The Journal of Basic & Applied Zoology (2016) 77, 41–48

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The Egyptian German Society for Zoology

The Journal of Basic & Applied Zoology

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Comparative studies on nutrient profiling of two deep sea fish (*Neoepinnula orientalis* and *Chlorophthalmus corniger*) and brackish water fish (*Scatophagus argus*)

Divya K. Vijayan [a], R. Jayarani [a], Dilip Kumar Singh [b], N.S. Chatterjee [a], Suseela Mathew [a], B.P. Mohanty [c], T.V. Sankar [a], R. Anandan [a,*]

[a] *ICAR – Central Institute of Fisheries Technology, Cochin, Kerala 682029, India*
[b] *ICAR – Central Institute of Fisheries Education, Kolkata, West Bengal 700 091, India*
[c] *ICAR – Central Inland Fisheries Research Institute, Barrackpore, Kolkata 700120, India*

Received 6 May 2016; revised 11 August 2016; accepted 20 August 2016

KEYWORDS

Nutrient profiling;
Malnutrition;
Deep sea fish;
Minerals

Abstract Extensive researches are in progress to explore the deep sea resources in our planet to conquer the dilemma and diminish the size of malnourished community. Nowadays the limelight has been broadened toward the deeper ocean. In the present study the nutrient profiling of two deep sea fish species (*Neoepinnula orientalis* and *Chlorophthalmus corniger*) was compared with a well-known edible brackish water fish (*Scatophagus argus*). The deep sea fish of interest (*N. orientalis* and *C. corniger*) were observed to possess relatively similar quantities of crude protein (18.6 ± 0.9 and 19.4 ± 0.9% respectively) as that of *S. argus* (20.4 ± 0.8%). The fat content of *N. orientalis* is commensurate with that of spotted scat, whereas *C. corniger* was found to contain very high fat content (14.6 ± 0.7%). Though their amino acid composition display slight variation with that of the brackish water fish, the deep sea fish were analyzed to contain significant amount of the essential amino acids viz. lysine, phenyl alanine, histidine, as well as the non essential amino acids aspartate, arginine, serine, glutamate, proline, glycine, alanine. The studies have also conceded that the fish from deep waters are the comparable sources of minerals, with those of the brackish water fish. Among the three fish of interest *N. orientalis* was noticed to be the richest source of sodium (5746 ± 27 mg kg^{-1}), potassium (3438 ± 19 mg kg^{-1}), calcium (4247 ± 16 mg kg^{-1}) and magnesium (2253 ± 21 mg kg^{-1}). Meanwhile, *C. corniger* is having highest levels of iron (120 ± 1.5 mg kg^{-1}) and zinc (135 ± 2.8 mg kg^{-1}), whereas *S. argus* was found to have the highest levels of manganese (35.8 ± 2.8 mg kg^{-1}) and nickel (10.1 ± 0.8 mg kg^{-1}). The level of cadmium

* Corresponding author.
E-mail address: kranandan@rediffmail.com (R. Anandan).

Peer review under responsibility of The Egyptian German Society for Zoology.

http://dx.doi.org/10.1016/j.jobaz.2016.08.003

in *N. orientalis* (0.75 ± 0.01 mg kg^{-1}) was demonstrated to be slightly higher than the prescribed limit. The present study has revealed that both deep sea fish of interest exhibit an analogous nutritive value with that of the common edible brackish water fish, *S. argus*.

Introduction

Congested population and inadequate resources are the catastrophe that India faces in the current century. According to World Bank report (The Economist, 2015) India is twice malnourished than other sub Saharan countries. India is occupied by a huge undernourished population especially children. FAO, 2015 reveals that about 2 billion people are reported to be at the risk of iron deficiency and 1.5 billion people endure from the threat of iodine dearth. Nowadays ocean is being considered as an excellent resource to conquer the problem. Marine fish species contribute tremendously to the delivery of macro and micro nutrients in our normal diet and most affordable for all categories in our society (Suvitha et al., 2015).

Adequate consumption of high quality protein and calories is to be essentially included in daily diet for the proper healthy growth and development of children, and their deficiency may lead to protein-calorie malnutrition (PCM). Kwashiorkor and marasmus, the severe stage of PCM mainly observed in children, are caused by chronic deficiency of protein and energy, respectively (Mohanty et al., 2014). Fish muscle protein is quite similar to muscle protein of terrestrial animals in their amino acid composition, which is easily digestible and a unique source of nutrients. The fish muscle fibers require less structural support than the muscles of land based animals as they are supported by a mass of water; hence, they tend to have less connective tissue than muscle from terrestrial animals, resulting in a more tender texture. The sole texture of fish meat is provided by the water holding capacity of the protein content (Okland et al., 2005).

