International Journal of Zoological Research

ISSN 1811-9778

Academic Journals Inc.

www.academicjournals.com

International Journal of Zoological Research 8 (1): 43-51, 2012
ISSN 1811-9778 / DOI: 10.3923/ijzr.2012.43.51

Variation in Nutritive Composition of Two Commercially Important Marine Fin Fishes

S. Ravichandran, F.R. Sharmila Joseph, R. Kanagalakshmi and M.S. Ramya
Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai, 608502, India

Corresponding Author: S. Ravichandran, Centre of Advanced Study in Marine Biology, Annamalai University Parangipettai, Tamil Nadu,608-502, India

ABSTRACT

The chemical compositions of fishes vary and are closely related to feed intake, migratory swimming and sexual changes in connection with spawning. The nutritive composition of many marine, estuarine and fresh water fishes were determined and have been implemented in fish consumption. Nutritive composition of *Dussumieria acuta* and *Sardinella brachysoma* were not yet determined and the present study was dealt with these fishes. Fatty acids, Vitamins (fat soluble and water soluble) and Minerals were quantified. Palmitic acid showed its higher level in both species (5.78 and 3.89%) in *D. acuta* and *S. brachysoma*, respectively). Water-soluble vitamins were higher in *D. acuta* and fat-soluble vitamins showed higher percentage availability in *S. brachysoma*. Calcium was the predominant mineral in both fishes and can be consumed by humans for bone strength. The finding has proved with strong evidence that both the fishes undertaken for the present study are rich in most of the nutrients essential for proper health maintenance of humans.

Key words: Fish nutrition, lipids, vitamins, minerals

INTRODUCTION

Fish is one of the most important sources of animal protein and has been widely accepted as a good source of protein and other elements for the maintenance of healthy body (Andrew, 2001). They have a significant role in nutrition, income, employment and foreign exchange earning of the country. Fisheries contribute about 80% to the nation's animal protein intake (DOF, 2003). Fish and shellfishes are the primary source of animal protein and valuable in the diet because they provide a good quality of protein of high biological value, particularly sulphur containing amino acids (Lavniegos and Lopez-Cortes, 1997).

Consumption of fish provides an important nutrient to a large number of people worldwide and thus makes a very significant contribution to nutrition (James, 1998). Stansby (1973) has established that information on the chemical composition of fish in respect to the nutritive value is important to compare with other source of animal protein, foods such as meat and poultry products in spite of huge amount of fish protein consumption, there are a few report on the nutritive or calorific values of small indigenous fish.

Dussumieria acuta and *Sardinella brachysoma* are believed to have high degree of nutritive elements. But the major nutritive compositions such as fatty acids, vitamins and minerals of these fishes were not yet determined. The composition of a particular species often appears to vary from one fishing ground to another and from season to season, but the basic causes of change in

composition are usually variation in the amount and quality of food that the fish eats and the amount of movement it makes.

MATERIALS AND METHODS

Fishes were collected from Parangipettai coastal waters (Lat 11° 29'N; 79° 46'E), which are one among the potential fishing zones of Tamil Nadu, South-East coast of India. The size groups of 10-13 cm in *D. acuta* and 12-16 cm in *S. brachysoma* were chosen for the present study. The edible tissues of pooled sample in each species were oven dried at 60°C for 24 h and used for the estimation.

Fatty acids: Fatty acid profiles of the fish samples were determined according to AOAC (1995) method 991.38 and their composition was determined by Gas Chromatography (GC). Extraction was performed with a (2:1) Chloroform/methanol mixture in a Soxhlet device (Folch *et al.*, 1957). After extraction, fats were completely dried with a rotary evaporator, reconstituted with 15 mL of solvent and washed with 3 mL of 0.1M KCl. The aqueous layer was re-extracted with solvent. Emulsions were then broken down by centrifugation and the extracts were dried with Sodium sulphate. After rotary evaporation, 4 mL of 0.5 M sodium hydroxide in methanol were added per 100 mg of lipid. To hydrolyze the lipid, the mixture was then refluxed until the oil disappeared. Methylation of fatty acids was conducted using a boron tri-fluoride/methanol reagent (14% BF_3 in methanol; 5 mL per 100 mg lipid) (Metcalfe *et al.*, 1966) which was added to the sample and refluxed for another 2 min. Heptane (5 mL) was added to extract the fatty acid methyl esters and heptanes layer was then concentrated with nitrogen gas. Fatty acid methyl esters (FAME) were quantified by gas chromatography on a GC-MS QP5050A S (Shimadzu) model (Japan). The carrier gas (helium) had a flow rate of 20 mL min^{-1} and split ratio 40. A sample was injected on a 60 mm X 0.25 mm X0.2 AZA ¼m df Non-bonded SP-2340/silar 10 CP (US Patent) capillary column.

