Comparative Evaluation of Proximate Composition of *Etroplus suratensis* from Ecologically Different Areas of Ashtamudi Lake, Kerala

Mano Mohan Antony

Department of Zoology, University College, Thiruvananthapuram, Kerala, India

Abstract: ***Muscle of fish is one of the best source of proteins, vitamins and minerals which are essential nutrients required for proper growth and maintenance of bodily functions. The widely different environmental conditions in which the fish live have profound influence on the biochemical composition of their tissues. Ashtamudi Lake contains a rich population of Etroplus, for the present study five areas exhibiting difference in environmental habitats were selected. No attempts have been made before to evaluate the nutritional quality and profiling of Etroplus species in Kerala especially Ashtamudi Lake. Therefore the present study was undertaken for a detailed account of the proximate composition, to evaluate the nutritional quality and also to understand whether the impact of environmental factors on the difference in palatability of individuals of same species obtained from different sites of the lake***

Keywords: Ashtamudi lake, Proximate composition, Etroplus, environment, quality

1. Introduction

Fish is a major and easily available source of food in nature for mankind. Muscle of fish is one of the best source of proteins, vitamins and minerals which are essential nutrients required for proper growth and maintenance of bodily functions (Ajiboyes, 2011). Fish muscle is an excellent source of amino acids and is a unique source for nutrients and easily digestible proteins (Yanes et al., 1976, Venugopal et al., 1996). Proper information on the biochemical composition of fish finds application in several areas. Now a day there is an ever-increasing awareness about healthy food and fish is finding more acceptances because of its special nutritional qualities. Moisture, fat, protein, and minerals are the main components of fish muscle and analysis of same is referred to as proximate composition (Love, 1980).

The widely different environmental conditions in which the fish live have profound influence on the biochemical composition of their tissues. There may be group-specific or even species-specific differences in the biochemical composition. Even within a species, variations occur for individual fish or abundance of fishes taken at different times or under different conditions. Also variation in proximate composition occurs between different parts of the same fish. The protein composition in muscles varies with the type of muscle tissue, whether it is striated, smooth or cardiac muscle. The striated muscles are the predominant form in fish and the flesh can be seen as white or dark meat (Suzuki, 1981). The white muscle contains fewer lipids than the dark muscle and is usually composed of about 18% to 23% of protein depending on the species and time of harvesting (Suzuki, 1981). The protein content and the water-holding capacity of the proteins are also very important for the texture of the fish flesh. Water-holding capacity refers to the ability of the proteins to imbibe water and retain it against gravitational force within a protein matrix. High protein content and a good water-holding capacity of proteins in fish muscle are therefore important as it often improves the texture of the fish flesh.

Fish is known to be a source of protein rich in essential amino acids viz. lysine, methionine, cystine, threonine, and tryptophan (Li, et al., 2004), micro- and macro elements (calcium, phosphorus, fluorine, iodine), lipids, fat-soluble vitamins and unsaturated fatty acids that have a hypocholesterolemic effect (Ismail, 2005). It is reported that certain amino acids like aspartic acid, glycine and glutamic acid are also known to play a key role in the process of wound healing (Chyun & Griminger, 1984). Amino acids also play a central role as the building blocks of proteins and as intermediates in metabolism and further help to maintain health and vitality. *Etroplus* is widely accepted as a nutritionally high valued fish in Kerala however, scanty information is available on this aspect. Ashtamudi Lake contains a rich population of *Etroplus*. For the present study five areas exhibiting difference in habitats were selected, namely an unpolluted site with clay environment(I), a site with rich supply of nutrients by Kallada river(II), a central area with diversified environmental conditions(III), a highly polluted area(IV) and a coconut husk retting area(IV).

No attempts have been made before to evaluate the nutritional quality and profiling of *Etroplus* species in Kerala. Therefore the present study was undertaken for a detailed account of the proximate composition to evaluate the nutritional quality and also to understand whether the impact of environmental factors on the difference in palatability of individuals of same species obtained from different sites of the lake

2. Materials and methods

Sample collection: Fishes from five sites were collected every two months interval for a period from 2007 February to 2010 December. They were immediately transferred to ice box. In the laboratory the fillets without skin of the fishes were separated, labelled and kept in deep freezer for further investigation.

Determination of Proximate composition of muscle

Determination of crude Protein Concentration

Protein content of the sample was determined spectrometrically by deploying Lowry's method using bovine serum albumin as standard (Lowry 1951).

Estimation of Crude fat:

Lipid was estimated by the method of Folch et al. (1957).

Estimation of ash content

The ash content was determined by Egan et al. (1990).

Estimation of moisture content

The moisture content of the fish was determined by Egan et al.(1990).

