Journal of Aquatic Biology & Fisheries | 2023 | 11(1) | pp. 35-41
ISSN 2321–340X
OPEN ACCESS
http://www.jabf.in/
University of Kerala, INDIA

Seasonal variation and bioavailability of vital elements recommend *Terapon jarbua* as a source of sustainable nutrition

Ancy Thomas and Manju K.G.*

Department of Zoology, Mar Ivanios College (Autonomous),
Nalanchira, Thiruvananthapuram, Kerala
**E.mail: manju.kg@mic.ac.in*

ABSTRACT

Dietary habits have illustrated a prominent impact on the better immune system and functions in human populations. As a high resource of various nutritional elements, the consumption of fish-based food is remarkably suggested for better health. This paper explores the nutritional evaluation of *Terapon jarbua* with special inference to the proximate composition and quantification of minerals and vitamins during the different climatic seasons of two consecutive years. The study elucidated a high concentration of protein in the pre-monsoon season of 2017 (13.28 ± 1.04 %) and fat (12.73 ± 0.21 %) in pre-monsoon season of 2016. The maximum vitamin concentration (0.47 ± 0.01 mg) was obtained during the pre - monsoon season of 2017.Various minerals such as calcium (384.26 ± 4.41 mg), phosphorus (2240.69 ± 19.23 mg) and iron (9.84 ± 0.25 mg) were detected in higher concentration during the pre-monsoon period. Post-monsoon season exhibited a higher concentration of magnesium (473.14 ± 3.45 mg) and sodium (482.02 ± 16.15 mg). The nutritional quality envisaged in the study suggests *Terapon jarbua* as an eminent fish choice to be incorporated into the diet for essential elements. The knowledge about the probable season of maximum nutritive value enhances the capturing and marketing of the fish as a sustainable dietary choice.

ARTICLE HISTORY

Received on: 03-12-2022
Revised on: 22-05-2023
Accepted on: 01-06-2023

KEYWORDS

Fish, Proximate composition, Nutritional evaluation, Seasonal variation, Dietary choice

1. Introduction

Attaining a level of zero hunger and malnutrition in 2030 should necessitate prominent dietary shifts that comprise augmenting the consumption of nutrient-rich elements among individuals inhabited in developing countries (Dlamini, 2020). Specifically, human health primarily hangs on numerous imperative elements that are to be integrated into the diet without which sundry deficiency disorders and ailments can arise (Bene *et al.,* 2016). In the past few years, animal-source foods have been prominently used since such foods can provide highly bio-available nutrients that are not found in other food sources. Because of their simple accessibility, economic benefits, and high nutritional value, fish have replaced animals as the primary food source in developing nations (Jennings *et al*., 2016). The nutrient elements of fishes primarily consist of easily digestible high-quality proteins, encompassing entire essential amino acids, highly unsaturated fatty acids (HUFA), polyunsaturated fatty acids (PUFA), mainly the omega-3 fatty acids, eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA), Vitamin (D, A and B) and Minerals (Calcium, Iodine, Zinc, Iron and Selenium) (Gladyshev, *et al*., 2009). In addition to the presence of these elements in higher amounts, it was also perceived that the extent fluctuates according to the species collected. Because of the conservation perspectives and sustainable use of aquatic resources along with their taste, nutrition, low cholesterol level, and ability to prevent coronary artery diseases, recent years have hence implemented the applicability of various strategies allied with aquaculture, which dealt with the mass production of fish for dietetic necessities, especially for proteins (Subasinghe, 2017).

Protein from fish has usually been known to be indispensable for maintaining the proper health, and reproduction of human beings. Marine fishes are known to provide all the necessary amino acids and fatty acids required for the growth and maintenance of the body (Mohanty *et al*., 2019). One such prominent element, calcium available from the fish food resources is previously known to play a significant role in the majority of metabolic processes including providing bone density (Ashraf *et al*., 2020). The way of getting calcium is comparatively not much easier than the other elements since it is mainly ingested into the body through a diet that contains calcium- rich food (Guéguen and Pointillart, 2000). Fish can be used to get various kinds of other nutrients and elements including phosphorus, iodine, selenium, zinc, calcium, phosphorous, and potassium (Lall, 2022). In addition to the introduced elements and their benefits for the human population, selenium has been known to constitute a major role allied with antioxidant enzyme mechanisms (Chauhan *et al*., 2019).