Majority of the trace elements such as Fe, Se, Zn and Mn, play a considerable role in the physiological functioning of our body as brain development, and their deficiency may direct to stunted growth (Chowanadisai et al., 2005). Since they possess a potential antioxidant property and capacity to moderate the oxidative stress (Mistry et al., 2014) and hence it is competent to reduce the risk of chronic diseases, such as cancer, cardiovascular disorders and age-related degenerative diseases. For instance, the activity of glutathione peroxidase is Se-dependent (Chu et al., 2004), while the activation of superoxide dismutase requires Cu, Mn and Zn. They play a considerable role in cellular metabolism and biochemical pathways in children and adults (Culotta et al., 2006).

To date, the dietary fish from the Indian subcontinent had been extensively investigated. Very recently, due to fishery over-exploitation and saturation in fish landings around coastal areas, the spotlight has shifted to explore the fish of deeper waters along Indian EEZ and assess their nutritive potential in comparison to dietary fish. Bulky amounts of several deep sea fish are being obtained while trawling as by-catch, whereas these are usually being utilized by fish feed industries. Present study has been focused on the biochemical composition of the following deep sea fish *N. orientalis* and *C. corniger* and their significance as a dietary component, an attempt has been made to compare the nutritive values of deep sea fish with familiar edible brackish water fish *S. argus*.

Materials and methods

Reagents

Potassium sulfate, Sodium carbonate, Sodium hypochlorite, Distilled ethanol (99.56%), O-Phthalaldehyde, Brij, Trisodium citrate and Sodium hydroxide were purchased from Sigma (St. Louis, MO), 2-mercaptoethanol, Methyl red, and Methylene blue were obtained from SiscoLaboratries (Mumbai, India), AR grade Perchloric acid, Petroleum ether, Copper sulfate, Sulfuric acid and Hydrochloric acid were procured from Merck (Mumbai, India), Standards of amino acids (AAS-18) and Boric acid were acquired from Sigma–Aldrich GmbH (Steinheim, Germany). The mineral standard reference materials (Sodium: BWB06NA; Potassium: BWB04K; Calcium: BWB02CA) were obtained from M/s. Aquanet International Limited, Berkshire, UK. Microelements standard materials (Iron: AAFE 1-1; Zinc: AAZN 1-1; Manganese: AAMN 1-1; Nickel: AANI 1-1; Magnesium: AAMG 1-1; Cadmium: AACD 1-1; Lead: AAPB 1-1) procured from Inorganic Ventures, Virginia, USA.

Fish species

Two species of deep sea fish were collected from fish landing center at Kollam at 9°02.00′N–75°55.000′E, Kerala, India. They were transported to laboratory under refrigerated condition. The morphometric characteristics of fish samples were recorded and they were identified namely *N. orientalis* (Gilchrist and VonBonde, 1924) (Sack fish) (length: 20 ± 1.2 cm and body weight: 280 ± 15 g) and *C. corniger* (Alcock, 1894) (Spiny jaw green eye) (length: 14 ± 0.7 cm and body weight: 210 ± 10 g) based on Food and Agricultural Organisation (FAO) fact sheet. The brackish water fish *S. argus* (Linnaeus, 1766) (Spotted scat) (length: 25 ± 1.8 cm and body weight: 330 ± 25 g) were collected from Cochin and they were also processed in a similar way as the deep sea fish were done (see Fig. 1 and Table 1). The fish samples were of mixed gender. Fish samples were processed immediately by removing the scales and intestines. The body of fish samples including head were homogenized and stored at −20 °C for further analysis. A portion of homogenized samples was used for the evaluation of proximate composition and their amino acid profiling.