Estimation of carbohydrate

Total carbohydrate was estimated by phenol sulphuric acid method (Dubois et al., 1956).

3. Results

Table 1.1: Analysis of Variance (One Way ANOVA) of Moisture (%) Content of Muscle of *E. suratensis* Comparing Seasons and Sites

Season	Site I		Site II		Site III		Site IV		Site V		F value (comparing sites)
	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	
Pre-monsoon	76.51b	2.07	81.01a	1.51	81.39a	1.58	83.82c	1.68	82.14a	1.61	30.593**
Monsoon	73.65b	1.56	79.64c	1.85	81.36a	1.75	83.62d	1.86	82.11e	1.28	64.252**
Post-monsoon	75.14a	2.88	80.99b	2.18	82.09bc	2.41	83.71d	2.29	82.52bc	2.15	23.579**
Annual	75.10	2.47	80.55	1.92	81.61	1.92	83.72	1.91	82.26	1.68	36.595**
F value (comparing season)	4.918*		2.115		0.531		0.029		0.207		

* P < 0.05; ** P < 0.01; Means within same raw with same alphabets do not differ each other (Duncan's Multiple Range Test)

Protein

Analysis of variance (One Way ANOVA) of protein (%) content of muscle of *E. suratensis* from five sites and three seasons are given in Table 1.2

Table 1.2: Analysis of Variance (One Way ANOVA) of Protein (%) Content of Muscle of *E. suratensis* Comparing Seasons and Sites

Season	Site I		Site II		Site III		Site IV		Site V		F value (comparing sites)
	Mean	+ SD	Mean	+ SD	Mean	+ SD	Mean	+ SD	Mean	+ SD	
Pre-monsoon	18.33a	2.01	15.71b	1.38	15.72b	1.51	13.18c	1.72	14.78b	1.61	15.211**
Monsoon	21.40d	0.99	17.23c	1.77	15.78b	1.79	13.56a	1.81	14.82ab	1.26	44.948**
Post-monsoon	19.40c	2.78	15.98b	1.92	15.23b	2.29	13.19a	2.30	14.47ab	2.19	12.231**
Annual	19.71	2.38	16.31	1.79	15.58	1.85	13.31	1.91	14.69	1.69	22.214**
F value (comparing season)	6.856**		2.718		0.307		0.144		0.149		

* P < 0.05; ** P < 0.01; - Means within same raw with same alphabets do not differ each other (Duncan's Multiple Range Test)

Carbohydrate

Analysis of variance (One Way ANOVA) of carbohydrate (%) content of muscle of *E. suratensis* from five sites and three seasons are given in Table 1.3.

Table 1.3: Analysis of Variance (One Way ANOVA) of Carbohydrate (%) Content of Muscle of *E. suratensis* Comparing Seasons and Sites

Season	Site I		Site II		Site III		Site IV		Site V		F value (comparing sites)
	Mean	+ SD	Mean	+ SD	Mean	+ SD	Mean	+ SD	Mean	+ SD	
Pre-monsoon	0.70c	0.05	0.65ab	0.08	0.62b	0.10	0.72c	0.05	0.70c	0.05	4.577**
Monsoon	0.52a	0.14	0.55ab	0.11	0.62b	0.13	0.58b	0.06	0.59b	0.06	1.491*
Post-monsoon	0.72bc	0.09	0.67b	0.05	0.60a	0.09	0.72bc	0.05	0.73c	0.03	8.059**
Annual	0.65	0.13	0.62	0.09	0.61	0.10	0.67	0.08	0.67	0.08	12.255**
F value (comparing season)	13.431**		7.244**		0.149		28.192**		26.164**		

* P < 0.05; ** P < 0.01; Means within same raw with same alphabets do not differ each other (Duncan's Multiple Range Test) 3. Monthly variation of Carbohydrate (%) in muscle of *E. suratensis* From different sites

Fat

Analysis of variance (One Way ANOVA) of fat (%) content of muscle of *E. suratensis* from five sites and three seasons are given in Table 1.4.

Table 1.4: Analysis of Variance (One Way ANOVA) of Fat (%) Content of Muscle of *E. suratensis* Comparing Seasons and Sites

Season	Site I		Site II		Site III		Site IV		Site V		F value (comparing sites)
	Mean	+ SD	Mean	+ SD	Mean	+ SD	Mean	+ SD	Mean	+ SD	
Pre-monsoon	2.87a	0.17	0.99b	0.13	0.81b	0.09	0.54c	0.14	0.69c	0.06	725.256**
Monsoon	2.75d	0.37	0.94c	0.03	0.86bc	0.08	0.54a	0.08	0.75b	0.11	293.226**
Post-monsoon	2.83c	0.29	0.96b	0.22	0.72a	0.13	0.59a	0.14	0.58a	0.23	250.577**
Annual	2.82	0.28	0.96	0.15	0.79	0.12	0.56	0.12	0.67	0.17	199.588**
F value (comparing season)	0.501		0.441		5.671**		0.863		3.887*		

*P < 0.05; **P < 0.01; Means within same raw with same alphabets do not differ each other (Duncan's Multiple Range Test) .

