



Seasonal Changes in Total Lipid Content and Fatty acid Profiles of Ribbon Fish, *Lepturacanthus savala* (Cuvier, 1829)

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Abstract

In order to evaluate the seasonal changes in nutritive value of ribbon fish, in relation to size, total lipid and fatty acid profiles of different sizes of ribbon fish, *Lepturacanthus savala* captured in different seasons were studied. Total lipid content was significantly ($p < 0.05$) high in large sized ribbon fish captured during winter and lowest in medium size groups during post-monsoon season. A total of 37 fatty acids were identified by Gas Chromatography - Mass Spectrometry encompassing saturated, mono unsaturated, n-6, n-3 poly unsaturated and odd and branched chain fatty acids. The highest content of eicosapentaenoic acid (9.42%) and docosahexaenoic acid (33.16%) were found in the post-monsoon season. The high levels of n-3 PUFA (12.37 – 43.14%) and favourable n-3/n-6 PUFA ratio of 1.79 to 5.04 revealed nutritional significance of ribbon fish in human diet. The difference between small, medium and large groups of ribbon fishes of the respective season based on fatty acid composition was clearly established by principal component analysis.

Keywords: Ribbon fish, lipid content, fatty acids, principal components, seasonal changes

Introduction

Marine fishes are nutritionally significant in human diet due to their high levels of n-3 (omega-3) polyunsaturated fatty acids (PUFA), which have been reported to reduce the risk of coronary heart diseases (Erkkila et al., 2003) and lower blood pressure and plasma triacylglycerol levels

(Dallongeville et al., 2003). These fatty acids have several health benefits such as prevention of human breast cancer growth, asthma and inflammatory disorders of the immune system. In addition, they can reduce the symptoms of diabetes (James et al., 2000). Lipid content and fatty acid composition of fish are known to vary significantly depending on the season, location, availability of food and environmental conditions such as temperature, salinity and pressure (Bandara et al., 1997; Ramesh et al. 2013). Previous studies have shown that n-3 PUFA of marine animals vary depending on various biological and environmental factors, such as taxonomy, diet of the animals, water temperature and the latitude at which they are harvested (Dunstan et al., 1999).

Ribbon fish (hair tail/cutlass fish) is a major fishery resource distributed in the Atlantic and Indo Pacific regions. Globally, the annual capture production of ribbon fish was 1 235 373 t (FAO, 2012) and formed 6% of total marine fish catch of India with 236 541 t (CMFRI, 2013). Currently large quantities of ribbon fish are exported from India in frozen form, contributing up to 30% to the total marine products export of India and constituting about 78% of the exported frozen finfish products (Radhakrishnan et al., 2003; Gopal et al., 2009; MPEDA, 2011).

Although the lipid profile of fresh and dried ribbon fish laminates (Jeevanandam et al., 2001) and fatty acid composition of small pelagic fishes including ribbon fish have been reported (Edirisinghe et al., 1998; Oduor-Odote, 2008), there is no comprehensive information available on seasonal changes on lipid content and fatty acid profiles of this fish with respect to size. Due to high demand in the export market for ribbon fish and its availability throughout the year, the present study was carried out to

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discern the seasonal changes in the fatty acid profiles of ribbon fish with respect to different size groups.

Materials and Methods

Samples were collected from different landing centers along Mumbai Coast during post-monsoon (August), winter (December) and summer (April) seasons. The morphometric data of fish selected for different size groups is presented in Table 1. Fish were classified as small, medium and large groups based on their average length and weight. In each season, edible muscle tissue from five specimens of each size were used for analysis.

Table 1. Morphometric data of different size groups of ribbon fishes (*Lepturacanthus savala*) sampled for the study

Size	Body length (cm)	Body weight (g)
Small	<30	0-50
Medium	30-60	50-150
Large	>60	>150

Total lipid was extracted from muscle tissue according to the method of Folch et al. (1957). Fatty acid methyl esters were analyzed using a Shimadzu QP2010 Quadruple Gas Chromatography Mass Spectrometer (GC-MS) equipped with a Carbowax (30 m x 0.25 µm ID; 0.25-µm film thickness) capillary column (Cromlab S.A.). Helium was used as the carrier gas. The values of fatty acids are presented in peak area percentages of total identified fatty acids.