Diverse fish species have been studied in India for their nutritional composition. Proximate composition of 17 species of Indian fishes was done by Ayyappan *et al*. (1976). The nutritional composition of commonly available fish in Agatti Island water of Lakshadweep Sea was evaluated by Dhaneesh *et al*. (2012). Previous studies on the proximate composition of fishes landed in Thoothukudi, Nagapattinam and Parangipettai coasts mainly examined the comparative difference of nutritive value of different fish species (Palani Kumar *et al*., 2014). Thomas and Manju (2015) studied the comparative evaluation of nutrients in three perciforme fishes from Kerala coast. However studies on the seasonal variation of nutritional composition of *Terapon jarbua* which is a common food fish available across Kerala coast has not been reported so far. The nutritional composition of the species has to be addressed to estimate the availability of essential nutrients so as to evaluate the relevance of the fish as a dietary source. In this ground, the current investigation has aimed to unveil the nutritional composition of *Terapon jarbua* by estimating the proximate composition, vitamins and mineral content.

2. Materials and Methods

2.1 Sample collection and processing

Samples of *Terapon jarbua* were collected from the Vizhinjam coast, South India during the pre-monsoon, monsoon and post- monsoon periods of 2016 and 2017. Specimens were identified by phenotypic traits and morphometric counts. For the biochemical analysis, the upper dorsal half muscle of the sample was removed just beneath the dorsal fin. Samples of similar length and weight were subjected to analytical studies as proposed by Williams (1984).

2.2 Estimation of proximate components

Proximate parameters (carbohydrate, fats, protein, moisture and ash) of *Terapon jarbua* were carried out following the methods by AOAC (2000).

The total protein present in the fish sample was quantified following the procedure of AOAC by Kjeldahl method. The fat content was evaluated using the Soxhlet apparatus. The moisture content was determined by drying the previously weighed sample in an electric hot oven at 105^0 C. The percentage of moisture content was calculated by comparing the two weights as denoted in the formula given below.

$$\text{Moisture \%} = \frac{\text{Wet weight of tissue} - \text{Dry weight of tissue}}{\text{Wet weight of tissue}} \times 100$$

The ash content was determined using muffle furnace ignition for 12-15 hours at 500°C and the estimation was carried out by finding the difference between the initial weight and the final weight. Carbohydrate content was obtained on difference calculation. It was computed by adding percentage moisture, and crude protein and then subtracting the amount from 100.

2.3. Estimation of vitamins

High-Performance Liquid Chromatography (HPLC) technique was chosen for the vitamin content estimation as described by Devi *et al.* (2012). Fish oil of 2.0 g was extracted and repressed with 30 ml methanol and 150 % potassium hydroxide (KOH) in a water bath for 30 min. Petroleum ether was used for the extraction of fat-soluble vitamins which were then dissolved in 10 ml acetonitrile. The Fat soluble vitamins were estimated by injecting 20 µl of the sample in HPLC (Thermo Scientific Dionex UltiMate 3000) with C18 RP column and UV detector and further identification and quantification were carried out by comparing with the vitamin standards of Sigma-Aldrich (Chatzimichalakis *et al*., 2004).

2.4 Estimation of Minerals

The minerals in the sample were analysed from a solution obtained when 5g of the samples were digested with nitric acid (HNO_3) and perchloric acid ($HClO_4$). The mixtures were placed in a water bath and evaporated almost to dryness. An atomic absorption spectrophotometer was used to analyze the minerals separately after acid digestion of the sample as described by AOAC (2000).

2.5. Statistical Analysis

The statistical analysis of the obtained data was conducted using SPSS 16.0 version software. The one-way ANOVA analysis at $p \leq 0.05$ was done and the significance mean was compared by Duncan's multiple range tests.

3. Results

3.1 Proximate composition

The proximate composition of the fish, *Terapon jarbua* was done to find out the protein, lipids, carbohydrates, ash, and moisture contents and the findings are summarised in Table 1. The proximate composition was analysed during three different seasons and the highest protein concentration was detected in the pre-monsoon season of 2017 (13.28 ± 1.04 %) and 2016 (12.88 ± 1.44 %) predominantly. Comparing the protein concentration data during 2016 and 2017, constancy in the values has been observed in all the seasons (Pre-monsoon (13.28 ± 1.04 %); monsoon (11.21±1.07 %); post-monsoon (12.28 ± 1.11 %) of 2017. Also, there was a noticeable increase in protein concentration from 10.11 % to 12.88 % in 2016 and from 11.21 % to 13.28 % in 2017. While considering the seasonal variations along with the comparison of protein composition in both years, the lowest concentration (10.11±1.23 %; 11.21 ±1.07 %) of protein was estimated during the monsoon season of 2016 and 2017 respectively. The present study estimated that the protein concentration of *Terapon jarbua* occurs in the range of 10.11±1.23% to 13.28±1.04 %.