Ash

Analysis of variance (One Way ANOVA) of ash (%) content of muscle of *E. suratensis* from five sites and three seasons are given in Table 1.5.

Table 1.5: Analysis of Variance (One Way ANOVA) of Ash (%) Content of Muscle of *E. suratensis* Comparing Seasons and Sites

Season	Site I		Site II		Site III		Site IV		Site V		F value (comparing sites)
	Mean	+ SD	Mean	+ SD	Mean	+ SD	Mean	+ SD	Mean	+ SD	
Pre-monsoon	1.67b	0.08	1.63a	0.18	1.47a	0.27	1.75ab	0.11	1.69a	0.06	5.451**
Monsoon	1.90c	0.12	1.64b	0.13	1.38a	0.15	1.70b	0.15	1.72b	0.10	23.871**
Post-monsoon	1.76bc	0.10	1.69b	0.05	1.46a	0.20	1.88c	0.21	1.70b	0.11	13.017**
Annual	1.77	0.14	1.65	0.13	1.43	0.21	1.78	0.17	1.70	0.09	18.565**
F value (comparing season)	15.823**		0.591		0.571		3.785*		0.366		

*P < 0.05; **P < 0.01; Means within same raw with same alphabets do not differ each other (Duncan's Multiple Range Test)

4. Discussion

In fishes muscle composition contributes strongly to quality considering texture, elasticity, and water holding capacity. The above features are highly related to quality, and are dependent on number and integrity of muscular fibers. The number and size distribution of fibers is referred to as muscle cellularity, and is an important determinant of the flesh texture (Johnston et al., 2004). Proximate composition obtained from this fish composed of moisture 75-83%, protein 13-19%, carbohydrate 0.61-0.67%, fat 0.56-2.82%, and ash 1.43-1.77%. According to Jacquot (1961) fishe body composed of principal constituents like water 66-84%, protein 15-24%,lipid 0.1-22%.ash 0.8-2% and carbohydrate in minute quantity 0.3%. The present study confirms the same ratio of these factors in this fish. Sivan and Radhakrishnan (2011) reported that fish *Scatophagus argus* from Cochin estuary contains moisture 72-76%, protein 15.13-17.47%, and fat 5-8%, but in the present study fat content is found low (0.9%- 2.3%) in *Etroplus*. Tawfik (2009) also reported this range of proximate compostion in fishes. Okland et al. (2005), Elgaba(2010), Usydus et. al. (2011) and Mazumdar (2008) were also reported this range of proximate composition in different fishes. Proximate composition of fish is affected by different factors such as size, sexual maturation, temperature, salinity, exercise, ration, time and feeding frequency, impacted by diet, but mainly is determined by the species type, genetic characteristics and size (Haard, 1992; Morris, 2001; Ackman, 2002).

Proximate composition of *E. suratensis* of Vellar estuary reported by Marichamy et al. (2011) as moisture 78.55%, protein 16.74%, lipid 1.15% and carbohydrate 2.43%. However in the present study there is a major difference is found with regard to carbohydrate and protein contents. Carbohydrate content shows higher value whereas protein content, they registered a lower value. This may be due to the difference in environmental conditions and food habits. So it is also an evidence to prove that proximate composition of fishes depends on the environmental factors. The number of muscle fibres recruited during growth is subjected to variations depending on several factors such as the fish strain, diet (Kiessling et al., 1993; Johnston et al.,2003), exercise training (Johnston & Moon, 1980) and temperature (Johnston et al., 2000).

In Ashtamudi Lake, the overall moisture content in *Etroplus* from site I was low compared to the other sites but with a high level of lipid content. This inverse relationship has also been reported in fishes such as *Mistus Seenghala* (Jafri, 1968), *Ophiocephalus punctatus* (Jafri, et al., 1968), *Mugil cephalus* (Das, 1978) , and, *Sarda sarda* (Zaboukas, 2006). Osman *et al*., (2001) reported that low fat fish have higher water content as has been observed from fishes of site III and IV in the present study. Available data indicate that fat content in fish is influenced by species, geographical region, age and diet (Piggott & Tucker, 1990). They also reported that difference fat content showed by the fishes is due to the geographical changes and difference in diet especially the diet contains more algae. The main food material of *Etroplus* from site I constitute the filamentous algae (Antony 2013). This may the reason for the observed high level of fat content and a low level of moisture content in this fish.