Analysis of variance (ANOVA) was performed on total lipid content data and differences in significance at $p < 0.05$ between mean values were evaluated using Duncan's test with multiple comparison by employing one way ANOVA using SPSS (Version 16.0) statistical package. The multivariate data on fatty acid composition subjected to different size and seasons were analyzed by principal component analysis (PCA) using software Unscrambler (Version 9.5, CAMO, Norway).

Results and Discussion

Total lipid content (%) recorded in the muscle tissue of different size groups of ribbon fish during

different seasons is shown in Table 2. Significant differences ($p < 0.05$) were observed during different seasons with respect to different sizes. The total lipid content in muscle was in the range of 1.5-3.7%. Generally, fish can be grouped into four categories based on their fat content: lean fish (<2%), low fat (2-4%), medium fat (4-8%), and high fat (>8%) (Ackman, 1976). In the present study, ribbon fishes fall under the category of lean and low fat fishes. The highest concentration ($3.70 \pm 1.02\%$) was recorded in winter compared to other seasons. Lipid content of fish also varied in response to changes in season, water temperature, salinity and depth through adaptive mechanisms (Tanakol et al., 1999). In muscle, higher percentage of lipid content was found in large size fish which was caught during winter, whereas, the lowest ($1.5 \pm 0.06\%$) amount was observed in medium size fish during post-monsoon compared to the other size groups. During winter season, lipid content in the fish as well as prey animals have been reported to be very high (Tanaka, 1980). As fish consumes prey with high lipid content, additional lipid would be deposited resulting in higher lipid levels during winter. Sideleva & Kozlova (1989) reported that, the relative mass of the edible tissues of pelagic fish species varied with different seasons.

Table 2. Total lipid content (%) in the muscle tissue of ribbon fish different size groups, recorded during different seasons (wet weight basis)

Seasons	Small	Medium	Large
Post-monsoon	1.86 ± 0.15^{aA}	1.50 ± 0.06^{aA}	2.50 ± 0.02^{aB}
Winter	2.87 ± 0.64^{bA}	3.21 ± 0.66^{cB}	3.70 ± 1.02^{bC}
Summer	2.48 ± 0.64^{bA}	2.97 ± 0.66^{bA}	3.60 ± 1.02^{bB}

Superscripts a, b and c represents significant differences ($p < 0.05$) among same sizes in different seasons (Mean $\pm$ SD). A, B and C represent significant differences ($p < 0.05$) among different sizes in each season.

A total of 37 fatty acids were identified in muscle tissue of three different sizes of ribbon fish during three different seasons and the data is presented in Table 3. Use of capillary column for resolution of components and MS (mass spectrometer) for identification of fatty acids enabled us to characterize 37 fatty acids encompassing n-3, n-5, n-6, n-7, n-9 and odd and branched chain fatty acids (OBCFA). In earlier studies, 11 fatty acids were identified by Oduor-Odote & Kazungu (2008) and 13 fatty acids

were reported by Edirisinghe et al. (1998) in ribbon fishes.

In muscle tissue of ribbon fish, the most common fatty acids among saturated fatty acids (SFA) were palmitic acid (15.02-29.26%) and stearic acid (9.24-19.94%). Among monounsaturated fatty acids (MUFA), oleic acid (18:1n-9) was the most abundant comprising of 7.57-16.81% of the total fatty acids followed by palmitoleic acid (16:1n-7) which formed 2.96-7.04%. Arachidonic acid (AA, 20:4n-6) was the principal n-6 PUFA at a level of 3.9-5.43% of total fatty acids. Eicosapentaenoic acid (EPA, 20:5n-3), docosapentaenoic acid (DPA, 22:5n-3) and docosahexaenoic acid (DHA, 22:6n-3) were the major n-3 PUFA identified, accounting 2.65-9.42, 0.98-5.03 and 7.27-33.16% respectively. The main OBCFA identified in the present study were isomers of pentadecanoic acid (*iso* C15:0), hexadecanoic acid (*iso* C16:0), heptadecanoic acid (*iso* C17:0) and octadecanoic acid (*iso* C18:0). The levels of n-6 and n-3 fatty acids were high during post-monsoon and winter season, whereas SFA and MUFA were abundant in summer season apparently in all the size groups.

Marine fishes have been reported to possess a substantial amount of fatty acids beneficial for human health like arachidonic acid, EPA and DHA. Lipid content and fatty acid composition changes according to species, diet, geographical origin and season (Tashiro et al., 1981; Hatano, 1990). In addition to the seasonal variations, body size, location and sexual maturity also have been reported to influence the fatty acid composition (Ackman, 1982). In general, the fatty acid composition of fish is mainly influenced by their prey animals (Watanabe, 1982). On the other hand, fishes generally change prey according to their own body size (Tanaka, 1980).