Biochemical analyses

The samples were then used for various biochemical analyses for instance, moisture (AOAC, 2000), total protein content

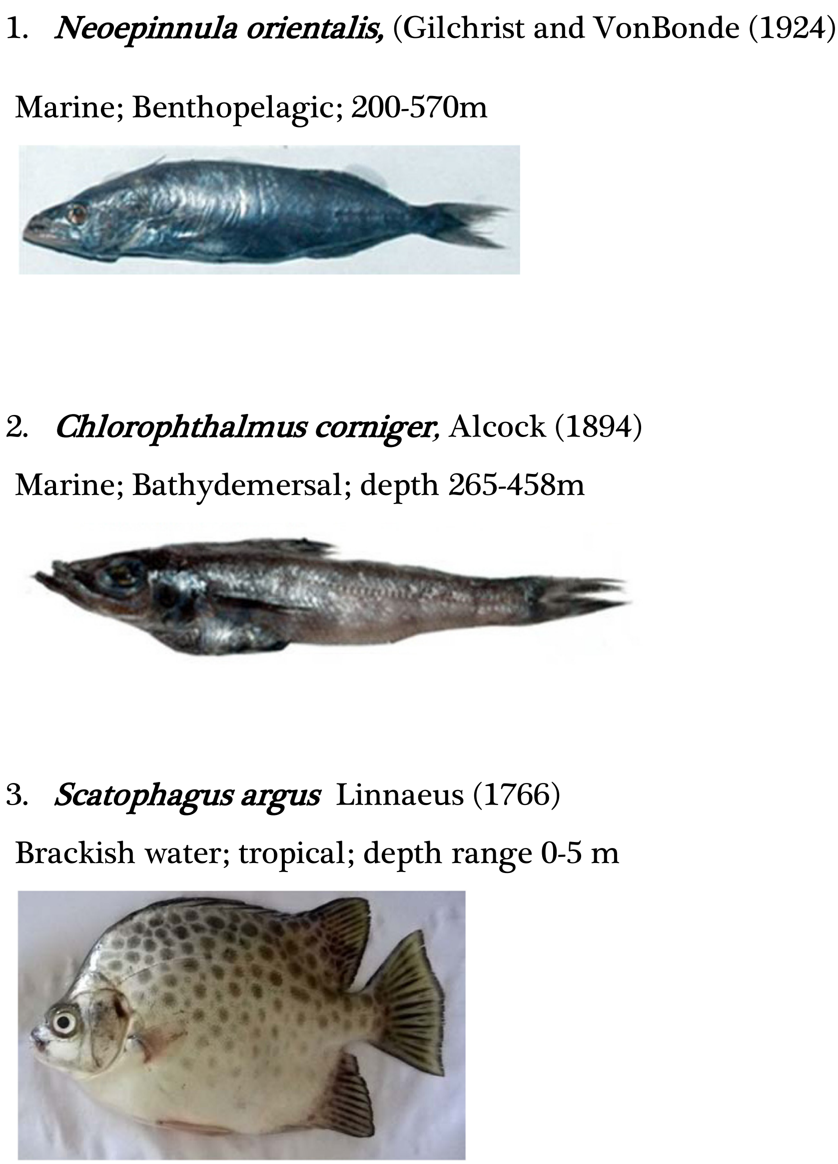

Figure 1 Images of deep sea fishes and brackish water fish selected for the analyses.

Table 1 Identification and classification of deep sea fishes (*N. orientalis* and *C. corniger*) and the brackish water fish (*S. argus*).

Classification	*N. orientalis*	*C. corniger*	*S. argus*
Class	Actinopterygii	Actinopterygii	Actinopterygii
Order	Perciformes	Aulopiformes	Perciformes
Family	Gempylidae	Chlorophthalmidae	Scatophagidae
Genus	*Neoepinnula*	*Chlorophthalmus*	*Scatophagus*
Species	*orientalis*	*corniger*	*argus*
Common name	Sack fish	Spiny jaw green eye	Spotted scat

using micro Kjeldahl method according to AOAC, 2000, total fat content using soxhlet method (SocsPlus Pelican Equipment) according to AOAC, 2000 and ash content (AOAC, 2000).

Determination of amino acid composition

To determine the amino acid composition, the fish samples were digested in an acidic solution of 6 mol/L Hydrochloric acid at 110 °C for 24 h. The samples were washed for the complete removal of acid content using vacuum roller evaporator. The amino acid profiling was done using an HPLC (HITACHI L-2130) model equipped with FL Detector (HITACHI L2485) and Column oven (HITACHI L-2350). The post-column derivatization was done with the aid of two Shimadzu LC-10AT VP pumps by using *O*-phthalaldehyde (OPA) reagent (Ishida et al., 1981). The imino acids were reacted with sodium hypochlorite and convert them to amino acid prior to binding with OPA.