Vitamins

Fat-soluble vitamins: The accurately weighted samples were taken into a separating funnel. To this 10 mL of dimethyl sulphoxide and 15 mL of n-hexane were added and shaken for 45 min on a wrist shaker in water bath maintained at 60°C. The contents were centrifuged at 3000 rpm for 10 min and hexane layer was transferred by means of a pipette to a 100 mL volumetric flask. Further 15 mL of n-hexane was added to the dimethyl sulphoxide layer and shaken thoroughly for 5 min and n-hexane layer was transferred to a 100 mL volumetric flask with hexane to the volume and mixed. This solution was used for the estimation of vitamins A, D and E. These vitamins were determined with the corresponding standards and the values were obtained in the chromatography conditions.

Water-soluble vitamins: VitaminB1 (Thiamin), vitaminB2 (Riboflavin), Niacin (Nicotinic acid) and vitamin C (Ascorbic acid) were determined following the standard methods suggested by Sadasivam and Manickam (1996).

Minerals: Five hundred milligram of dried sample was digested by microwave sample preparation system (Anton paar multiwave 3000) using an acid mixture containing nitric acid and perchloric acid (3:1v/v). The residues were dissolved in 2 N hydrochloric acid and filtered through Whatmann No.1 filter paper and the volume was made up to 25 mL with de-ionized water in a standard flask.

The clear solution was used to measure the concentration of different minerals. Minerals such as sodium, potassium and calcium were analyzed using digital flame photo meter (model CL 22D) pre-calibrated with respective standards. Magnesium, phosphorus, iron, zinc, copper, manganese, nickel and cobalt determinations were performed by optical emission spectrophotometer (Perkin Elmer Model Opium 2100 dr).The trace minerals were quantified on the basis of peak areas and comparison with a calibration curve obtained with the corresponding standards.

Statistical analysis was carried out and difference between mean was assessed by Duncan's multiple range test (DMRT). All statistical tests were considered significant at 5% level ($p<0.05$).

RESULTS

Fatty acid composition: The composition of fatty acids in the *D.acuta* and *S. brachysoma* fishes were studied. Twenty two fatty acids were found in total and the composition of each fatty acid was different from one another (Table 1). The present study indicates that the major SFA palmitic acid (16:0) content was 3.89% in *S. brachysoma* and 5.75% in *D. acuta*. The percentage of SFA C14:1, C15, C17, C18 and C20 were present in minor quantities in both fish species. The major fatty acid (oleic acid) was present in 0.08% in *S. brachysoma* and absent in *D. acuta*. C23 and C24 were present only in identifying levels in *D. acuta* species. But for *S. brachysoma* these were present as 0.1065 and 0.6755%, respectively. C20 was accumulated as 0.7756% in *S. brachysoma* and 0.0054% was recorded in *D. acuta*. EPA (C20:5n-3) value was meager in *D. acuta* and that was not in *S. brachysoma*. *S. brachysoma* C22:6 (DHA) level was observed as 13.78 and 13.05% was observed in *D. acuta*. No significant differences were found between the two species of sardines in DHA. DPA content of *D.acuta* was comparatively higher than that of *S. brachysoma*. Fractions of EPA were noted only in *D. acuta*. Rate of C15 in *D. acuta* and *S. brachysoma* have quantified as 0.465 and 0.0675 respectively. Comparisons have been performed between the two species values in behenic acid. 4.787% was detected in *S. brachysoma* and was absent in *D. acuta*, instead euruic acid was present in 1.454%.

