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Nutritional variability in selected deep-sea fish species from the southeastern Arabian Sea: A comparative proximate analysis

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Deep-sea fishes are a valuable and underexplored resource with significant potential in the food and nutraceutical industries. This study investigates the proximate composition of eight deep-sea demersal fish species, focusing on protein, fat, ash, and moisture content to assess their suitability for food applications. The results revealed a promising protein profile ranging from 10.03 – 17.36 % across the species analyzed. Ash content ranged from 3.25 – 7.35 %, lipid content varied between 1.21 – 7.03 % and moisture content fell between 70.78 – 79.95 %. These findings demonstrate the diverse nutritional profiles of these deep-sea fishes, with significant implications for their potential use in food and nutraceutical formulations. The promising proximate composition data of these deep-sea fishes, along with their protein content, indicate their potential as a versatile source of high-quality ingredients for food and nutraceutical products. The ash content reflects the mineral composition, while lipid and moisture content provides insights into the fishes' overall nutritional value and culinary applications. Further exploration of their bioavailability, sensory characteristics, and processing methods is essential to unlock their full potential in these industries. Harnessing the nutritional advantages of these fishes offers an exciting opportunity to diversify and enhance the food and allied sectors while ensuring the sustainable use of deep-sea resources.

[**Keywords**: Bycatch, Deep-sea fishes, Fish protein, Proximate composition, Southeastern Arabian Sea]

Introduction

Fish is an important source of animal protein, which is inexpensive and easily digestible compared to other animal proteins for most people worldwide[1-2]. Marine fish is regarded as a high-protein food and a primary source of fatty acids, such as polyunsaturated fatty acids (PUFAs) like eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are either absent or insignificant in freshwater fish[3]. In addition, marine fish species contribute significantly to the delivery of both macro and micronutrients in our normal diet and are the most cost-effective option for all strata of our society[4]. The world's per capita demand for fish has increased due to the rising population, and by 2050, about 21 to 44 million tons, or a 36 – 74 % increase over present levels, will be needed to meet the level of consumption[5]. According to estimates, 3.49 million tonnes of marine fish were brought ashore throughout the Indian subcontinent's coastline in 2022, an increase of 14.53 % from landings in 2021. The marine fish landings in 2022 increased by 28.02 % as compared to the COVID-19 pandemic year of 2020. However, it was also 2.0 % less when compared to the estimated landings for the pre-COVID year 2019[(ref. 6)]. Thus, despite a modest increase in marine fish production, it may not be sufficient to meet the needs of the rapidly expanding population. The marine fish production within the Indian Exclusive Economic Zone (EEZ) has either reached or is approaching its maximum sustainable level, with inshore seas already attaining the Maximum Sustainable Yield (MSY) threshold[7]. However, the exploration of offshore waters remains limited, accounting for only 31.46 % so far[8-9]. This scenario has led to the recognition of deep-sea species as a promising future resource, as coastal fisheries alone are unable to meet the nutritional demands of a growing population[10]. India ranks 100 out of 119 countries on the 2017 Global Hunger Index, and more than one-third of the world's malnourished children reside in India[11]. In this view, as deep-sea ecosystems harbour a diverse range of fish species, their sustainable exploitation holds the potential for addressing such malnutrition concerns within the Indian EEZ[12]. Nonetheless, the advancement of fishing gear technology has resulted in overfishing and unintended capture of deep-sea species, causing significant bycatch issues[13-14]. Notably, the southwest coast of India experiences substantial amounts of bycatch consisting of deep-sea fish, often resulting in low market prices and frequent discarding back into the sea[15]. However, researchers are examining alternative processing techniques, products, and applications that might enhance the value of these resources. Order Scorpaeniformes is a good example of such types that form a major component among these deep-sea fishes and find limited application in the fisheries except for a few being used for fertilizers. Being the fourth largest order with 1400 species globally, some of them attain larger sizes and are valuable food fishes that are consumed in countries like Hong Kong, the Philippines and Japan[16]. But, the public in India is unaware of the nutritional value as well as pharmaceutical and nutraceutical potential of these non-conventional resources[10, 17]. The majority of our knowledge on the proximate composition of finfishes is therefore restricted to species collected from conventional resources abundant in pelagic or coastal waters[18-19]. Considering that limited information exists regarding the biochemical makeup of many deep-sea resources, evaluating their nutritional value becomes imperative[20]. Earlier, renowned works about the nutrient composition of deep-sea fishes from Indian waters were limited to deep-sea sharks, shrimps, chimaeras, myctophids and other fishes[21-23]. Furthermore, in recent years, there has been a minor increase in the consumption of deep-sea fishes by humans, highlighting the need for mineral and proximate analysis studies to understand their nutritional characteristics[24]. In light of these knowledge gaps, the present study aims to provide novel data on the proximate composition of selected deep-sea fishes captured as bycatch from the southeastern Arabian Sea. The findings may have implications for fisheries management, conservation efforts, and public health, guiding strategies for sustainable exploitation and promoting the responsible consumption of deep-sea fish species.