Tryptophan content was determined colorimetrically using a spectrophotometer (HITACHI U-2910) according to the method of Sastry & Tammuru, 1985. The fresh fish meat was digested in 5 g/100 ml sodium hydroxide solution at

110 °C for 24 h under Nitrogen. The solution was made to neutral pH before the estimation of tryptophan.

Mineral and heavy metal status

The ash of fish homogenate were dissolved in concentrated hydrochloric acid and diluted with distilled water. The levels of heavy metals were quantified using Varian Atomic Absorption Spectrometer 220. The mineral contents (Na, K and Ca) in samples were carried out by means of flame photometer (BWB Technologies, UK).

Statistical analyses

The experimental results were expressed as mean ± standard deviation for triplicate samples. Multiple comparisons of the significant one-way ANOVA were performed by Duncan's multiple range comparison tests. A level of $p < 0.05$ was used to designate significant differences among the samples. The statistical analyses were done with the aid of statistical package program SPSS 16.0 for Windows.

Results

Biochemical analyses

Among the deep sea fish *N. orientalis* (Sack fish) had a red colored eye and *C. corniger* (Spiny jaw green eye) has got a green eye. The focus of the present study was to investigate the nutritive value of certain deep sea fish and it has been compared with that of a brackish water fish *S. argus* (Spotted scat) with respect to proximate composition, amino acid profiling and mineral as well as metals status.

Fig. 2 depicts the gram percentage measurements of moisture content, total protein, total fat and ash of two deep sea fish spiny jaw green eye, sack fish and common edible brackish water fish Spotted scat. Among the fish analyzed, *C. corniger* was found to contain comparatively less moisture content (66.1 ± 2.1%) and highest level of crude fat (14.6 ± 0.7%), whereas another deep sea fish of interest, *N. orientalis*, was analyzed to contain highest moisture content (80.1 ± 2%) and lowest level of total fat (1.18 ± 0.1%) when compared with those of the reference fish *S. argus* (76.9 ± 1.8% and 1.49 ± 0.1% respectively). *C. corniger* was observed to contain a total protein content of (19.4 ± 0.9%) which is analogous with that of the deep sea fish *N. orientalis* (18.6 ± 0.9%) and the brackish water fish *S argus* (20.4 ± 0.8%). Similarly both the deep sea fish (*C. corniger* and *N. orientalis*) were found to possess comparable levels of ash contents (2.35 ± 0.1% and 3.11 ± 0.1% respectively) with that of the reference fish (1.37 ± 0.08%).

Determination of amino acid composition

The amino acid composition of two deep sea fish (*N. orientalis* and *C. corniger*) were carried out in comparison with that of the brackish water fish *S. argus*. The result of the prevailing experiment was found to appear with statistically significant differences in the levels of both essential and non-essential amino acids between two deep sea fish and the brackish water fish (see Fig. 3). In marine origin fish amino acids may be proficient to regulate the osmotic pressure as well as they could be the root of sea food flavor. The two deep sea fish used in the present study (*N. orientalis* and *C. corniger*) were observed to exhibit similar levels of the acidic amino acids aspartate (10.4 ± 0.31 g/100 g protein) and glutamate (15.7 ± 0.57 g/100 g protein), moreover their levels in the reference fish were higher in case of both amino acids (11.3 ± 0.9 and 17.2 ± 1.5 g/100 g protein respectively). The levels of leucine were found to be comparatively lower in two deep sea fish (*N. orientalis* and *C. corniger*) 5.58 ± 0.17 and 5.42 ± 0.1 g/100 g protein respectively, while slightly higher in the brackish water fish (7.48 ± 0.51 g/100 g). In the present study *C. corniger* was observed to possess the highest levels of lysine (14.9 ± 0.37 g/100 g protein), proline (5.06 ± 0.15 g/100 g protein), and cystine (1.45 ± 0.04 g/100 g). Likewise *N. orientalis* was observed to contain the highest levels of arginine (7.75 ± 0.18 g/100 g protein), glycine (7.87 ± 0.19 g/100 g protein), histidine (5.50 ± 0.07 g/100 g protein), phenyl alanine (4.57 ± 0.1 g/100 g protein), and tyrosine (2.96 ± 0.04 g/100 g protein) (see Table 2).