Composition of vitamins: The composition of fat soluble vitamins (A, D, E and K) and water soluble vitamins (B_1 and B_6) of the two experimental animals were determined and tabulated in Table 2. In the current investigation, fat soluble vitamins varied greatly between them the two experimented species. *S. brachysoma* showed 231.0 IU/100 mg and in *D. acuta* it was132.3 IU/100 mg. The observations of vitamin E in *D. acuta* and *S. brachysoma* recorded as 1.678, 1.589 in, respectively. The concentration of D in *D. acuta* varied only two mg from *S. brachysoma*. The water soluble vitamin, B1 also suffered one mg difference between the two fishes. B6 vitamin was identified as 0.121/100 mg in *S. brachysoma* and 0.256/100 mg in *D. acuta*.

Composition of minerals: Iron content of the two species has not shown accountable variations. Minerals such as Ca, Na, K, Co, Fe, Mg, Zn, P and S were determined (Table 3). Zn and Co were completely absent in both the fishes. The highest value of the major trace elements Ca (321.67 mg) was obtained in *D.acuta* and 240.56 mg in *S. brachysoma*. The major element Ca (321.67 mg) obtained in *D. acuta* and (240.56 mg) *S. brachysoma* were found to be highest. *S. brachysoma* reported to be particularly rich in sodium as 323.24 mg followed by 120.32 mg in *D. acuta*. In case of potassium, 67.55 and 44.45 mg were recorded in *Dussumieria acuta* and *S. brachysoma*,

Table 1: Proximate composition of fatty acids in the musle tissue of edible fin fishes

Fatty acids	Name	*Dussumieria acuta*	*Sardinella brachysoma*
C4:0	Butyric acid	Nil	Nil
C10:0	Capric acid	Nil	Nil
C11:0	Undeconoic acid	Nil	Nil
C12:0	Lauric acid	Nil	Nil
C13:0	Tidecanoic acid	Identified	Identified
C14:0	Myristic acid	0.4045%	0.89%
C14:1	Myristoleic acid	0.1085%	0.675%
C15:0	Pentadecanoic acid	0.465%	0.675%
C16:0	Palmitic acid	5.7856%	3.89%
C17:0	Margaric acid	0.2086%	0.5455%
C18:0	Stearic acid	0.1189%	0.1067%
C20:0	Arachidic acid	0.2061%	0.10678%
C18: 2	Linoleic-conjecated acid	Nil	Nil
C22:0	Behenic acid	Nil	4.787%
C22:1	Erucic acid	1.454%	0.7756%
C20:4	Arachidonic acid	0.0054%	0.7756%
C23:0	Tricosanoic acid	Identified	0.1065%
C24:0	Lignoceric acid	Identified	0.6755%
C20:5	Eicosapentaenoic acid	0.0068%	Nil
C22:5	Docosapentaenoic acid	1.412%	0.7865%
C22:6	Docosahexanoic acid	13.05%	13.78%
C18:1	Oleic acid	Nil	0.0856%

Table 2: Composition of vitamins

Vitamins	*Dussumieria acuta*	*Sardinella brachysoma*
Vitamin A	132.3 IU/100 mg	231.0 IU kg^{-1}
Vitamin D	22.078 IU/100 mg	218.78 IU kg^{-1}
Vitamin E	1.678 IU/100 mg	15.78 IU kg^{-1}
Vitamin K	Identified	Identified
Vitamin B1	3.56 mg kg^{-1}	2.56 mg kg^{-1}
Vitamin B6	2.56 mg kg^{-1}	1.21 mg kg^{-1}