Muscle tissue recorded high levels of PUFA which may be attributed to their feeding habits that depend entirely on the marine food chain, which is a known source of long chain PUFA. Muscle of larger pelagic fish has a greater concentration of EPA and DHA compared to smaller fish (Pozo et al., 1992). In contrast to earlier reports, no significant seasonal variation was observed in fatty acid contents among different sizes of ribbon fish in the present study. The presence of high levels of saturated fatty acids indicates the presence of active enzymes responsible for *de novo* synthesis. These

SFA and MUFA are generally abundant in fish from warm or tropical regions, whereas PUFA show high levels in fish from cold regions (Dey et al., 1993; Wodtke, 1981). It is in agreement with earlier studies that ribbon fishes contained higher levels of saturated fatty acids.

n-3 PUFA levels were found higher than those of n-6 PUFA, as typical of marine fish (Greene et al., 1987). The n-3/n-6 ratio is a better index of comparing the relative nutritional value of fish (Pigott, 1989). In the light of the diversified roles of n-3 and n-6 PUFA, the right balance between these fatty acid groups is recommended. High levels of n-6 PUFA in the human diet can lead to many health disorders (Sargent & Tacon, 1999) whereas, n-3 PUFA modulate the undesirable effects of n-6 PUFA. Hence, the observed high ratio of n-3/n-6 PUFA in the present study (1.79 to 5.04) emphasizes the excellent quality of ribbon fish meat.

Fatty acid composition of fish in general is known to be affected by diet (Olsen & Skjervold, 1995), food deprivation (De Silva et al., 1997) and non-dietary factors including environmental temperature (Bell et al., 1986). PUFA content in fish and shellfish varies inversely with water temperature, while the SFA content changes positively with water temperature (Dunstan et al., 1999). Habitat temperature is known to affect the fatty acid composition of poikilothermic fish in a way that the degree of unsaturation increases with decreasing temperature (Morris & Culkin, 1989). In agreement with the earlier studies, PUFA content increased during the post-monsoon and winter seasons in ribbon fish. This could be due to its cannibalistic feeding habits and availability of marine algae in the food chain during monsoon and winter seasons (James et al., 1986). Small size ribbon fish had lowest lipid contents compared to the other size groups during all the seasons. However, all the size groups of ribbon fish harvested during the different seasons possessed relatively high proportion of nutritionally important PUFA with highly favorable n-3/n-6 ratio.

Odd and branched-chain saturated fatty acids (OBCFA) were identified by mass spectrometry of the methyl ester derivatives based on the molecular ions (*m/z* value), especially *iso* fatty acids such as *iso*-15:0, *iso*-16:0, *iso*-17:0 and *iso*-18:0, were in the range of 0.07 to 1.78%. (Table 3). Vlaeminck et al. (2006) suggested that PUFA and OBCFA of marine food chain received considerable attention because

Table 3. Fatty acid composition (% of total fatty acids by peak area) of muscle tissue in different size groups of ribbon fish caught during three seasons

