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Comparison of Nutritional Characteristics of Myctophid Fishes (*Diaphus effulgens* and *D. hudsoni*) with Common Indian Food Fishes

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Abstract

Though myctophids (Family: Myctophidae) are the most predominant mesopelgic fishes available in Western and Eastern Indian Ocean, they are the least utilized fishery resources. Myctophids constitute a substantial quantity of the discards of deep-sea shrimp trawlers operating off South-west coast of India. As most of the conventional fish stocks have reached a state of full exploitation or over-exploitation, efficient utilization of mesopelagic resources is necessary to fill in the supply-demand gap for fish-based products. An attempt has been initiated to compare the nutritional composition, minerals, trace elements, fatty acid and amino acid profiling of two myctophid species *viz*., *Diaphus effulgens* and *D. hudsoni* with commonly available Indian food fishes (*Sardinella longiceps, Mugil cephalus* and *Rastrelliger kanagurta*). Proximate composition indicate that protein and lipid levels in these myctophid fishes are comparable to that of the selected food fishes. These myctophids contained n-3 polyunsaturated fatty acids (n-3 PUFA) and essential amino acids in significant proportions. Results of the present study show that *D. effulgens* and *D. hudsoni* are potential resources of nutrients required for the formulation of nutritional supplements for human healthcare.

Keywords: Myctophids, nutritional composition, n-3 PUFA, amino acid composition

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Introduction

World per capita food fish supply increased from an average of 9.9 kg (live weight equivalent) in the 1960s to 18.6 kg in 2010 (FAO, 2012a). With the increasing global population, in order to maintain at least the current level of per-capita consumption an additional 23 million t of fish will be required by 2020 (FAO, 2012b). As most of the conventional fish stocks have reached a state of full exploitation or over-exploitation, efficient utilization of underutilized resources is necessary to fill in the supply-demand gap for fish-based products. Mesopelagic fishes can be considered to be one such promising resource of fish protein, if efficient harvest and post-harvest technologies are evolved for them (Boopendranath et al., 2009). Stock sizes of mesopelagic fishes, in which myctophids (Family: Myctophidae) are predominant constituents, have been re-estimated as 263 and 102 million t, in the Western Indian Ocean and Eastern Indian Ocean, respectively (Lam & Pauly, 2005). Gopakumar et al. (1983) stated that myctophid fishes commonly known as lantern fishes resemble most marine fish with regard to its biochemical constituents and can be exploited for formulation of various food products for both man and animals. Various studies (Nair et al., 1983; Noguchi, 2004; Olsen et al., 2010; Rajamoorthy et al., 2013) show that myctophids can be utilized for the production of commercial fishery products like fish meal, fish oil, fish silage, surimi, seasoning products, feed for cultured fish, nutrient resource in the formulation of poultry feed as well as crop fertilizers and products like lubricating oil, cosmetics and wax.

Boopendranath et al. (2009) and Pillai et al. (2009) have shown that commercial exploitation of deep-sea prawns off South-west coast of India yields a considerable amount of bycatch, in which myctophids contribute a major component. These myctophids along with other mesopelagic fishes are discarded back to the sea due to low or no value. In the present study, an attempt has been initiated to compare the nutritional composition of two Indian Ocean myctophid species *viz*., *Diaphus effulgens* and *D. hudsoni* with commonly available Indian food fishes (*Sardinella longiceps, Mugil cephalus* and *Rastrelliger kanagurta*) to check the possibility of utilizing these resources for human consumption.

Materials and Methods

Myctophid species *D. effulgens* and *D. hudsoni* of average length 15 and 8.4 cm respectively collected from the bycatch of deep sea shrimp trawlers operating off south-west coast of India, between 8°30′50"N - 9°07′50"N and 75°49′20"E - 75°58′60"E, in February 2012 were used for the study. *S. longiceps, M. cephalus* and *R. kanagurta* with an average length of 15.5, 12.3 and 21.8 cm respectively, were collected from the local landing centres during the same period. Fish samples were obtained under iced condition in styrofoam boxes and transported to the laboratory. Species authentification of myctophids was done as per Fischer & Bianchi (1984). Filleted, skinned and homogenised fish samples were used for various nutritional analyses.