Table 3: Composition of minerals

Minerals	*Dussumieria acuta*	*Sardinella brachysoma*
Calcium	321.67 mg	240.56 mg
Sodium	120.32 mg	323.24 mg
Potassium	67.55 mg	44.45 mg
Cobalt	Nil	Nil
Iron	0.71 mg	0.8967 mg
Magnesium	Nil	1.897 mg
Ziuc	Nil	Nil
Phosphorus	2.12 mg	1.78 mg
Sulphur	0.21 mg	0.23 mg

respectively. Iron content of both species has not shown much variation. Magnesium was not observed as in the case of *D. acuta*, yet it was in *S. brachysoma* as 1.897 mg. Level of phosphorus possessed high amount in *D. acuta* (2.12 mg) and in *S. brachysoma* it was 1.78 mg. Sulphur level for both species was indicated as 0.12 and 0.23 mg in *D. acuta* and *S. brachysoma*, respectively.

DISCUSSION

Fresh water fishes have higher level of ὼ fatty acids than marine species. Fishes in general contain more than 6 poly-unsaturated fatty acids and fresh water fishes were more saturated than marine fishes, palmitic acid was the more important one (Gopakumar and Nair, 1972). Fresh water fish oils contain small amount of C22, but large amount of palmitic acids and C_{18} unsaturated acids (Kinsella *et al.*, 1977). The percentages of polyunsaturated fatty acids (PUFA) were higher than the percentages of saturated fatty acids (SFA) and double the percentages of monounsaturated fatty acids (MUFA) (Kinsella, 1987; Sanchez-Muniz *et al.*, 1992). Fish from Indian waters were reported to contain about 13% of C18:1. The PUFA content in the case of marine fish ranges from 28 to 57% with C20:5 and C22:6 predominating and constituting about 50% in most cases (Viswanathan-Nair and Gopakumara, 1978). As referred in earlier research reports, fish contain high amounts of n-3 and low amounts of n-6 PUFA, a fact that has been connected, among other factors, to the type of the diet, which varies in the different marine regions (Ackman, 1989; Lavniegos and Lopez-Cortes, 1997). Miniadis-Meimaroglou *et al.* (2007) reported that the sum of saturated fatty acids of the examined red porgy (Scnegal marine region, east Atlantic Ocean) was quite similar to the one reported for *Sardinella madrensis, Sardinella aurita* and *Cephalopoholis taeniops* (47.3, 43.6 and 49.4%), respectively fish from east Atlantic Ocean (Nijinkoue *et al.*, 2002) and this is probably due to the fact that the SFA tend to increase in fish leaving in warm water (Ackman, 1989). Fatty acid of *Atherina boyeri* of open sea, *A. lagunae* from lagoon and *Atherina* sp. of island coasts from Tunisian waters were determined by Bouriga *et al.* (2010) and saturated fatty acids were found to be 43.54% in which eicosapentaenoic acid, docosahexaenoic acid and linoleic acid were prominent.

The composition of fatty acids in the *D. acuta* and *S. brachysoma* fishes when compared to other fishes. *S. brachysoma* was found to have decreased level of SFA palmitic acid. For instance, sea bass contained about 65.8% whereas, our animals had 3.85 and .75% in S. brachysoma and *D. acuta*, respectively. The previous findings of Alasalvar *et al.* (2002), Periago *et al.* (2005), Ozyurt and Polat (2006) and Baki *et al.* (2009) showed higher level of palmitic acid in Black sea fishes (19.5 to 29.0% of the total FA). High level of oleic acid was found in the liver of wild sea bass (20.16% of TFA). Results of present study showed a dramatic decrease in *S. brachysoma* (0.08%) and it was completely absent in *D. acuta*. (Satio *et al.*, 1999) suggested that the fatty acid composition of fishes can be influenced by intrinsic factors like fish species, size and sexual maturity and extrinsic factors like season, water salinity, temperature etc. Also, the study has revealed difference in fatty acid profile of fishes present in marine and fresh water. This difference may be due to diet or physiological adaptation of fishes to the environment. Size or age, reproductive status, geographical location and season are also responsible for the amount of fat content and composition of fish muscle (Ackman, 1989; Satio *et al.*, 1999).