Fatty acids	Pre-monsoon			Winter			Summer		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
6:0	0.01	0.02	0.01	0.01	0.01	0.02	0.03	0.10	0.08
8:0	0.02	0.03	0.02	0.03	0.02	0.04	0.01	0.02	0.01
12:0	0.12	0.49	0.14	0.13	0.07	0.06	0.19	0.23	0.30
13:0	0.02	0.05	0.03	0.06	0.04	0.03	0.05	0.23	0.19
14:0	3.31	4.00	3.28	4.54	2.62	1.95	1.71	2.01	1.62
iso-15:0	0.13	0.15	0.10	0.23	0.12	0.07	0.21	0.12	0.17
15:0	0.94	0.97	0.77	1.33	0.95	0.71	0.98	0.93	1.04
iso-16:0	0.41	0.11	0.47	0.74	1.72	1.78	0.15	0.35	0.21
16:0	15.34	15.02	15.48	15.94	16.02	17.53	17.00	29.26	22.45
iso-17:0	0.21	0.50	0.51	0.45	0.56	0.38	0.24	0.43	0.35
17:0	1.47	1.54	1.40	1.86	1.75	1.57	1.78	2.01	1.54
iso-18:0	0.23	0.21	0.16	0.34	0.34	0.24	0.17	0.39	0.26
18:0	9.24	9.62	9.35	11.26	12.67	12.48	13.63	19.94	15.74
19:0	0.24	0.25	0.20	0.47	0.48	0.38	0.47	0.48	0.51
20:0	0.28	0.54	0.24	0.75	0.49	0.39	0.48	0.56	0.32
23:0	0.08	0.32	0.13	0.40	0.80	0.06	0.15	0.49	0.44
Total SFA	32.05	33.82	32.29	38.54	38.66	37.69	37.25	57.55	45.23
16:1n-9	0.21	0.39	0.66	1.27	0.85	0.65	0.28	1.03	0.98
16:1n-7	7.04	6.02	4.25	4.83	3.18	2.96	3.76	2.43	3.21
18:1n-9	9.61	8.98	7.57	11.83	12.06	12.51	13.57	14.45	16.81
18:1n-7	4.78	3.14	3.06	3.09	3.10	2.63	3.20	3.36	3.12
18:1n-5	0.14	0.08	0.09	0.18	0.07	0.07	0.10	0.49	0.33
20:1n-9	0.38	0.17	0.13	0.48	0.47	0.36	0.42	0.39	0.24
20:1n-7	0.20	0.18	0.09	0.25	0.28	0.15	0.17	0.28	0.34
22:1n-9	0.08	0.01	0.04	0.26	0.20	0.05	0.15	0.75	0.44
Total MUFA	22.44	18.97	15.89	22.19	20.21	19.38	21.65	23.18	25.47
18:2n-6	1.39	1.37	1.28	1.52	1.28	1.03	1.25	1.44	1.51
20:2n-6	0.21	0.19	0.20	0.25	0.26	0.18	0.26	0.36	0.47
20:3n-6	0.15	0.11	0.16	0.22	0.17	0.16	0.18	0.24	0.32
20:4n-6	4.51	4.63	4.69	4.46	4.51	4.70	5.43	3.90	4.34
22:4n-6	0.24	0.11	0.18	0.66	0.73	0.51	1.20	0.67	0.86
22:5n-6	1.53	1.40	2.07	1.47	1.92	2.08	1.82	0.29	0.66
Total n-6 PUFA	8.03	7.81	8.58	8.58	8.87	8.66	10.14	6.90	8.16
18:3n-3	0.38	0.58	0.41	0.71	0.40	0.36	0.41	0.33	0.32
18:4n-3	0.39	0.65	0.42	0.23	0.13	0.09	0.07	0.12	0.12
20:3n-3	0.07	0.05	0.05	0.10	0.10	0.10	0.15	0.15	0.09
20:4n-3	0.23	0.33	0.23	0.84	0.39	0.24	0.43	0.13	0.65
20:5n-3	7.15	9.42	7.49	4.05	4.03	5.31	4.68	2.65	3.89
22:5n-3	0.98	1.43	1.38	3.80	3.05	2.35	5.03	1.72	2.62
22:6n-3	28.28	26.94	33.16	20.96	24.16	25.82	20.19	7.27	13.45
Total n-3 PUFA	37.48	39.4	43.14	30.69	32.26	34.27	30.96	12.37	21.14
n3/n6 ratio	4.66	5.04	5.02	3.57	3.64	3.95	3.05	1.79	2.59

of their biological activities in health and diseases. These fatty acids occur in small amounts and have been detected in the range of 0.1-1% each (Ackman, 1976; Young, 1982). In the present study, OBCFAs did not show any specific trend either with respect to size or season.

To observe the relationships among different seasons and sizes with respect to fatty acids, a graphic representation of the projection of variables and samples onto the first two principal components is given in Fig. 1 in the form of bi-plot.

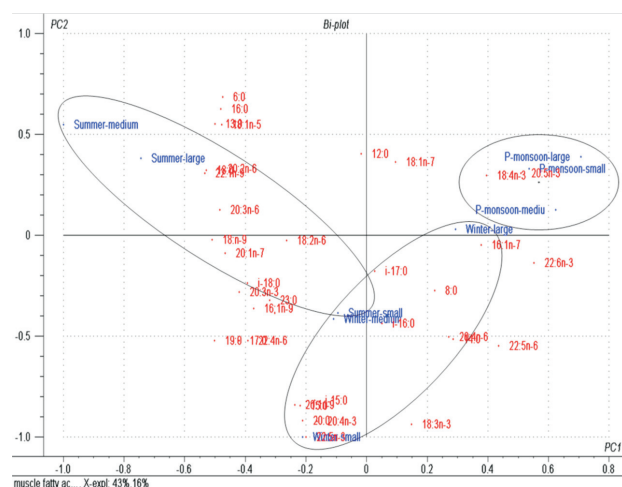


Fig. 1. Bi-plot showing muscle fatty acid distribution in ribbon fish with respect to size and season