Moisture content, total nitrogen, crude fat and ash content of the homogenised sample were determined by AOAC method (2005). Samples were microwave digested and analysed for minerals and heavy metals using inductively coupled plasma spectrophotometer (Thermoscientific, iCAP 6000 Series) following the method of AOAC (2005).

Amino acid composition was determined using Shimadzu (LC-10 AT) HPLC (Amino acid analyser) system equipped with cation exchange column (sulphonated polyvinyl styrene column) and fluorescence detector (Lakshmanan et al., 2013). Tryptophan content of the samples was determined spectrometrically after alkali hydrolysis (Sastry & Tummuru, 1985).

Fatty acid methyl esters (Metcalfe et al., 1966) of lipid extracted by the method of Folch et al. (1957) were analysed with Trace Thermo Gas chromatography Ultra equipped with Elite-225 silica capillary column (60 m length and 0.25 ID) and Flame ionizing detector using nitrogen as carrier gas. Calibration of GC was done using standared FAME mixtures (Supelco Germany). Analyses were repeated three times and the results expressed as mean ± standard deviation.

Results and Discussion

Proximate composition of myctophid fishes (*D. effulgens and D. hudsoni)* and selected food fishes *viz*., *S. longiceps, M. cephalus and R. kanagurta* is given in Table 1. Moisture content in *D. effulgens* was significantly higher (78.06%) while in other species, it was in the range of 73.38-76.51%. Among the species studied, fat content was comparatively high in *S. longiceps* (7.93%), followed by *D. hudsoni* (7.73%) while low fat content was observed in *M. Cephalus* (0.42%). Protein content was higher in *M. cephalus* (19.7%) followed by *R. kanagurta* (19.02%), *S. longiceps* (16.3%), *D. effulgens* (16.54%) and *D. hudsoni* (14.45%). Proximate composition shows myctophid fishes having comparable quantity of protein and fat with food fishes and in *D. effulgens*, the protein content was higher than in *S. longiceps.*

Biochemical composition of other species of myctophid fishes also indicates that they are good source of protein and minerals while fat content was reported to be high in some species (Gopakumar et al., 1983; Lekshmy et al., 1983; Noguchi, 2004; Rajamoorthy et al., 2013). The proximate composition of *Benthosema pterotum* caught from Gulf of Oman, a myctophid fish which is reported as the largest single species stock of fish in the world

Table 1. Proximate composition (%) of myctophids and selected food fishes

Fish species	Moisture	Protein	Fat	Ash
Diaphus effulgens	78.06±0.1	16.54±0.7	4.86±0.3	0.54±0.1
Diaphus hudsoni	74.12±0.3	14.45±0.3	7.73±0.2	3.63±0.3
Sardinella longiceps	73.38±1.2	16.3±0.1	7.93±0.4	1.86±0.5
Mugil cephalus	76.51±0.5	19.7±0.4	0.42±0.8	1.6±0.2
Rastrelliger kanagurta	75.81±0.4	19.02±0.2	3.06±0.1	1.78±0.1

(GLOBEC, 1993) with moisture (77.2%), protein (16.1%), fat (3.4%) and ash (3.5%) (Gopakumar et al., 1983). Noguchi (2004) has reported biochemical composition of ten lantern fishes caught in Pacific Ocean near Northern part of Japan. The moisture content in these fishes varied from 57.5 to 79.2%, protein content from 11.3 to 15.7%, lipid content from 4.9 to 28.5% and ash content from 1.8 to 3.1%. Studies by Rajamoorthy et al. (2013) have shown significantly higher fat content in *Diaphus watasei* (15.13%), a myctophid species commonly seen in the discards of deep sea shrimp trawlers operating off south-west coast of India. They had also reported higher protein content in myctophid fishes *viz., D. watasei* (21.40%) and *Myctophum obtusirostre* (22.64%) respectively. Both the species have higher protein content compared to *S. longiceps* (16.9%) as reported by Mohan et al. (2012) and the protein content observed in the present study in *S. longiceps* was 16.3%.