The lipids of marine fishes are characterized by their higher proportion of polyunsaturated fatty acids, such as the nutritionally important EPA and DHA, which are highly susceptible to autoxidation because of their high degree of unsaturation (Gunstone and Norris, 1983). With the exception of sardine, in all marine fish, DHA was found in higher levels than EPA. The data of present research also confirmed earlier observations of Gruger *et al.* (1964) and Gunstone *et al.* (1978). *S.brachysoma* and *D. acuta* also showed increased amount of DHA while EPA was negligible in *D.acuta* and absent in *S. brachysoma*.

The lipid profile of marine fishes was different and was higher in the case of *Sardinella longiceps*, the value being 8.45%. In the case of *Rastrelliger kankurta*, the lipid content was

moderate, the value being 0.65%. Presence of lipids in *Sardinella longiceps* is the highest value which justifies it being called oil *Sardinella longiceps*. The pattern of variation in lipid content of fresh water fishes resembles as that of brackish water fishes. *Catla catla* exhibited lipid content of 1.5% whereas, in *O.mossambicus*, the lowest value of 0.45% was observed (Ramesh, 2005). In the case of marine fishes, Behenic acid was present but it was not observed in the other two habitats namely, Brackish and fresh water habitat. Such a pattern clearly shows that habitat has an impact on the biochemical composition of fishes, especially fatty acid.

Fishes contain very small amounts of minerals. The mineral content of the two fishes *S. brachysoma* and *D. acuta* showed much variation. It is known that variation in the mineral concentrations of marine foods is closely related to seasonal and biological differences like species, size, muscle complexion, age, sex and sexual maturity, geographical location, processing method, food source and environmental conditions like water chemistry, salinity, temperature and contaminants (Alasalvar *et al*., 2002; Turhan *et al*., 2004; Yildiz, 2008; Akinneye *et al*., 2010). Bhouri *et al*. (2010) explained the difference between total lipid content, fatty acid and mineral contents in sea bass based on the habitat.

Fishes generally have higher calcium content than the meat alone. According to Da Costa and Stern (1956), Portuguese sardines preserved in oil contain per 100 g, respectively, depending upon whether they are intact, boneless, or without both skin and bore. The corresponding amounts of phosphorus are 624, 545 and 320 mg per 100 g.The calcium/phosphorus ratio varies between 0.05 and 0.6 with an average of 0.2.on the whole fish and is less unbalanced than meat as to phosphorus and calcium. Rose (1933) reported calcium contents of 22/100 mg in the meat of lean fish (edible parts) and 19 mg/100 g in fat fish. As the phosphorus level remains normal, this means a substantially changed ca/p ratio. Analyses on numerous fishes of the Indian seas, values of 150 to 360 mg of phosphorus per 100 g were encountered (Khorana *et al*., 1943). Results of current research also supported the previous results of marine and fresh water fishes. Calcium and Potassium were higher in *S. brachysoma* and *D. acuta* compared to other minerals. Mg was higher in shellfishes than in teleosts (Carteni and Aloj, 1934). The present study also confirmed these results, *S. brachysoma* showed trace amount of Mg while it was nil in *D. acuta*.

Several studies have considered fish as a major source of Fe for children and adults (Fraga, 2005). Highest iron amount was observed in the liver of wild fish (581.4 $mgkg^{-1}$), while in the muscle the Fe concentration ranged from 0-18.42 mg kg^{-1} in wild and farmed sea bass. The Fe concentration in muscle tissue of *S. brachysoma* and *D. acuta* was also more or less similar and hence these fishes can also be considered as healthy food for children.

Decreasing order of minerals (K>Na>Mg>Ca) was explained and proved in fishes like *Sardinella* spp., *Sarotheroderum galilarus, Lates niloticus* and *Sprodinit schal* by Oladimeji and Sadiku (1991) and Mazumder *et al*. (2008) (oven-dried). But, results of Ako and Salihu (2004) showed no well defined decreasing order of magnitude in the major element evaluated in several species of fish. The present study also coincide with studies by Ako and Sahhu (2004)) and disprove the decreasing order of mineral concentration, K>Na>Mg>Ca.