About 59% of total information of the data was explained by the two principle components PC₁ and PC₂. PC₁, which explained 43% of the total information in the data, has clearly separated post-monsoon from other seasons. Ribbon fish samples were segregated into clusters mainly based on the season rather than size demonstrating the profound effect of season on fatty acid profile compared to the size of fish. Further, it is clear from the bi-plot that, the ribbon fish caught in post-monsoon season was rich in n-3 fatty acids such as EPA, 18:4n-3 and DHA. The fish caught in summer season were found rich in SFA namely palmitic and stearic acid.

The present study revealed that ribbon fish possess higher levels of n-3 PUFA, especially EPA and DHA, which are known for their human health promoting effects. The lipid content of ribbon fish muscle significantly ($p < 0.05$) varied among different seasons. The fish harvested in winter season had more lipid content compared to the fish caught in other seasons irrespective of the body size.

References

- Ackman, R. G. (1976) Fish oil composition. In: Objective Methods for Food Evaluation, pp103-131, National Academy of Science, Washington D C
- Ackman, R. G., (1982) Origin of marine fatty acids in nutritional evaluation of long chain fatty acids. In: Fish Oil (Barlow, S. M., Stansby and M. E., Eds), pp 25-88, Academic Press, London
- Bandara, N. M., Batista, I., Nunes, M. L., Empis, J. M. and Christie, W. (1997) Seasonal changes in lipid composition of sardine, *Sardina pilchardus*. J. Food Sci. 62: 40-42
- Bell, M. V., Henderson, R. J. and Sargent J. R. (1986) The role of polyunsaturated fatty acids in fish. Com. Biochem. Physiol. 83B: 711-719
- CMFRI (2013) CMFRI Annual Report 2012-13, CMFRI, Cochin, India
- Dallongeville, J., Yarnell, J., Ducimetiere, P., Arveiler, D., Ferriers, J., Montaye, M., Luc, G., Evans, A., Bingham, A. and Hass, B. (2003) Fish consumption is associated with lower heart rates. Circulation, 108 (7): 820-825
- De Silva, S. S., Gunasekera, R. M., Collins, R., Ingram, B. A. and Austin, C. M. (1997) Changes in the fatty acid profile of the Australian short fin eel in relation to development. J. Fish Biol. 50 (5): 992-998
- Dey, I., Buda, C., Wiik, H., Halver, J. E. and Farkas, T. (1993) Molecular and structural composition of phospholipid membranes in livers of marine and freshwater fish in relation to temperature. Proc. Natl. Acad. Sci. USA. 90 (16): 7498-7502
- Dunstan, G. A., Olley, J. and Ratkowsky, D. A. (1999) Major environmental and biological factors influencing the fatty acid composition of seafood from Indo-Pacific to Antarctic waters. Rec. Res. Dev. Lipid Res. 3: 63-86
- Edirisinghe, E. M. R. K. B., Perera, W. M. K. and Bamunuarachchi, A. (1998) Fatty acid composition of some pelagic fishes in Srilanka. In: Fish Utilization in Asia and the Pacific region (Proc. APFIC symposium, Eds), pp 172-181, FAO, Beijing, China
- Erkkila, A. T., Lehto, S., Pyorala and K., Uusitupa, M. I. (2003) N-3 fatty acids and 5-y risks of death and cardiovascular disease events in patients with coronary artery disease. Amer. J. Clinical Nutr. 78: 65-71
- FAO (2012) FAO Year book, Fisheries and Aquaculture Statistics, 12 p
- Folch, J. L., Sloane, M. and Stanley G. H. S. (1957) A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226: 497-509