Materials and Methods

Materials

All solvents and chemicals utilized for proximate analysis were of analytical grade and purchased from Sigma Aldrich (Steinheim, Germany).

Sample collection

Fish samples were collected monthly, spanning from September 2021 to December 2022, from a depth range of 200 to 400 m. The samples were obtained as bycatch from deep-sea demersal shrimp trawlers operating along Quilon Bank, a well-known fishing ground located between Kollam and Alappuzha in the southeastern Arabian Sea. After landing at Sakthikulangara fishing harbour (08°56’ N; 76°32’ E) (Fig. 1), the samples were carefully sorted and identified using available keys and relevant literature sources[25-26]. Subsequently, selected samples were promptly transported in an iced box to the designated facility and stored at -80 °C for further analysis.

Determination of proximate composition

The fish samples were blended to achieve homogenization. Proximate values were determined by conducting triplicate procedures in accordance with the Association of Official Analytical Chemists (AOAC), 2005 guidelines[27].

Fig. 1 — Map illustrating the specific location of sample collection

Moisture

AOAC method No. 934.01 was used to determine the moisture content. A 20 g portion of the homogenized sample was evenly spread onto a petri plate. The fish samples were then dried in a hot air oven at 105 °C, cooled in a desiccator, and the moisture content was determined. This process of heating and cooling was repeated until a constant value was achieved.

Crude protein

The Micro-Kjeldahl method, as specified by method 978.04, is utilized to analyze the total protein content in the tested sample. Approximately 0.1 g of the sample was taken in a clean Kjeldahl flask, and a pinch of digestion mixture was added along with 10 ml of concentrated H_2SO_4. The flask is swirled to ensure thorough mixing. The digestion process is carried out on a standbath until the solution becomes colourless. After cooling, the solution is brought up to a desired volume of 100 ml. Distillation and titrations were carried out following the standard procedure.

The protein content was estimated using the following equation

$$Protein\ content\ (\%) = \frac{(X * 0.14 * V * 6.25 * 100)}{(V_1 * W * 1000)}$$

Where, X - Titre value of the sample, V - Total volume of digest, V_1 - Volume of digest for distillation, and W - Weight of sample for digestion.

Crude fat

The crude fat analysis is performed using the Soxhlet extraction method (Method No. 930.09). The dried sample (1 g) is extracted with petroleum ether using a pre-weighed flask (W_2). Ether is evaporated, and the dried fat is weighed (W_3) to determine the extracted quantity.

$$Fat\ content\ (\%) = W_3 - W_2/W_1$$

Ash

The minced sample was dried at 105 °C until a constant weight was reached. It was then crushed into a fine powder. 2 g (W_2) of the homogenized sample was charred in a porcelain crucible at 600 °C in a furnace for 12 h. This produced an ashy-white mineral concentrate. After cooling, the crucible was weighed (W_3), heated again for 30 min, cooled, and weighed again. These steps effectively eliminated organic matter, leaving a mineral concentrate for further analysis. Weight measurements before and after combustion provide valuable information about the sample's mineral content. AOAC method No. 923.03 was employed to quantify the ash content with slighter modifications.

$$Ash\ Content\ (\%) = (W_3 - W_1)/W_2 \times 100$$

Statistical analysis

To ensure accuracy and reliability, all of the experiments mentioned were completed in triplicates. The resulting output values were then expressed as mean ± standard deviation (SD). One-way analysis of variance (ANOVA) was performed on experimental data, and the means and standard deviation for three replications were compared using the Duncan test at 5 % level of significance by using SPSS 22 software ($p < 0.05$)[28].

Results

The deep-sea fishes selected for this study were major groups caught, other than shrimps and myctophids, during deep-sea trawling in the southeastern Arabian Sea. Eight dominant species namely *Grammoplites suppositus* (Troschel, 1840), *Pterygotrigla hemisticta* (Temminck & Schlegel, 1843), *Lythrichthys longimanus* (Alcock, 1894), *Setarches guentheri* Johnson, 1862, *Dactyloptena orientalis* (Cuvier, 1829), *Minous dempsterae* Eschmeyer, Hallacher & Rama-Rao, 1979, *Snyderina guentheri* (Boulenger, 1889), and *Satyrichthys laticeps* (Schlegel, 1852) were analysed for their proximate compositions. Table 1 displays the proximate composition values of these fishes. The moisture content of the fishes ranged from 70.78 to 79.95 % with *M. dempsterae* exhibiting the highest moisture content, and the protein content of the fishes ranged from 10.03 to 17.36 %. *Setarches guentheri* exhibited significantly ($p < 0.05$) higher protein content (17.36±0.60 %), indicating that this species may be a good dietary source of protein. The fat content of the fishes ranged from 1.21 to 7.03 %, and *L. longimanus* contained the highest level of crude fat (7.03±0.26 %). Ash content of the fishes ranged from 3.25 to 7.35 %, out of which *D. orientalis* exhibited the highest ash content (7.35±0.27 %).