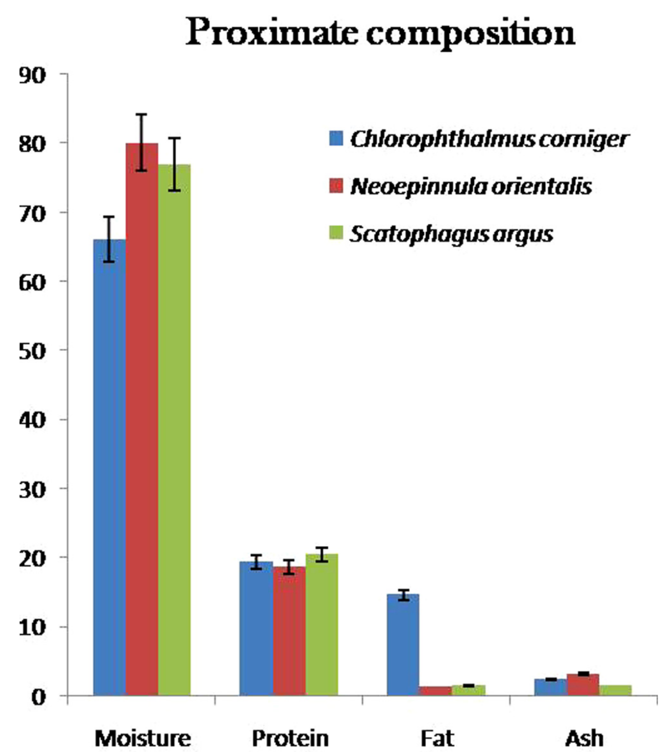

Figure 2 The proximate analysis (g/100 g) of deep sea fishes (*N. orientalis* and *C. corniger*) in comparison with *S. argus*. The results were plotted as mean ± standard deviation, $n = 3$. Values expressed: g/100 g amino acid.

Mineral and heavy metal status

The fish samples were analyzed for their mineral and metal status which play vital roles in maintaining cell functioning associated with human health. Table 3 indicates that *N. orientalis* contains the highest quantities of Calcium (4247 ± 16 mg kg^{-1}), Sodium (5746 ± 27 mg kg^{-1}) and Potassium