Shekhar et al. (2004) reported that moisture content did not significantly differ with season in *Labeo rohita.* which is a constituent with the present study that no significant variation in moisture content observed different the sites during various seasons. (Table 1.1) According to Feeley et al. (1972) the low fat fish have higher water content and as a result the meat is whiter in colour. Ramaiyan et al. (1976) reported that generally when oil content is high the moisture content is low in *Septipinna taty*. In present study *Etroplus* from the site IV and V were showed more moisture content and less fat content. The various sites showed remarkable difference in fat content. This may be due to difference in diet they preferred. This diet difference was contributed by the environmental factors.

The present study revealed a site wise difference in protein content of fish. A significant difference in protein value was observed throughout the period study. An increase of protein value during monsoon months were observed from all sites. Jayaprakas (1980) reported that spawning season of *Etroplus* is usually found during monsoon in Kerala. Protein content goes on increasing with the advancement in maturity. Das (1978) noticed that high values of protein coinciding with spawning season when gonads ripe and the decline in protein content is considered with post spawning period. Rattan (1994) suggested that protein and visceral lipid resource may be utilizing in the pre spawning period in *E. suratensis*. Phillps et al. (1966) reported that fish was utilizing fat as main source of energy, sparing proteins for body building. Protein is not an efficient energy source for fish. It will be used for energy if the available energy from other sources is insufficient (Phillips,1969). In fishes change in protein content during spawning season may occur due to change in the endocrine system that monitors supply of nutrient to gonads from all parts of body including liver and muscles (Sinha & Pal 1990; Jyotsna et al., 1995). Norman (1980) reported that protein catabolism is reducing with onset of starvation in fishes like snakehead. An increase in protein volume during rainy season in snakehead was also reported by Gam et al. (2006).

Fish quality usually defined in terms of appearance, taste, smell, firmness, texture, juiciness and physiological characteristics (Johnston, 1999). The biochemical composition, particularly lipids, may change the nutritional and sensorial quality of fish flesh (Waagabo et al.,1993; Arzel et al.,1994; Regost et al., 2001). The present study showed significant variation in crude lipid value from different sites. Based on the fat content, this fish can be distinguished as a lean fish (Bennion & Scheule, 2003) as the fat content was lower than 5 % by weight in fishes collected from all five sites. Feeley et al. (1972) and Osman et al. (2001) reported that low fat species have higher water content and as a result, their flesh are white in colour. These results show a clear inverse relationship between the lipid and moisture contents, with high lipid values being matched by low moisture content and vice versa (Hernandez et al., 2003). Fishes with high lipid contents had less water and more protein than low-lipid fishes. This is in-line with the report of Steffens (2006) that protein forms the largest quantity of dry matter in fish. The lipid stored in muscle is largely neutral lipids in the form of oil droplets (Shindo et al., 1986). These oil droplets were replaced by interstitial water, thus the moisture contents in the muscle was reduced while the crude protein content remained unchanged. An inverse relationship between these values has been also shown in other studies (Ackman, 1989; Mok et al,. 2007). In the present study fishes from Site I showed significant higher value of lipid compared to other sites in all seasons where the moisture content was low.

Fishes from site I showed most palatable, may be due to the higher value in fat content (Table 4.1& figure 4.1). Lipid content is an aspect affecting the flesh taste in many fish species (Robb et al., 2002). The most important intrinsic quality traits in fish are the colour, texture, physiological processing characteristics, fat content and chemical composition of the flesh (Johnston, 1999; Grigorakis et al., 2003; Periago et al., 2005). The factor for the difference in fat content of fishes from this site may be due to the food available in this site. Marichamy et al. (2011) reported that *Etroplus* from Vellar estuary contains 1.5% fat. Food of fishes from site I consists mainly of filamentous algae at all season. (Antony 2013)This may be the reason for the higher value of lipid content of fishes at site I. This finding was supported by observations in other fishes. Percentage of lipids in fish depends on diet (Sargant, 1997, Arts, et al. 2001). Fat and fatty acids lipid of sardine were influenced by planktons they feed (Shirai et al. 2002). Ackman et al. (1986) reported that a lipid composition variation in fish is due to the different types of food in the stomach. The fat difference contents may be due to the algal feed consumed by the fish and that those consuming more algal feed have more fat content which may be contributed by this feed. The variation in algal contents variation were depending mainly on the environmental factors.

The variations recorded in the concentration of the different nutritional components in the fish examined could have been a result of the rate which these components are available in the water body (Yeannes & Almandos, 2003), and the ability of the fish to absorb and convert the essential nutrients from the diet or the water bodies where they live. This is supported by the findings of Window et al., (1987) ; Adewoye and Omotosho (1997) ; Fawole et al. (2007). Lipid content of fish flesh is directly related to the nutrition of the fish. When comparing wild and farmed fish, higher lipid contents are found in farmed fishes and were due to the accessible and well formulated diets (Nettleton & Exler, 1992; Alasalvar et al., 2002).