Analysis of minerals (calcium, sodium, potassium and barium) and trace elements (copper, iron, manganese, zinc and cadmium) shows that myctophid fishes have comparable quantities of sodium, potassium and calcium with the food fishes studied (Table 2). *D. hudsoni* contained higher amount of calcium than *D. effulgens*, but sodium, potassium and barium were observed in significantly higher level in the latter. Lithium and cadmium was not detected in any of the myctophid species studied. Iron (142 ppm) and manganese (1 ppm) were observed in *D. hudsoni* but significantly lower level of iron (80 ppm) was observed in *D. effulgens.* Gopakumar et al. (1983) have reported that in *B. pterotum,* sodium content varied from 100 to 184.6 mg 100 g^{-1}, potassium from 118 to 137.4 mg 100 g^{-1} and calcium from 110 to 137.5 mg 100 g^{-1}. Among the food fishes, *S. longiceps* recorded the highest amount of calcium, sodium and potassium compared to other two species.

Amino acid profiles of the two species of myctophids and the food fishes are given in Table 3. Among myctophids, essential amino acids were found to be comparatively high in *D. effulgens* (52.03%) than in *D. hudsoni* (41.94%). The amount of essential amino acids (52.03%) was more than that of non-essential amino acid content (46.12%) in *D. effulgens*, but in case of *D. hudsoni*, non-essential amino acid content was higher than essential amino acids. Most abundant amino acids in these species are valine, leucine, isoleucine, histidine, lysine, aspartic acid, glutamic acid and glycine. Nair et al. (1983) studied the amino acid composition of *B. pterotum* caught from the Gulf of Oman and the most abundant amino acids were reported as glutamic acid, proline, aspartic acid, histidine and serine. The present study shows that myctophids are rich in essential amino acids and the amount of total essential amino acids was comparable to that of common food fishes *viz., S. longiceps, M. cephalus and R. Kanagurta.* Among the essential amino acids, except phenylalanine, histidine and lysine, all other amino acids were seen in higher level in myctophids than the food fishes studied. Amino acids of 17 species of myctophids caught from sub-Arctic and tropical Pacific Ocean comprised of significant amount of glutamic acid, aspartic acid, lysine, leucine and arginine (Seo et al., 1998b).

Table 2. Minerals and trace elements (ppm) in myctophids and selected food fishes

Fish species	Ca	Na	K	Ba	Cu	Fe	Mn	Zn	Cd
Diaphus effulgens	1450±1.2	1900±1.2	1840±1.4	2800±1.5	ND	80±0.8	ND	ND	ND
Diaphus hudsoni	4050±1.3	980±0.7	490±0.8	700±1.1	ND	142±1.1	1±0.2	ND	ND
Sardinella longiceps	8003±0.6	4396±1.6	17710±1.2	8±0.7	12±0.4	156±0.9	6±0.2	118±1.3	0.43±0.01
Mugil cephalus	3408±1.4	2324±1.3	12718±1.7	1±0.6	5±0.2	35±1.1	2±0.4	37±0.5	0.05±0.01
Rastrelliger kanagurta	2719±0.8	3956±0.9	12702±1.4	1±0.4	6±0.3	92±0.8	1±0.4	52±0.3	0.12±0.01

ND – Not Detected

Table 3. Amino acid composition (%) of myctophids and selected food fishes

Amino acids	*Diaphus hudsoni*	*Diaphus effulgens*	*Sardinella longiceps*	*Mugil cephalus*	*Rastrelliger kanagurta*
Essential amino acids					
Valine	8.31	9.04	6.41	5.83	6.35
Methionine	0.84	0.55	1.25	1.16	1.38
Isoleucine	5.7	6.6	4.37	4.06	4.3
Leucine	8.82	8.71	4.43	4.23	4.21
Tyrosine	0.65	0.9	0.33	0.86	0.81
Phenylalanine	3.86	3.85	6.08	6.81	5.89
Histidine	3.57	8.32	11.32	10.59	15.39
Lysine	3.48	6.74	16.12	16.54	15.62
Threonine	5.48	6.16	4.59	4.26	4.67
Tryptophan	1.23	1.16	0.95	0.83	0.92
Total	**41.94**	**52.03**	**55.85**	**55.17**	**59.54**
Non essential amino acids					
Aspartic acid	10.73	18.74	8.27	5.74	6.65
Arginine	2.43	0.55	11.73	16.93	11.03
Serine	7.14	5.93	2.04	2.08	2.0
Glutamic acid	14.76	8.91	6.51	6.27	6.56
Proline	1.37	2.39	0.18	0.09	0.17
Glycine	10.92	7.51	15.83	13.14	13.48
Alanine	8.11	1.54	0.47	1.13	1.17
Cysteine	0.82	0.55	0	0.21	0.23
Total	**56.28**	**46.12**	**45.03**	**45.59**	**41.29**