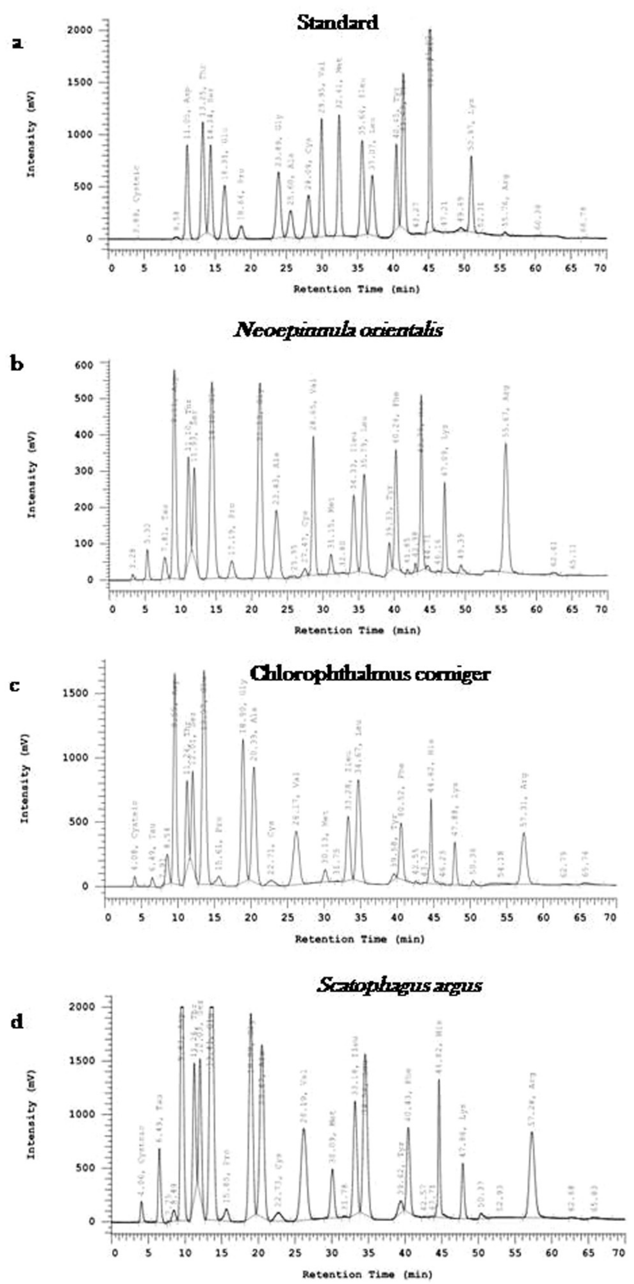

Figure 3 Chromatograms of the amino acid profiling of deep sea fishes in comparison with that of common edible brackish water fish; (a) standard amino acid (1:5 dilution), (b) *N. orientalis*, (c) *C. corniger*, (d) *S. argus*.

(3438 ± 19 mg kg^{-1}) among the other two species of interest. In addition to that, *C. corniger* was found to contain comparable level of Potassium (3131 ± 25 mg kg^{-1}) as those of *N. orientalis*.

Among the three fish used in the current study *C. corniger* was determined to contain the highest levels of Iron (120 ± 1.5 mg kg^{-1} wet weight) and Zinc (135 ± 2.8 mg kg^{-1} wet weight) whereas moderate in Manganese (17 ± 1.5 mg kg^{-1} wet weight), Nickel (0.8 ± 0.02 mg kg^{-1} wet weight), and Magnesium (1821 ± 19 mg kg^{-1} wet weight). At the same time *N. orientalis* was found to accommodate highest level of Magnesium (2253 ± 21 mg kg^{-1} wet weight) when compared with the reference fish. *S. argus* was found to have the highest levels of manganese (35.8 ± 2.8 mg kg^{-1} wet weight) and nickel (10.1 ± 0.8 mg kg^{-1} wet weight).

The fish were assessed for toxic heavy metal contamination during the current study. The levels of heavy metal contamination in the samples were evaluated and the deep sea fish *N. orientalis* was found to possess slightly higher level of cadmium (0.75 ± 0.01 mg kg^{-1} wet weight) while the levels of lead were found to be not-detectable in all the three fish of interest (see Table 4).

Discussion

Based on the monitored results, locomotory properties of the deep water fish could be interpreted as they possess a reduced muscular capacity because denying light level droops reactive distance between predators and prey that literally depends on vision. As a consequence, the selective pressure for active swimming capacities to pursue prey or avoid predators is reduced. The cold water stream fish rainbow trout was reported to have higher lipid content and lower moisture (Rønsholdt and McLeanb, 2004) the fresh water fish *Capoeta damascina* was found to have quite different proximate composition (Fallah et al., 2013). Recent fishery research trends have been attempting to correlate the buoyancy mode of fish with its proximate composition (Drazen, 2007). From the analytical data, the fish species *N. orientalis* was found to have relatively high moisture content and lower fat content, whose habitation is in the deepest region of Indian waters.

Since the nutritional value of fish depends on their biochemical components, the fish of interest analyzed are found to be the rich sources of essential and non-essential amino acids. Considering the role of amino acids in regulating the metabolic pathways in marine organisms, some amino acids should necessarily be provided through diet under certain conditions where rates of consumption exceed the rates of biosynthesis (Li et al., 2009). Amino acids, being the basic component of protein biosynthesis plays a major role in maintaining the cellular homeostatic mechanism by mediating cell–cell communication, gene expression, metabolic pathways etc. Moreover the metabolic intermediates of some amino acids present in these fish species are essentially involved in neuronal transmission in both aquatic as well as terrestrial animals. Though the amino acid composition of the deep water fish display slight variation with that of the brackish water fish, the deep sea fish were analyzed to contain significant amounts of the essential amino acids viz. lysine, phenyl alanine, histidine, as well as the non essential amino acids aspartate, arginine, serine, glutamate, proline, glycine, alanine. Aspartate could act as a precursor molecule of the de novo biosynthesis of non-essential amino acids (NEAA) as well as it also has a capacity to regulate the endocrine function in human system (Ota et al., 2012). Leucine is an important molecule that could stimulate the synthesis of muscle proteins and also has a therapeutic role in stress like trauma, burns etc (Norton and Layman, 2006). Histidine is an essential amino acid which is capable to perform multiple roles in human beings such as protein–protein interaction, precursor of histamine, an important neurotransmitter that is involved in local immune response of human beings. It is also needed for the growth and repair of tissues, involved

Table 2 Amino acid profiling of deep sea fishes (*N. orientalis* and *C. corniger*) and the brackish water fish (*S. argus*).