Discussion

This paper provides the first time data on the proximate composition of all the eight deep-sea fish species from the southeastern Arabian Sea. The nutritional and sensory characteristics of deep-sea fish species are significant factors when assessing their potential as commercial replacements[24]. All the customers have some kind of concerns about the aroma, texture, and general eating experience, and any new species presented to the market should satisfy or beat these prospects. Moisture content is a vital parameter that affects the total texture and quality of fish[29]. The observed range of moisture content in our study was 70.78 to 79.95 %, showing inconsistency in water-holding capacity between the fish species. Factors like age, sex, freshness, and processing methods can influence the moisture content[30-31]. Higher water holding capacity is commonly connected with fresher fish, as it shows lesser dehydration. Therefore, customers always look for fresh fish with a good texture, aroma, and taste. Total protein content is a significant parameter when estimating the nutritional value of fish[32]. Proteins are vital nutrients required for several physiological functions in the human body. The range of protein content observed in our study, *i.e.* from 10.03 to 17.36 %, demonstrates significant variations among the fish species. Notably, *Setarches guentheri* exhibited the highest protein content (Fig. 2), suggesting that it could serve as a valuable dietary source of protein. Including fish species with higher protein content in the diet can contribute meeting the recommended daily intake of protein, which may help with overall metabolism and health[33]. Previous studies state that the majority of the selected food fishes of India contain greater than 15 % protein, which contributes 30 – 50 % of the daily protein requirement (%DV) in the human diet compared to values of the pulses as well as animal protein sources. However, fish is preferable in terms of accessibility and affordability in meeting the protein needs of people in developing nations. Percentage of protein in a major proportion of the selected deep-sea fishes is not meager compared to the previous reports of food fishes studied from

Table 1 — Proximate composition of eight deep-sea fish species examined

Species	Family	Moisture	Protein	Crude fat	Ash
Grammoplites suppositus (Troschel, 1840)	Platycephalidae	74.5 ± 0.31^{c}	16.67 ± 0.88^{de}	1.43 ± 0.21^{ab}	5.18 ± 0.19^{de}
Pterygotrigla hemisticta (Temminck & Schlegel, 1843)	Triglidae	73.44 ± 0.06^{b}	14.94 ± 0.88^{cd}	5.19 ± 0.13^{e}	4.79 ± 0.14^{c}
Lythrichthys longimanus (Alcock, 1894)	Setarchidae	75.25 ± 0.10^{c}	14.08 ± 2.89^{c}	7.03 ± 0.26^{f}	3.25 ± 0.10^{a}
Setarches guentheri Johnson, 1862	Setarchidae	74.73 ± 0.16^{c}	17.36 ± 0.60^{e}	2.3 ± 0.14^{c}	5.33 ± 0.15^{de}
Dactyloptena orientalis (Cuvier, 1829)	Dactylopteridae	70.78 ± 0.50^{a}	11.45 ± 0.82^{b}	3.55 ± 0.06^{d}	7.35 ± 0.27^{f}
Minous dempsterae Eschmeyer, Hallacher & Rama-Rao, 1979	Synanceiidae	79.95 ± 0.09^{f}	10.03 ± 0.18^{a}	1.58 ± 0.02^{b}	3.90 ± 0.06^{b}
Snyderina guentheri (Boulenger, 1889)	Tetrarogidae	77.08 ± 0.67^{d}	16.84 ± 0.40^{de}	1.21 ± 0.14^{a}	5.48 ± 0.23^{e}
Satyrichthys laticeps (Schlegel, 1852)	Peristediidae	78.72 ± 1.09^{e}	14.00 ± 0.19^{c}	2.13 ± 0.13^{c}	5.09 ± 0.23^{cd}

Triplicate sampling was conducted for each fish species in the analysis, and the results are presented as Mean±SD. Significant differences are denoted by different superscripted letters at $P < 0.05$