Fishes of same species caught from different locality show difference in fat conten. It was formerly reported by Rossano et al. (2005) from the fish *Mora moro*. The increased rate of fat contents found fishes also showed that the feed they consumed is the main factor for fat content difference (Johnston et al., 2006). Lipid content of fishes are known to vary between and within species (Haliloglu, 2001; Haliloglu, et al., 2002). A number of factors, such as the temperature, the salinity, the season (Chouch et al,. 2003), the type and availability of food, the habitat, the stage of maturity and individual variability are contributing to these variations (Mnari et al., 2007). So it may be concluded that the difference in total lipid content found in the fishes of site I may be attributed mainly to the dietary constituents.

A significant variation in carbohydrate content among these samples was not observed between different sites. Comparatively low values of carbohydrate content were observed from all sites. Marichamy et al. (2011) reported the carbohydrate value of *E. suratensis* from Vellar estuary as 2.43%, but compared to that all the values obtained in the present study are low. Carbohydrates formed a minor percentage of the total biochemical composition of the muscle in fishes. The low value of carbohydrate recorded in the present study could be attributed to the fact that glycogen in many fishes does not contribute much to the food reserve in the body and they plays a minor part in energy reserve (Vijayakumaran,1979). Phillips et al. (1966) reported that carbohydrates are utilized for energy in trouts, thus sparing protein for building of the body. This may be also applicable to *Etroplus.*

Ash content also shows almost similar values from fishes caught from all sites but a remarkable variation was seen in fishes at site III which may be due to the environmental characteristics of this site. Present finding states that the ash content of this fish species are less than that of similar fishes (Shearer, 1994). It may be due to lesser amount of skeleton in this species.

