHA. The level of total Omega-6 series of sea water fish was found to be low, ranging from 5.4% for Opisthopterus tardoore and 12.67% for Sphyraena obtusa. AA is the principle Omega-6 FAs in the brain and together with DHA is important in the brain development of infants. While GLA is metabolic precursor to ARA, its conversion to ARA mediated by the enzyme Δ-6 desaturase, is slow and this enzyme is present only in low levels in humans. Hence it is considered preferable to feed ARA to humans rather than GLA. ARA is also a direct precursor of a number of eicosanoids regulating lipoprotein metabolism, blood rheology, and leucocytes function and platelet activation. Good nutritional source of ARA are animal livers and yolk [40]. Linoleic acid (LA) is the most abundant PUFA in the human skin. Among other things, it plays vital role in preserving our epidermal water barrier. Defiencies in this EFA (Essential Fatty Acid) result in scaly skin and excessive water loss [41].

The results of the present study revealed that the most abundant individual FAs were Palmitic acid, Oleic acid, Arachidonic acid (AA), Docosahexaenoic acid (DHA) in most the tissues. This result was confirmed by several other studies for some tissues of different fish [42, 43]. The total Arachidonic acid (C20:4 ω-6) was found to be higher proportion (0.17-4.86%), when compared with other Omega-6 fatty acids. In this present study, we investigated the fatty acid composition of muscle from 4 different fish species and found more amounts of polyunsaturated fatty acids like ALA, EPA, DHA, GLA, ARA, DGLA, SA and LA etc. The values found for Linoleic acid (C18:2 ω-6) ranging from 0-7.23%. *Siganus javus* has 7.23% of Linoleic acid. People eat specific foods because of their taste, easy availability and affordability, but are often unaware of the health benefits and risks. Better food habits can help reduce the risk of CVD, diabetes, stroke and death. A healthy eating plan means choosing the right foods to eat, and preparing them in a healthy way. Thus a healthy diet rich in ω-3 fatty acids is beneficial for all age groups.

Conflict of interest statement

We declare that we have no conflict of interest.

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