Teeny *et al*. (1984) that Zinc was found to be highest in concentration among the element determined in fish samples. However, Cu, Mn and Zn were also known as essential nutrients which were absent in the two fishes taken for the present study. Mazumder *et al*. (2008) defined the decreasing order of magnitude (Zn>Fe>Mn>Cu) which was evident in most of the fishes.

Vitamins are organic compounds that are necessary in very small amounts in the diet and fish is one of the major sources of vitamins. Fat soluble vitamins are generally more stable than the

water soluble ones. But they were usually prone to degradation at high temperatures in the presence of oxygen, perhaps by free radical mechanisms (Priestley, 1979). Alao, fishes as a whole show a higher vitamin A level than those of most terrestrial animals, this particularly applies to the liver oils. Vitamin A is concentrated in the liver oils of older fish, more highly than in younger specimens (Ripley and Bolomey, 1946). Normally vitamin A content is found within the range of 50-150 IU/100 g (Higashi *et al*., 1953; Hirao *et al*., 1954a, b, 1955; Pradhan and Magar, 1956). The present study also coincides with the previous results. Vitamin A was comparatively higher in both the study animals and was within the range (132.3IU/100 mg in *S. brachysoma* and 231 IU/100 mg in *D. acuta*) as designed by previous researchers.

The lateral red muscle of the fish generally carries large quantities of biologically active substances, chiefly vitamins of the B complex (Umemura, 1951; Braekkan, 1959). Vitamin B1 and B6 were estimated in the present study and were found to be present in minimal amount in both the fishes when compared to Vitamin A. However, minimal difference may be found between marine and fresh water fishes. Certain geographical and climatic factors influence the content of B vitamins.

The study concludes that *D. acuta* is the best fish from nutritional point of view as it has comparatively high and steady calorific value and it has sufficient and good combination of all essential nutrients, closely followed by *S. brachysoma*.

REFERENCES

AOAC, 1995. Official Methods of Analysis of Association of Analytical Chemist International. 16th Edn., AOAC, Washington DC., Pages: 1094.

Ackman, R.G., 1989. Marine Biogenic Lipids, Fats and Oils. Vol. 2, CRC Press, Florida, ISBN: 9780849348907, Pages: 504.

Akinneye, J.O., I.A. Amoo and O.O. Bakare, 2010. Effect of drying methods on the chemical composition of three species of fish (*Bonga* spp., *Sardinella* spp. and Heterotis niloticus). Afr. J. Biotechnol., 9: 4369-4373.

Ako, P.A. and S.O. Salihu, 2004. Studies on some major and trace metals in smoked and oven-dried fish. J. Applied Sci. Environ. Manage., 8: 5-9.

Alasalvar, C., K.D.A. Taylor, E. Zubcov, F. Shahidi and M. Alexis, 2002. Differentiation of cultured and wild sea bass (*Dicentrarchus labrax*): Total lipid content, fatty acid and trace mineral composition. Food Chem., 79: 145-150.

Andrew, A.E., 2001. Fish Processing Technology. University of Iiorin Press, Nigeria, pp: 7-8.

Baki, B., M.E. Erdem and S. Samsun, 2009. Fatty acid and amino acid compositions of cultured and wild sea bass (*Dicentrarchus labrax* L., 1758) from different regions in Turkey. J. Anim. Vet. Adv., 8: 1959-1963.

Bhouri, A.M., I. Bouhlel, L. Chouba, M. Hammami, M. El-Cafsi and A. Chaouch, 2010. Total lipid content, fatty acid and mineral compositions of muscles and liver in wild and farmed sea bass (*Dicentrarchus labrax*). Afr. J. Food Sci., 4: 522-530.

Bouriga, N., S. Selmi, E. Faure and M. Trabelsi, 2010. Biochemical composition of three Tunisian silverside (fish) populations caught in open sea, lagoon and island coasts. Afr. J. Biotechnol., 9: 4114-4119.

Braekkan, O.R., 1959. A comparative study of vitamins in the trunk muscles of fishes. Report of the Technological Research on Norwegian Fishing Industries, pp: 42.