References

[1] Ackman, R. G., 1989. Nutritional composition of fats in seafoods. Prog. in Food and Nutri. Sci. 13, 161–241.
[2] Ackman, R. G., 2002. Freshwater fish lipids – an overlooked source of beneficial long-chain n-3 fatty acids. Euro. J. of Lipid Sci. Tech. 104, 253–254.
[3] Ackman, R. G., Ratnayake, W. M. N., 1986. An initial investigation of lipids and fatty acids of Nova Scotian soft cod. Proc. N. S. Inst. Sci. 36, 107-113.
[4] Adewoye, S. O., Omotosho, J. S., 1997. Nutrient composition of some freshwater fishes in Nigeria. Biosci. Res. Commun. 11, 333-336.
[5] Ajiboye, E. A., Alhassan, S., Adedaya, R., Majekodummi, Olatuji, K. M., Tolu, O. O., 2011. Physical chemical properties and microorganism isolated from dried meat obtained in Oja Oba market in Ilorin, Nigeria. Advances in Appl. Sci. Reser. 2(4), 391-400.
[6] Alasalvar, C., Taylor, K. D. A., Zubcov, E., Shahidi, F., Alexis, M., 2002. Differentiation of cultured and wild sea bass (*Dicentrarchus labrax*): total lipid content, fatty acid and trace mineral composition. Food Chemistry 79, 145-150.
[7] Antony, M. M. 2013. Ecophysiology of *Etroplus suratensis* at various regions of Astamudi Lake. Ph. D. thesis, Unity. Of Kerala, India.
[8] Arts, M. T., Ackman, R. G., Holub, B. J., 2001. ‘‘Essential fatty acids” in aquatic ecosystems: a crucial link between diet and human health and evolution. Can. J. of Fish. and Aqua. Sci. 58, 122–137.
[9] Arzel, J., Martinez, L. F. X., Metailler, R., Stephan, G., Viau, M., Gandemer, G., Guillaume, J., 1994. Effect of dietary lipid on growth performance and body composition of brown trout *Salmo trutta* reared in seawater. Aquaculture 123, 361–375.
[10] Bennion, M., Schelue, B., 2003. Introductory foods. 12th ed. Printice Hall, New York.
[11] Chaouch, A., Bouhlel, I., Chraief, I., Hammami, M., Elhani, A., Romdhane, M. S., Elcafsi, M., 2003. Seasonal varioation of polyunsaturated fatty acids (n 3) composition in *Diplodus annularis* from gulf of Tunis: nutritional benefits. J. De la Soc. Clin. Tun. 5, 55-63.
[12] Das, H. P., 1978. Studies on the Grey Mullet, *Mugil cephalus* (Linnaeus) from the Goa Waters; Ph. D. Thesis, University of Bombay.
[13] Dubois, M., Gilles, K.A., Hamilton, J.K., Robers, R.A., Smith, F., 1956. Colorimetric method for determination of sugars and related substances. Analytical chemistry 28, 350-356.
[14] Egan, H., Krik, R. S., Sawyer, R., 1990. Pearsons chemical analysis of foods. 9th Ed., Longman, London, 609 -634 pp.
[15] Elagaba, M. H. A., Al-Maqbaly, R., Mansour, H. M. 2010 Proximate composition, amino acid and mineral contents of five commercial Nile fish in Sudan. African J. of Food Sci. 4(10), 650-654.
[16] FAO/WHO. 1991. Protein quality evaluation. Report of the Joint FAO/WHO Expert Consultation. FAO Food and Nutrition Paper 51, Food and Agriculture Organization of the United Nations, Rome, Italy.
[17] Fawole, O. O., Ogundiran, M. A., Ayandiran, T. A., Olagunju, O. F., 2007. Mineral Composition in some selected fresh water fishes. Nigeria. J. Food Safety. 9, 52-55.
[18] Feeley, R. M., Criner, D. E. C., Watt, B. K., 1972. Cholesterol content of foods. J. of Ameri. Diabetic Asso. 61, 134 – 148.
[19] Folch, T., Lees, M., Sloane, S. G. H., 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. of Biolo. Chem. 226, 497–509.
[20] Gam, L. H., Leow, C. Y., Baie, S., 2006. Proteomic analysis of snake heads fish (*Channa striata*) muscle tissue. Malaysian J. of Biochem. And Mol. Bio. 14, 25-32.
[21] Grigorakis, K., Alexis, M. N., Taylor, K. D. A., Hole, M., 2002. Comparison of wild and cultured gilthead sea bream (*Sparus aurata*); composition, appearance and seasonal variations. Int. J. Food Sci. Technol. 37, 477-484.
[22] Haard, N. F., 1992. Control of chemical composition and food quality attributes of cultured fish. Food Res. Inter. 25, 289-307.
[23] Haliloglu, H. I., Aras, N. M., Yetim, H., 2002. Comparison of muscle fatty acids of three trout species rainbow trout, (*Salvelinus alpinus, Salmo trutta fario, Onchorhynchus mykiss*) raised under the same conditions. Turkish J. of Vet. and Anim. Sci. 26, 1097–1102.
[24] Hernandez, M. D., Egea, M. A., Rueda, F. M., Martinez, F. J. Garcia, B. G., . 2003. Seasonal condition and body composition changes in sharpsnout seabream (*Diplodus puntazzo*) raised in captivity. Aquaculture 220, 569-580.
[25] Jacquot, R., 1961. Organic constituents of fish and other aquatic animals foods. In: Fish as Food, Vol. 1, Borgstron (Ed.), G Academic press Inc., New York, 145-192 pp.
[26] Jafri, A. K., 1968. Seasonal Changes in the Biochemical Composition of the Cat-Fish, *Mystus seenghala* (Sykes). Broteria 37, 45-58.
[27] Jafri, A. K., Khawaja, K. D., 1968. Seasonal Changes in the Biochemical Composition of the Freshwater Murrel, *Ophicephalus punctatus* Bloch. *Hydrobiologia* 32, 206-218.
[28] Jayaprakas, V., 1980. Biology of *Etroplus suratensis* (Bloch). Ph. D Thesis , Unity. Of Kerala, India
[29] Johnston, I. A., 1999. Muscle development and growth: potential implications for flesh quality in fish. Aquaculture 177, 99–115.