Amino acids (g/100 g of amino acid)	*Neoepinnula orientalis*	*Chlorophthalmus corniger*	*Scatophagus argus*
Essential amino acids			
Valine	4.28 ± 0.1[b]	4.11 ± 0.1[a]	4.96 ± 0.11[c]
Methionine	0.69 ± 0.01[a]	0.63 ± 0.01[a]	1.84 ± 0.09[b]
Isoleucine	3.24 ± 0.06[a]	3.41 ± 0.01[a]	4.04 ± 0.25[b]
Leucine	5.42 ± 0.1[a]	5.58 ± 0.17[a]	7.48 ± 0.51[b]
Tyrosine	2.96 ± 0.04[c]	0.14 ± 0.01[a]	1.70 ± 0.05[b]
Phenyl alanine	4.57 ± 0.1 [b]	4.52 ± 0.5[b]	3.31 ± 0.02[a]
Histidine	5.50 ± 0.07[c]	4.18 ± 0.47[b]	3.48 ± 0.2[a]
Lysine	10.8 ± 0.34[b]	14.9 ± 0.37[c]	6.46 ± 0.32[a]
Threonine	4.42 ± 0.12[a]	5.85 ± 0.19[c]	4.71 ± 0.2[b]
Tryptophan	1.05 ± 0.04[b]	0.88 ± 0.09[a]	2.24 ± 0.15[c]
Non-essential amino acids			
Aspartate	10.4 ± 0.32[a]	10.4 ± 0.31[a]	11.3 ± 0.9[b]
Arginine	7.75 ± 0.18[c]	7.24 ± 0.16[b]	5.40 ± 0.41[a]
Serine	4.18 ± .03[a]	5.08 ± 0.05[b]	5.22 ± 0.15[c]
Glutamate	15.7 ± 0.57[a]	15.8 ± 0.69[b]	17.2 ± 1.5[c]
Proline	4.95 ± 0.02[b]	5.06 ± 0.15[c]	3.28 ± 0.12[a]
Glycine	7.87 ± 0.19[c]	5.73 ± 0.08[b]	6.25 ± 0.21[a]
Alanine	6.49 ± 0.12[a]	5.86 ± 0.09[a]	11.9 ± 1.09[b]
Cystine	0.58 ± 0.02[a]	1.45 ± 0.04[c]	1.22 ± 0.08[b]

Mean values ± standard deviation, n = 3. Values expressed: g/100 g amino acid. One-way ANOVA; Duncan's multiple comparison test. Values that have a different superscript letter (a, b, and c) differ significantly ($p < 0.05$) with each other.

Table 3 Micro elemental and mineral status (mg kg^{-1}) of deep sea fishes *N. orientalis* and *C. corniger* and brackish water fish *S. argus*.

Samples/elements (mg kg^{-1})	*C. corniger*	*N. orientalis*	*S. argus*
Sodium	3079 ± 12[b]	5746 ± 27[c]	3000 ± 18[a]
Potassium	3131 ± 25[b]	3438 ± 19[c]	1700 ± 8.5[a]
Calcium	2037 ± 11[b]	4247 ± 16[c]	185 ± 5.2[a]
Iron	120 ± 1.5[c]	43 ± 1.7[a]	108 ± 3.3[b]
Zinc	135 ± 2.8[c]	85 ± 5.2[b]	39.1 ± 2.5[a]
Manganese	17 ± 1.5[b]	5 ± 0.4[a]	35.8 ± 2.8[c]
Nickel	0.8 ± 0.02[b]	0.3 ± 0.01[a]	10.1 ± 0.8[c]
Magnesium	1821 ± 19[b]	2253 ± 21[c]	1415 ± 25[a]

Mean values ± standard deviation, $n = 3$. Values expressed: milligram per kg of dried sample. One-way ANOVA; Duncan's multiple comparison test. Values that have a different superscript letter (a, b, and c) differ significantly ($p < 0.05$) with each other.

Table 4 Levels of toxic metals in deep sea fishes *N. orientalis* and *C. corniger* and brackish water fish *S. argus*.