Carteni, A. and G. Aloj, 1934. Chemical composition of marine animals of the Gulf of Naples. Quaderni della Nutrizione, 1: 49-63.

DOF, 2003. Fish fortnight publication. Ministry of Fisheries and Livestock, Dhaka, Bangladesh, pp: 134.

Da Costa, A. and J.A. Stern, 1956. The calcium and phosphoeus contents op some foreign and domestic canned sardines. J. Food Sci., 21: 242-249.

Folch, J., M. Lees and G.H.S. Stanley, 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem., 226: 497-509.

Fraga, C.G., 2005. Relevance, essentiality and toxicity of trace elements in human health. Mol. Aspects Med., 26: 235-244.

Gopakumar, K. and M.R. Nair, 1972. Fatty acid composition of eight species of Indian marine fish. J. Sci. Food Agric., 23: 493-496.

Gruger, E.H., R.W. Nelson and M.E. Stansby, 1964. Fatty acid composition of oils from 21 species of marine fish, freshwater fish and shellfish. J. Am. Oil Chem. Soc., 41: 662-667.

Gunstone, F.D. and F.P. Norris, 1983. Lipids in Foods. Pergamon Press, New York

Gunstone, F.D., R.C. Wijesundera and C.M. Scrimgeour, 1978. The component acids of lipids from marine and freshwater species with special reference to furan-containing acids. J. Sci. Food Agric., 29: 539-550.

Higashi, H., S. Hirao, K. Shimizu, J. Yamada and R. Kikuchi, 1953. Studies on fluctuation of the vitamin A content in fishes-1. Studies on vitamin A in sharks. Bull. Japan Soc. Sci. Fish., 18: 349-352.

Hirao, S., J. Yamada and R. Kikuchi, 1954a. Vitamin A in fish meat-1. Variation in the vitamin A content in fish meat by the anatomical locality. Bull. Japan Soc. Sci. Fish., 19: 1047-1056.

Hirao, S., J. Yamada and R. Kikuchi, 1954b. Vitamin A in fish meat-2. Variation in the vitamin A content in fish meat by the body side. Bull. Japan Soc. Sci. Fish., 20: 736-740.

Hirao, S., J. Yamada and R. Kikuchi, 1955. Vitamin A in fish meat-3. Individual fluctuation in the vitamin A content in fish meat. Bull. Japan Soc. Sci. Fish., 20: 853-859.

James, D., 1998. Production Consumption and Demand. In: Fish Drying and Smoking Production and Quality, Doe, P.E. (Ed.). Technomic Publishing Company, USA., pp: 1-12.

Khorana, M.L., M.L. Sarma, P.S. Rao and K.V. Giri, 1943. Investigations on the food value of fish and other marine products part II. The protein and mineral contents. Indian J. Med. Res., 31: 25-27.

Kinsella, J.E., 1987. Sea Food and Fish Oils in Human Diseases. Marcel Deccar, NewYork, pp: 239-300.

Kinsella, J.E., J.L. Shimp, J. Mai and J. Weihrauch, 1977. Fatty acid content and composition of freshwater finfish. J. Am. Oil Chem. Soc., 54: 424-429.

Lavniegos, E. and D. Lopez-Cortes, 1997. Fatty acid composition and community structure of Plankton from the San Lorenzo Channel Gulf of California. Estuarine Coastal Shelf Sci., 45: 845-854.

Lavniegos, E. and D. Lopez-Cortes, 1997. Fatty acid composition and community structure of Plankton from the San Lorenzo Channel Gulf of California. Estuarine Coastal Shelf Sci., 45: 845-854.

Mazumder, M.S.A., M.M. Rahman, A.T.A. Ahmed, M. Begum and M.A. Hossain, 2008. Proximate composition of some small indigenous fish species (sis) in Bangladesh. Int. J. Sustain. Crop Prod., 3: 18-23.

Metcalfe, L.D., A.A. Schmitz and J.R. Pelka, 1966. Rapid preparation of fatty acid esters from lipids for gas chromatographic analysis. Anal. Chem., 38: 514-515.