[30] Johnston, I. A., Moon, S., 1980. Exercise traning in skeletal muscles of brook trout (Salvelinus fontinalis). J. of Expt. Bio. 87, 177-194.
[31] Johnston, I. A., Strugnell, G., McCracken, M. L., Johnstone, R., 1999. Muscle growth and development in normal-sex-ratio and all-female diploid and triploid Atlantic salmon. J. Exp. Biol. 202, 1991–2016.
[32] Johnston, I. A., Alderson, R., Sandham, C., Dingwall, A., Mitchell, D., Selkirk, C., Nickell, D., Backer, R., Robertson, B., Whyte, D., Springate, J., 2000. Muscle fibre density in relation to the colour and texture of smoked Atlantic salmon (*Salmo salar* L.). Aquaculture 189, 335-349.
[33] Johnston, I. A., Manthri, S., Alderson, R., Smart, A., Campbell, P., Nickell, D., Robertson, B., Paxton, C. G., Burt, M. L., 2003. Freshwater environment affects growth rate and muscle fibre recruitment in seawater stages of Atlantic salmon (Salmo salar L.). J. Exp. Biol. 206, 1337–1351.
[34] Johnston, I. A., Manthri, S., Bickerdike, R., Dingwall, A., Luijkx, R., Campbell, P., Nickell, D., Alderson, R., 2004. Growth performance, muscle structure and flesh quality in out-of-season Atlantic salmon (*Salmo salar*) smolts reared under two different photoperiod regimes. Aquaculture 237, 281–30
[35] Johnston, I. A., Li, X., Viera, V. L. A., Nickell, D., Alderson, R., Campbell, P., Bickerdike, R., 2006. Muscle and flesh quality traits in wild and farmed atlantic salmon. Aquaculture 256, 323-336. .
[36] Jyotsna, K., Nilesh, K., Verma, P. K., Fasihuddin, M. D., 1995. Distribution of Bio Constituents in Various Tissues during Pre and Post-Spawning Periods of *Channa striatus* (Bloch). J. Inland Fish. Soc. India. 27(2), 14-17.
[37] Kiessling, A., Hung, S. S. O., Storebakken, T., 1993. Differences in protein mobilization between ventral and dorsal parts of white epaxial muscle from fed, fasted and refed white sturgeon (*Acipenser transmontanus*). J. Fish Biol. 43, 401-408.
[38] Li, P., Mai, K., Trushenski, J., 2008. New developments in fish amino acid nutrition: towards functional and environmentally oriented aquafeeds. Review aricle , Springer
[39] Love, R. M., 1980. The Chemical Biology of Fishes, Vol. II; Academic press, London. 547 pp.
[40] Lowry, O. O., Rosebrough, N. J., Farr, A. L., Randall, R. J., 1951. Protein measurement with the Folin phenol reagent. J. Biol. Chem. 193, 265 – 275.
[41] Marichamy, G., Shanker, S., Saradha, A., Nazar, A. R., Haq, M. A. B., 2011. Proximate composition and bioaccumulation of metals in some fin fishes and shell fishes of velar estuary(South East coast of India). Euro. J. Exp. Bio. 1(2), 47-55.
[42] Mazumder, M. S. A., Rahman, M. M., Ahmed, A. T. A., Begum, M., Hossain, M. A., 2008. Proximate composition of some small indigenous fish species in Bangladesh. Int. J. Sustain. Crop Prod., 3(4), 18-23.
[43] Mnari, A., Bouhlel, I. Chraief, I. Hammami, M. Romdhane, M. S., Casfsi, M. E., Chauch, A., 2007. Fatty acids in mussel and liver of Tunisian wild and farmed gilthead sea bream *Sparus aurata*. Food chemistry 100, 1393-1397.
[44] Mok, J. S., Lee, D. S., Yoon, H. D., Park, H. Y., Kim, Y. K. , Wi, C. H., 2007. Proximate composition and nutritional evaluation of fisheries products from the Korean coast. J. Korean Fish. Soc. 40, 259-268 .
[45] Nettlton, J. A., 1985. Seafood Nutrition, Van Nostrand Reinhold, New York.
[46] Norman, Y. S. W., Cheung, S. I, 1980. Metabolic Effects of Starvation in the Snakehead, *Ophiocephalus maculates*, Compa. Biochem. and Physio. Part A 97(4), 623-627. .
[47] Okland, H. M. W., Stokness, I. S., Remme , J. F., Kjerstad, M., Synnes, M., 2005. Proximate composition , fatty acid and lipid class composition of the muscle from deep sea teleosts and elasmobrahes. Com. Biochemistry. and Physiology, part B 140, 437-443.
[48] Osman, H., Suriah, A. R., Law, E. C., 2001. Fatty acid composition and cholesterol content of selected marine fish in Malaysian waters .FoodChemistry, 73, 55–60.
[49] Periago, M. J., Ayala, M. D., López-Albors, O., Abdel, I., Martinez, C., García-Alcázar, A., Ros, G., Gil, F., 2005. Muscle cellularity and flesh quality of wild and farmed sea bass Dicentrachus labrax L. Aquaculture, published on-line.
[50] Phillips, A. M., 1969. Nutrition, Digestion and Energy Utilization. In: Fish Physiology. Hora, W. S. and Randall, R. J. (Eds.), Academic press, London, 391-432 pp.
[51] Phillips, A. M., Livingstone, D. L., Poston, H. A., 1966. The Effect of Changes Protein Quality, Caloric Sources, Caloric Level up on the Growth and Chemical Composition of Brook Trout. Fish. Res. Bull. N. Y. 29, 6-14.
[52] Ramaiyan, V., Paul, A. L., Pandian, T. J., 1976. Biochemical Studies on the Fishes of the Order clupeiformes. J. Mar. Biol. Assoc. India. 18(3), 516-524.
[53] Rattan, P., 1994. Ecobiology of Pearl Spot, *Etroplus suratensis* (Bloch) in Goa Waters. Ph. D. Thesis Goa University.
[54] Ravichandran, S., Sharmila, J. F. R., Kanagalekshmi, R., Ramya, M. S., 2012. Variation in nutritive composition of two commercially important marine fishes. Inter. J. of Zoological Res. 8(1), 43-51.
[55] Regost, C., Arzel, J., Cardinal, M., Robin, J., Laroche, M., Kaushik, S. J., 2001. Dietary lipid level, hepatic lipogenesis and flesh quality in turbot *Psetta maxima*. Aquaculture 193, 291–309.
[56] Robb, D. H. F., Kestin, S. C., Warriss, P. D. Nute, G. R., 2002. Muscle lipid content determines the eating quality of smoked and cooked Atlantic salmon (*Salmo salar*). Aquaculture 205, 345–358.
[57] Rossano, R., Caggiano, M. A., Mastrangelo, L., Lauro, R. D., Ungaro, N., Ettorre, M., Ricco, P., 2005. Proteins, fatty acid, nutritional value in the mussel of the fish species *Mora moro*. Mol. Nutr. Food res. 49, 926-931.
[58] Sargent, J. R., 1997. Fish oil and human diet. British J. of Nutri. 78, S5- S13.
[59] Shekhar, C., Rao, A. P., Abidi, A. B., 2004. Changes in Muscle Biochemical Composition of *Labeo rehita* (Ham.) in Relation to Season. Indian. J. Fish. 51(3), 319-323.
[60] Shindo, K., Tsuchiya, T. Matsumoto, J. J., 1986. Histological study on white anddark muscles of various fishes. Nippon Suisan Gakkaishi 52, 1377-139.