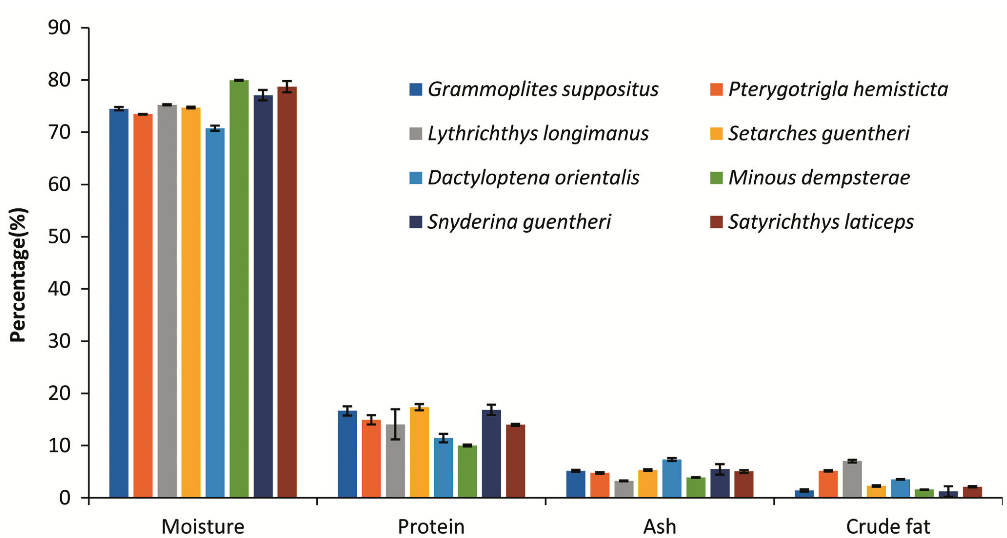

Fig. 2 — Comparative analysis of moisture, protein, ash, and crude fat levels in the investigated fish species

Indian waters[34-35]. According to Stansby & Olcott's[36] classification, the fishes currently being studied, such as *Grammoplites suppositus*, *Setarches guentheri*, and *Snyderina guentheri*, are low oil- high protein fishes, whereas *Dactyloptena orientalis*, *Minous dempsterae*, and *Satyrichthys laticeps* can be classified as low oil-low protein fishes. Fat content is another vital constituent when considering the nutritional arrangement of fish[37]. Fats play a major role in providing the basic energy and essential fatty acids that are important for maintaining human health[38]. *Lythrichthys longimanus* displayed the highest fat content, representing that it may be considered relatively high in fat compared to other species studied. Of the eight fish species examined, three namely *Grammoplites suppositus*, *Snyderina guentheri* and *Minous dempsterae* were found to be lean fishes since their fat contents were less than 1 %, whereas, *Setarches guentheri*, *Dactyloptena orientalis* and *Satyrichthys laticeps* were found to be low-fat fishes. *Pterygotrigla hemisticta* and *Lythrichthys longimanus* were found to be medium-fat fishes as per the results. It is also crucial from a nutritional standpoint to focus on species with high amounts of omega-3 fatty acids rather than just fat level. The presence of marine omega-3 fatty acids contributes to the preventive effect against coronary heart disease[39]. Consumption of lean fishes, along with fatty fishes has shown to be advantageous in the prevention of cardiovascular illnesses[40]. Lipid composition is, hence, an excellent signal for potential survival of some species and an effective indicator of reproductive capacity for some fish stocks[41-42]. Ash content represents the inorganic mineral content of fish, which includes minerals like sodium, potassium, calcium, phosphorus, magnesium and other trace elements. The observed ash content in our study ranged from 3.25 to 7.35 %, with *Dactyloptena orientalis* exhibiting the highest ash content. Higher ash content suggests a relatively higher concentration of minerals, which can be beneficial for certain dietary needs, such as individuals requiring increased mineral intake[43]. Additionally, current study examined a limited number of fish species, and there may be significant variations in nutritional composition among other species not included in this study. Further research is needed to comprehensively assess the nutritional composition of a broader range of deep-sea fish species belonging to scorpaeniformes. The observed variations in moisture, protein, fat, and ash contents underscore the importance of considering species-specific differences when evaluating the dietary value and potential health benefits of consuming fish. These findings can guide individuals in selecting fish species that align with their specific nutritional requirements and contribute to a healthy and balanced diet. In addition, it serves as baseline information for further research on data-deficient deep-sea fish species in the Arabian Sea.

Conclusion

In conclusion, the proximate composition analysis of selected deep-sea scorpaeniform fishes in this study demonstrated their high protein content and the potential to be utilized beyond their current applications, such as feed or fertilizer sources. The high protein content highlights their suitability for human consumption as a valuable dietary protein source. These findings encourage further exploration of the utilization of these deep-sea fishes in the development of nutritionally rich food products or supplements, thereby maximizing their economic and nutritional value.

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Conflict of Interest

The authors of this paper declare no competing or conflicts of interest.

Ethical Statement

Not applicable.

Author Contributions

DN, KVAK: Sample collection, taxonomic identification, writing- original draft. DN, NA, MV, KVV: Analysis of proximate composition, statistical analysis, writing- original draft, visualization of figures and editing. HM: Sample collection, taxonomic identification, conceptualization, writing, review and final draft editing.

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