Compared to other components, carbohydrate concentration was observed to be low in *Terapon jarbua*. The maximum concentration (1.87 ± 0.78 %) of carbohydrates was detected in the post-monsoon season of 2016. The lowermost concentration (1.02 ± 0.15 %) of carbohydrates was in the monsoon season of 2017. During the year 2016, variation in the concentration remained in the range of 1.16 ± 0.99 % to 1.87 ± 0.78 % while in 2017, it was in the range of 1.02 ± 0.15 % to 1.75 ± 0.25 %.

The fat content of *Terapon jarbua* was analysed during different seasons throughout the two years and found that the maximum fat production occurred during the post-monsoon season. Specifically, the maximum percentage (12.73 ± 0.21 %) of fat was observed during the pre-monsoon season of 2016 while the lowest percentage (9.16 ± 1.33 %) of fat was in the monsoon season of 2016 (Table 1).

The moisture content of the muscles of the fish sample *Terapon jarbua* during the three different seasons over the two years indicated that the pre-monsoon season of 2017 had the highest percentage (78.22 ± 0.63 %) of moisture content whereas the least amount (64.22 ± 0.55 %) of moisture content was detected during the monsoon season of 2017 which have been represented in Fig. 1. The monsoon season of the year 2017 experienced a remarkable decrease in the moisture content of fish muscles with a value of 64.22 ± 0.55 %. Findings of the year 2016 displayed a minute deviation in the moisture concentration from 75.88 ± 1.64 % to 76.34 ± 1.33 % through the seasons, pre-monsoon to post-monsoon.

Ash content, which is one of the most important components of the biochemical composition of a fish body was assessed to estimate the seasonal variations during the years 2016 and 2017. According to the results, the post-monsoon season of the year 2017 evidenced the highest ash percentage with 1.99 ± 0.12 % while the lowest ash

Table 1. Proximate composition of *Terapon jarbua* during pre-monsoon, monsoon and post- monsoon seasons in 2016 and 2017

Parameter	Mean±SD (2016)	Mean±SD (2017)	Range
Pre-monsoon(March-May)			
Total Protein (%)	12.88±1.44[b]	13.28±1.04[b]	8.73-14.29
Carbohydrate (%)	1.46±0.76[e]	1.52±0.25[d]	0.34-3.21
Fat (%)	10.76±1.92[c]	12.06±0.44[c]	6.61-13.74
Moisture (%)	75.88±1.64[a]	78.22±0.63[a]	73.5-78.97
Total Ash (%)	1.79±0.39[d]	1.22±0.14[e]	1.17-2.36
Monsoon (June-September)			
Total Protein (%)	10.11±1.23[b]	11.21±1.07[b]	8.73-14.29
Carbohydrate (%)	1.16±0.99[d]	1.02±0.15[e]	0.34-3.21
Fat (%)	9.16±1.33[c]	11.06±0.95[c]	6.61-13.74
Moisture (%)	75.26±1.07[a]	64.22±0.55[a]	73.5-78.97
Total Ash (%)	1.06±0.22[e]	1.03±0.12[d]	1.17-2.36
Post-monsoon (October-February)			
Total Protein (%)	12.18±1.08[b]	12.28±1.11[c]	8.73-14.29
Carbohydrate (%)	1.87±0.78[d]	1.75±0.25[e]	0.34-3.21
Fat (%)	11.55±1.95[c]	12.73±0.21[b]	6.61-13.74
Moisture (%)	76.34±1.33[a]	74.22±0.63[a]	73.5-78.97
Total Ash (%)	1.05±0.32[e]	1.99±0.12[d]	1.17-2.36

content was observed during the monsoon season of the year 2017 with a value of 1.03 ± 0.12 %. Considering the year 2016, the maximum percentage of ash content was observed during the pre-monsoon season at 1.79 ± 0.39 % while the post-monsoon season had the lowest percentage of 1.05 ± 0.32.

3.2 Vitamins

The whole vitamin content estimation of the fish species, *Terapon jarbua* was done during the pre-monsoon, monsoon, and post-monsoon seasons of 2016 and 2017 (Table 2). Among the three seasons, the pre-monsoon season experienced a high content of vitamins with values of 0.43 ± 0.03 mg, 0.47 ± 0.01 mg in the years 2016 and 2017 respectively. There was a slight increase in the vitamin concentration from 0.31 ± 0.07 mg to 0.47 ± 0.01 mg during the year, 2017, and a similar deviation occurred in the year 2016 from a concentration of 0.34 ± 0.15 mg to 0.43 ± 0.03 gm.