- Gopal, N., Jeyanthi, P., Geethalakshmi, V. and Unnithan, G.R. (2009) Indian finfish exports – an analysis of export performance and revealed comparative advantage. *Agric. Econ. Res. Rev.* 22: 291-297
- Greene, D. H. S. and Selivonchick D. P. (1987) Lipid metabolism in fish. *Pro. Lipid Res.* 26: 53-85
- Hatano M. (1990) Lipids. In: *The Nutritive Components of Fish and New Fish Utilization Technology* (Takeuchi K. K. M., Ed), pp 34-43, Tokyo
- James, P. S. B. R., Narasimham, K. A., Meenakshisunderam, P. T. and Appana Sastry, Y (1986) The present status of ribbonfish fishery in India. CMFRI special publication, Cochin, India. 24: 1-45
- James, M. J., Gibson, R. A. and Cleland, L. G. (2000) Dietary polyunsaturated fatty acids and inflammatory mediator production. *Amer. J. Clinical Nutr.* 71: 343S-348S
- Jeevanandam, K., Venugopal, V., Doke, S. N., Rao, B. Y. K. and Bongirwar, D. R. (2001) Preparation and Storage Characteristics of Ribbon Fish Laminates. *J. Aquat. Food Prod. Technol.* 10(4): 77-86
- Morris, R. J. and Culkin F. (1989) Fish. In: *Marine Biogenic Lipids, Fats and Oils* (Ackman, R. G., Ed), pp 145-178, CRC Press, Boca Raton, Florida
- MPEDA (2011) Marketing news. In: *News letter*, March, 2011. 1p, Cochin, India
- Oduor-Odote, P. M. and Kazungu, J.M. (2008) The body composition of low value fish and their preparation into a higher value snack food. *Western Indian Ocean J. Mar. Sci.* 7(1): 111-117
- Olsen, Y. and Skjervold, H. (1995) Variation in content of ω -3 fatty acids in farmed Atlantic salmon, with special emphasis on effects on non-dietary factors. *Aquacult. Int.* 3: 22-35
- Pigott, G.M. (1989) The need to improve omega-3 content of cultured fish. *World Aquaculture Magazine*, 20: 63-68
- Pozo, R., Perez-Villarreal, B. and Saitua E. (1992) Total lipids and omega-3 fatty acids from seven species of pelagic fish. In: *Pelagic Fish - The Resources and its Exploitation* (Burt, J. R., Hardy, R. and Whittle, K. J., Eds), pp 142-147, Fishing News Books, London
- Radhakrishnan Nair, P. N. and Prakasan, D. (2003) Ribbon fishes In: *Status of Exploited Marine Fishery Resources of India* (Mohan Joseph, M. and Jayaprakash, A. A., Eds), pp 76-87, CMFRI, Cochin
- Ramesh, R., Pal, A. K. Chakraborty, S. K. and Venkateshwarlu, G. (2013) Variation in total lipid content and fatty acid composition in the muscle of Bombay Duck *Harpodon nehereus* (Hamilton, 1922) with respect to size and season. *Indian J. Fish.* 60(1): 111-116
- Sargent, J. R., Tacon, A. (1999) Development of farmed fish: a nutritionally necessary alternative to meat. *Proc. Nutr. Soc.* 58: 377-383
- Sideleva, V. G. and Kozlova, T. A. (1989) Specialization of the *Cottoidei* to the pelagic habitat of Baikal. *Doklady AN SSSR*, 309: 1499-1501
- Tanaka, S. (1980) Biological research on salmon sharks (*Lamna ditropis*). Report on the research of new resources development on shark. Japan Marine Fishery Resources Research Centre, pp 59-84
- Tanakol, R., Yazici, Z., Sener, E. and Sencer, E. (1999) Fatty acid composition of 19 species of fish from the Black Sea and the Marmara Sea. *Lipids*, 34(3): 291-297
- Tashiro, I., Itoh, S. and Tsuyuki, H. (1981) Seasonal variation of lipids of horse mackerel. *Nip. Su. K. Ga.* 28: 309-317
- Vlaeminck, B., Fievez, V., Cabrita, A. R. J., Fonseca, A. J. M. and Dewhurst, R. J. (2006) Factors affecting odd- and branched-chain fatty acids in milk: A review. *Animal Feed Sci. Technol.* 131(3-4): 389-417
- Watanabe, T. (1982) Lipid nutrition in fish. *Comp. Biochem. Physiol.* 73B: 3-15
- Wodtke, E. (1981) Temperature adaptation of biological membranes. The effects of acclimation temperature on the unsaturation of the main neutral and charged phospholipids in mitochondrial membranes of the carp (*Ciprinus Carpio* L.). *Biochim. Biophys. Acta.* 640(3): 698-709
- Young, F. V. K. (1982) The production and use of fish oils. In: *Nutritional Evaluation of Long Chain Fatty Acids in Fish Oils* (Barlow, S. M. and Standsby, M. E., Eds), pp 1-23, Academic press, London