[61] Shirai, N., Terayama, M., Takeda, H., 2002. Effects of season on the fatty acid composition and free amino acid content of sardine *Sardinopes melanoticus*. Comp. Biochem. And Physio. Part B 131 , 387-393.
[62] Sinha, G. M., Pal, P. C., 1990. Seasonal Variation in Protein, Lipid and Carbohydrate Contents of Ovary, Liver and Body Muscle in Relation to Gonado Somatic Index and Oogenesis of *Clarias batrachus* (Linn.); In: Impacts of Environment on Animals and Aquaculture ,Manna, G. K. and Jana, B. B. (Eds.),University of Kalyani, 107-112pp.
[63] Sivan, G., Radhakrishnan, C., K., 2011. Food and feeding habits and biochemical composition of *Scatophagus argus*. Turkish J. of fisheries and aqutic sciences, 11, 603-608.
[64] Steffens, W., 1997. Effects of variation in essential fatty acids in fish feeds on nutritive value of freshwater fish for humans. Aquaculture 151, 97-119.
[65] Suzuki, T., 1981. Fish and Krill Protein: Processing Technology. Applied Science, London, UK.
[66] Usydus, M., Richert, J. S., Adamczyk, M., Szatkowska, U., 2011. Marine and farmed fish in the polish market: composition of nutritional value. Food chemistry 126, 78-84.
[67] Venugopal, V., Chawla, S. P., Nair, P. M., 1996. Spray dried protein powder from threadfin beam: preparation properties and comparison with FPC type-B. J. Muscle Foods. 7, 55.
[68] Vijayakumaran, M., 1979. Chemical composition and caloric content of *Ambassis gymnocephalu.* J. Mar. Biol. Assoc. India. 21(1&2), 182-184.
[69] Waagbo, R., Sandnes, K., Torrissen, O. J., Sandvin, A., Lie, O., 1993. Chemical and sensory evaluation of fillets from Atlantic salmon *Salmo salar* fed three levels of n3 fatty acids at two levels of vitamin E. Food Chemistry 46, 361–366.
[70] Window, H., Stein, D., Scheldon, R., Smith, J. R., 1987. Comparison of trace metal concentrations in muscle of a benthopelagic fish *Coryphaenoides armatus* from the Atlantic and Pacific oceans. Deep Sea Res. 34, 213-220.
[71] Yanes, E., Ballester, D., Monckeberg, F., 1976. Enzymatic fish protein hydrolyzate: chemical composition, nutritive value and use as a supplement to cereal protein. J. Food Sci. 41, 1289.
[72] Yeannes, I. M., Almandos, M. E., 2003. Estimation of fish proximate composition starting from water content. J. Food Comp. Anal. 16, 81-92.
[73] Zaboukas, N., 2006. Biochemical Composition of the Atlantic Bonito*, Sarda sard*a from Aegean Sea (Eastern Mediterranean Sea) in different stages of sexual maturity. J. Fish. Biol. 69 (2), 347-362.