3.3. Minerals

The estimation of the mineral profile of the fish, *Terapon jarbua* was carried out to find the concentration of essential elements including calcium, phosphorus, iron, magnesium, and sodium during pre-monsoon, monsoon, and post-monsoon seasons of the year 2016 and 2017 which is presented in Fig. 2. When the concentration of calcium was assessed, the highest value of 384.26 ± 4.41 mg was observed during the pre-monsoon season in 2016 and the lowest concentration of 376.53 ± 8.40 mg was during the monsoon season. A notable variation of 313.74 ± 7.21 mg to 384.26 ± 4.41mg in the calcium concentration in *Terapon jarbua* was detected during the transition from the year 2016 to 2017.

Compared to all other mineral constituents phosphorus had the highest concentration in both 2016 and 2017 as shown in Table 2. Pre-monsoon season experienced the highest concentration value of 2240.69 ± 19.23 mg and 2276.69

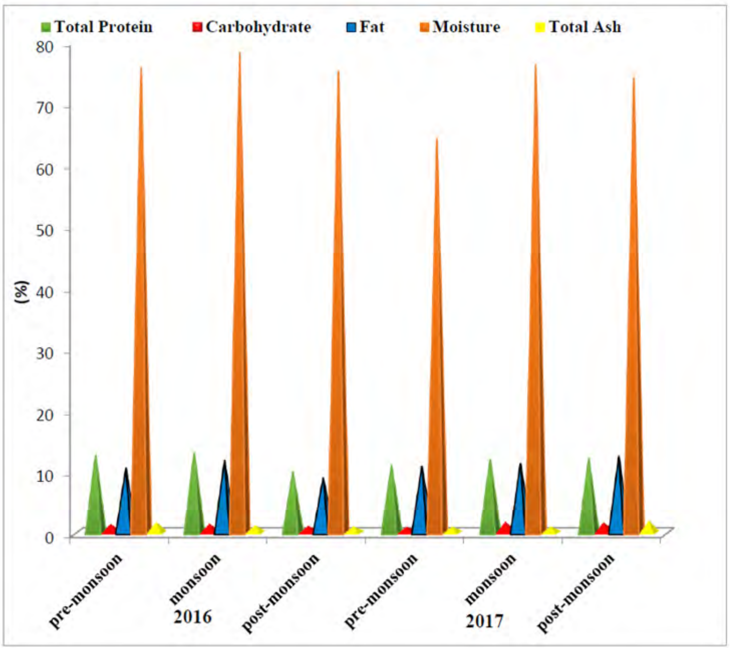

Fig. 1. Proximate composition of *Terapon jarbua* during pre-monsoon, monsoon and post -monsoon seasons in 2016 and 2017

Table 2. Mean concentration and range of vitamin-mineral analysis of *Terapon jarbua.*

Samples/elements (mg)	Mean±SD (2016)	Mean±SD (2017)	Range
Pre-monsoon (March-May)			
Vitamin	0.43±0.03[f]	0.47±0.01[f]	0.39-0.49
Sodium (Na)	439.41±4.22[b]	449.02±5.15[c]	429.34-484.18
Calcium (Ca)	384.26±4.41[d]	383.74±3.21[d]	390.52-401.47
Iron(Fe)	9.84±0.25[e]	9.12±0.75[e]	9.61-10.23
Magnesium (Mg)	416.91±3.79[c]	468.14±3.19[b]	406.92-489.72
Phosphorous (P)	2240.69±19.23[a]	2276.69±8.73[a]	2192.96-2381.23
Monsoon(June-September)			
Vitamin	0.34±0.15[f]	0.31±0.07[f]	0.39-0.48
Sodium (Na)	412.92±4.94[b]	402.08±16.15[c]	429.34-484.18
Calcium (Ca)	376.53±8.40[d]	313.74±7.21[d]	390.52-401.47
Iron (Fe)	8.32±3.76[e]	8.12±0.75[e]	9.61-10.23
Magnesium (Mg)	408.99±6.79[c]	445.14±3.08[b]	406.92-489.72
Phosphorous (P)	2101.55±16.31[a]	2116.69±9.23[a]	2192.96-2381.23
Post-monsoon(October-February)			
Vitamin	0.36±0.03[f]	0.34±0.07[f]	0.39-0.48
Sodium (Na)	416.13±12.04[c]	482.02±16.15[b]	429.34-484.18
Calcium (Ca)	379.19±1.96[d]	368.74±7.21[d]	390.52-401.47
Iron (Fe)	8.94±0.45[e]	9.52±0.75[e]	9.61-10.23
Magnesium (Mg)	423.29±1.36[b]	473.14±3.45[c]	406.92–489.72
Phosphorous (P)	2130.82±19.05[a]	2203.45±7.78[a]	2192.96-2381.23