Miniadis-Meimaroglou, S., C. Dimizas, V. Loukas, A. Moukas and A. Vlachos *et al.*, 2007. Proximate composition, fatty acids, cholesterol, minerals in frozen red porgy. Chem. Phys. Lipids, 146: 104-110.

Nijinkoue, J.M., G. Barnathan, J. Miralles, E.M. Gaydou and A. Samp, 2002. Lipids and fatty acids in muscle, liver and skin of three edible fish from Senegalese coast: *Sardinella maderensis*, *Sardinella aurita* and *Cephalopholis taeniops*. Comp. Biochem. Physiol., Part B, 131: 395-402.

Oladimeji, A.A. and S.O.E. Sadiku, 1991. Mineral constituents of *Lates niloticus*, (L.) *Synodontis schall* (Broch and Schneider) and *Sarotherodon galilaeus* (Trewaves) from Zaria (Nigeria) Dam. J. Anim. Prod. Res., 11: 45-52.

Ozyurt, G. and A. Polat, 2006. Amino acid and fatty acid composition of wild sea bass (*Dicentrarchus labrax*): A seasonal differentiation. Eur. Food Res. Technol., 222: 316-320.

Periago, M.J., M.D. Ayala, O. Lopez-Albors, I. Abdel and C. Martinez *et al.*, 2005. Muscle cellularity and flesh quality of wild and farmed sea bass, *Dicentrarchus labrax* L. Aquaculture, 249: 175-188.

Pradhan, S.K. and N.G. Magar, 1956. Vitamin A1, A2 and neo-vitamin A in shark-liver oils. Indian J. Med. Res., 44: 11-20.

Priestley, R.J., 1979. Vitamins. In: Effect of Heat Processing on Foodstuffs, Priestley, R.J., (Ed.). Applied Science Publishers Ltd., London, pp: 121-178.

Ramesh, S., 2005. Nutritional evaluation of commercially important fin fishes of Parangipettai coast, Southeast coast of India. Ph.D. Thesis, Annamalai University

Ripley, W.E. and R.A. Bolomey, 1946. The relation of the biology of the soupfin to the liver yield of vitamin A. Calif. Fish Game, 64: 39-72.

Rose, M.S., 1933. The Foundations of Nutrition. Macmillan, NewYork.

Sadasivam, S. and A. Manickam, 1996. Biochemical Methods. 2nd Edn., New Age International (P) Ltd., New Delhi, pp: 179-186.

Sanchez-Muniz, F.J., J.M. Viejo and R. Medina, 1992. Deep-frying of sardines in different culinary fats. Changes in the fatty acid composition of sardines and frying fats. J. Agric. Food Chem., 40: 2252-2256.

Satio, H., R. Yamashiro, C. Alasalvar and T. Konno, 1999. Influence of diet on fatty acids of three subtropical fish, subfamily caesioninae (*Caesio digrumna* and *C. tile*) and family siganidae (*Siganus canaliculatus*). Lipids, 34: 1073-1082.

Stansby, M.E., 1973. Polyunsaturates and fat in fish flesh. J. Am. Dietetic Asso., 63: 625-630.

Teeny, F.M., E.J. Gauglitz Jr., A.S. Hall and C.R. Houle, 1984. Mineral composition of the edible muscle tissue of seven species of fish from the Northeast Pacific. J. Agric. Food Chem., 32: 852-855.

Turhan, S., N.S. Ustun and T.B. Altunkaynak, 2004. Effect of cooking methods on total and heme iron contents of anchovy (*Engraulis encrasicholus*). Food. Chem., 88: 169-172.

Umemura, K., 1951. Respiratory enzymes of tial (fish red muscle). Nagoya J. Med. Sci., 14: 81-85.

Viswanathan-Nair, P.G. and K. Gopakumara, 1978. Fatty acid compositions of 15 species of fish from tropical waters. J. Food Sci., 43: 1162-1164.

Yildiz, M., 2008. Mineral composition in fillets of sea bass (*Dicentrarchus labrax*) and sea bream (*Sparus aurata*): A comparison of cultured and wild fish. J. Applied Ichthyol., 24: 589-594.