Docosahexaenoic acid, oleic acid, palmitic acid and stearic acid were the predominant fatty acids present in myctophids (Table 4). Contribution of saturated fatty acids (SFAs) to the total fatty acids ranged from 31.08% in *R. kanagurta* to 43.9% in *D. hudsoni*, among the five species studied. A comparison of the availability of SFAs, Mono-unsaturated fatty acids (MUFAs) and poly-unsaturated fatty acids (PUFAs) among the myctophids and the food fishes showed that MUFAs ranged from 7.04% of the total fatty acids in *R. kanagurta* to 26.4% in *D. Effulgens.* In myctophids, the most abundant was MUFA oleic acid, 21% in *D. effulgens* and 16.8% in *D. hudsoni* whereas palmitoleic acid was higher in food fishes especially in S. *longiceps and M. cephalus*. Ambasankar & Balakrishnan (2006) also reported that the predominant fatty acids in sardine oil are the palmitic (22.64%), followed by EPA (13.18%), palmitoleic acid (12.91 %), DHA (10.61 %) and oleic acid (9.61%). Even though *S. longiceps, M. cephalus* and *R. kanagurta* contained significantly higher amount of PUFA (55.48, 38.93 and 61.81% respectively), the amount of nutritionally significant PUFAs in *D. hudsoni* (32.80%) *and D. effulgens* (32.00%) were comparable to that of food fishes. DHA in *D. effulgens* (20.10%) and in *D. hudsoni* (19.2%) were found in less quantity when compared to *S. longiceps* (33.81%) and *R. kanagurta* (36.39%), but higher than the DHA content in *M. cephalus* (6.07%).

Nutritional profiling has revealed the presence of good amount of protein, essential amino acids, minerals and fatty acids in myctophids, in comparison to food fishes. Some myctophid species are used for production of fish meal and oil and only a small percentage is used directly for human consumption. However, myctophids have potential to become a major source of fish protein, when efficient harvesting, appropriate processing and value addition technologies are evolved. In view of the presence of substantial level of EPA and DHA;

Table 4. Fatty acid composition (%) of myctophids and selected food fishes

Carbon No.	Fatty acids	*Diaphus hudsoni*	*Diaphus effulgens*	*Sardinella longiceps*	*Mugil cephalus*	*Rastrelliger kanagurta*
Saturated fatty acids						
C14	Myristic acid	3.60	3.40	7.81	5.49	3.66
C15	Pentadecyclic acid	1.00	0.00	1.18	13.31	2.08
C16	Palmitic acid	26.70	24.10	17.40	18.30	15.73
C17	Margaric acid	0.80	0.00	1.22	3.67	1.0
C18	Stearic acid	11.80	13.90	4.40	2.77	8.61
	Total SFA	**43.9**	**41.4**	**32.01**	**43.54**	**31.08**
Mono-unsaturated fatty acids (MUFA)						
C16:1	Palmitoleic acid	3.60	4.60	10.32	10.72	3.26
C17:1	Cis-10 Heptadecenoic acid	0.40	0.00	0.62	3.11	1.60
C18:1	Oleic acid	16.80	21.00	1.51	1.11	1.19
C20:1	Gadoleic acid	1.90	0.80	-	2.53	0.99
	Total MUFA	**22.7**	**26.4**	**12.45**	**17.47**	**7.04**
Poly-unsaturated fatty acids (PUFA)						
C18:2	Linoleic acid	1.30	1.60	1.55	1.05	2.06
C18:3	á-Linolenic acid	0.40	0.00	1.32	1.76	0.52
C20:2	Cis-11,14 – Eicosedienoic acid	0.30	0.20	-	-	0.51
C20:4	Arachidonic acid	4.40	4.90	-	10.77	10.81
C20:5	Eicosapentaenoic acid	7.10	5.20	18.80	19.28	11.52
C22:6	Docosahexaenoic acid	19.20	20.10	33.81	6.07	36.39
	Total PUFA	**32.7**	**32**	**55.48**	**38.93**	**61.81**

myctophids can be considered as a viable source for the extraction and purification of these compounds. It can also be considered as a potential nutrient resource in the formulation of fish-based products, pharmaceuticals and animal feeds.

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