Samples	Metals (mg kg^{-1})	
	Cd	Pb
C. corniger	0.32 ± 0.01[a]	Trace amount
N. orientalis	0.75 ± 0.01[b]	Trace amount
S. argus	Trace amount	Trace amount

Mean values ± standard deviation, $n = 3$. Values expressed: milligram per kg of dried sample. One-way ANOVA; Duncan's multiple comparison test. Values that have a different superscript letter (a, b, and c) differ significantly ($p < 0.05$) with each other.

in the maintenance of myelin sheath, and removal of metals (Liao et al., 2013). Lysine being an essential amino acid, it is crucial for the optimal growth, possesses an immunomodulatory potential, in addition it uses to prevent and cure cold sores (Chen et al., 2003). Arginine is an important component involved in modulating cell division and endocrine glands functioning (Sarma et al., 2013) Being an intermediary component in urea cycle it is essential for the removal of ammonia from the cells. It is also involved in the de novo synthesis of NO an important neurotransmitter. As well as this amino acid plays an important role in the process of blood clotting and normalizing the blood pressure (Mohanty et al., 2014). It is essential for the regulation of metabolic detoxification process. Glutamate is an important neurotransmitter in the Central nervous system of mammals (Nedergaard et al., 2002; Meldrum, 2000).

The studies reveals that the deep sea fish used for the present study possess tremendous levels of minerals and microelements, which are essential for proper maintaining of homeostasis. The deep sea fish *N. orientalis* was observed to contain significantly higher amounts of calcium, sodium and potassium. Calcium plays an important role in the production of healthy bones and teeth, blood clotting, muscular functioning, blood pressure regulation, immune system and also maintains acid-base balance in the body (Tandogan and Ulusu, 2005). Calcium binding ligand proteins involved in signal transduction in animal cells such as calmodulin, troponin C, protein kinase C and synaptotagmin (Blaustein and Lederer, 1999). Sodium is reported to be engaged in important physiological activities, for instance in voltage gated sodium channels (Catterall, 2000) and also mediate the osmotic pressure regulation.

The levels of microelements (such as Fe, Mg and Zn) in the deep sea fish were estimated to be higher than the brackish water fish meanwhile, the reference fish was found to contain comparatively higher levels of manganese and nickel.

The accumulation of metals in fish may cause long-term impacts on our ecosystem, as they move up the food chain and gets recycled, and grow up to a perilous levels for human health (Gu et al., 2012; Ip et al., 2005; Sapkota et al., 2008; Yi et al., 2011). Cadmium and lead are generally categorized as potentially toxic metals, since even at low concentrations, the prolonged ingestion leads to harmful effects (Tuzen, 2009; Uluozlu et al., 2007; Waqar, 2006). The admissible levels of Cadmium in diet is proposed by the FAO is 0.5 mg kg^{-1}. In the present study, the level of cadmium was detected below the prescribed limit in the deep sea origin *N. orientalis* and the brackish water fish *S. argus*, demonstrating their safety for human consumption, whereas *C. corniger* was found to exhibit slightly higher levels than the prescribed limit. Cadmium gets accumulated in human body and leads to kidney dysfunction, skeletal damage, and reproductive deficiencies (Uluozlu et al., 2007). Lead poisoning can cause reduced cognitive development, intellectual performance in children, increased blood pressure and cardiovascular disease in adults (Canfield et al., 2003; Goyer, 1993; Hsu and Guo, 2002).

Conclusion

The results of the present study have provided supportive information to explore nutritive connotation of Deep Ocean for countering the factors associated with malnutrition extremity in developing and underdeveloped countries. The present observation revealed that the deep water origin fish could serve as efficient sources of high quality protein, thereby helping to eliminate the complications of Protein Calorie Malnutrition. Being the balanced sources of essential amino acids, and minerals, they may also be capable of positively modulating the physiological processes, signal transduction system, and biosynthesis of vitamins. However, further processing methods should be standardized to effectively utilize these deep sea fish for human consumption.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgements

The authors acknowledge the Director, Central Institute of Fisheries Technology (CIFT), Cochin, Kerala, India for providing the facilities to carry out this work and also for granting permission to publish the data acquired from the study. The authors would like to extend their sincere gratitude to Indian Council of Agricultural Research (ICAR), New Delhi, India for providing funds to carry out the research work. The authors are grateful to the Senior Technical Officers, Dr. G Usha Rani and Mrs. G Ramani, and the Senior Technical Assistant Mrs. Jaya PA Central Institute of Fisheries Technology (CIFT), Cochin, Kerala for providing support to carry out the analyses.

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