Value represents mean±SD of triplicates

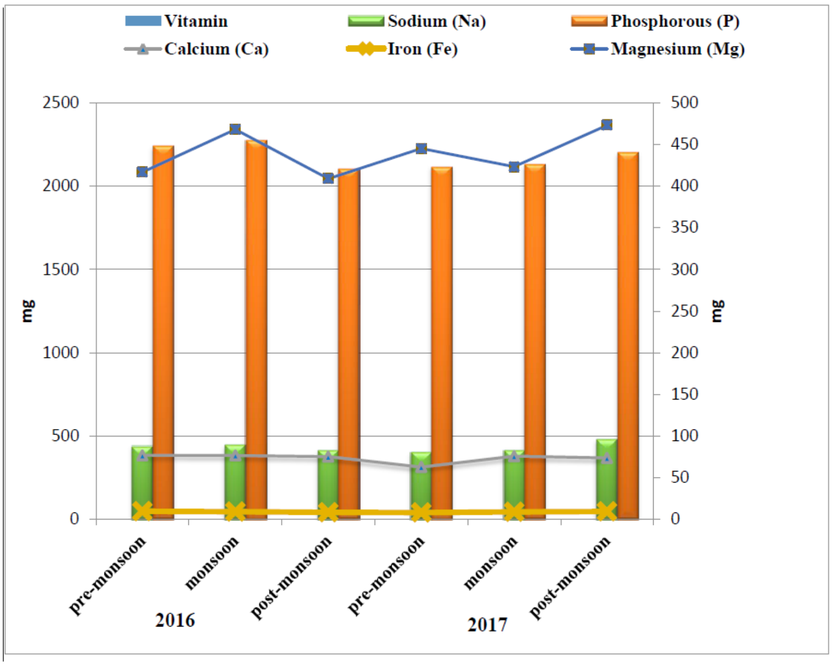

Fig. 2. Mean concentration and range of vitamin-mineral analysis of *Terapon jarbua* during 2016 and 2017

± 8.73 mg in the years 2016 and 2017 respectively. The lowest concentration of 2101.55 ± 16.31 mg was noticed during the monsoon season of 2016. Similarly, the pre-monsoon season of the year 2017 had a lower concentration (2116.69 ± 9.23 mg) of phosphorus.

Iron content in the fish was estimated and found that seasonal variations were negligibly low. The pre-monsoon period exhibited the highest concentration with a value of 9.84 ± 0.25 mg during both years 2016 and 2017. And a concentration percentage of 9.52 ± 0.75 mg was observed in the post-monsoon season.

The magnesium concentration exhibited varying levels according to different seasonal periods in both years and the monsoon season had the lowest content of magnesium in both years. The post-monsoon season had the highest values of magnesium with 423.29 ± 1.36 mg in the year, 2016 and 473.14 ± 3.45 mg in 2017. During the year 2017, the highest concentration of sodium was in the post-monsoon season having a concentration of 482.02 ± 16.15mg. Meanwhile, in 2016 the highest concentration of sodium was observed during pre-monsoon season with 439.41 ± 4.22mg.

4. Discussion

The thorough and elaborate profiling of the nutrients of *Terapon jarbua* focusing on the seasonal variations envisaged the proximate composition and presence of essential elements in the fish body. During the period of study, the highest protein concentration (13.28±1.04% and 12.88±1.44 %) was observed in pre-monsoon season of 2017 and 2016 respectively. The protein concentration varied from 10.11 % to 12.88 % in the year 2016 whereas in 2017 there was an increase from 11.21% to 13.28 %. The study shows that the protein level declined in the monsoon period more than the pre-monsoon and post-monsoon seasons. Such a kind of decrease in protein content was evidenced in similar studies that worked on comprehending seasonal variations in proximate composition and nutrients of fish varieties suitable for human consumption (Langer *et al*., 2008, Sivakami *et al*., 2011). This steady decline in protein concentration in the monsoon season is due to the high energy requirement for spawning. In this period, protein is utilized for ovulation, gonad formation, and gonadocyte development. The findings of the present study on protein concentration of the fish (ranging from 8.73±14.29 to 13.28±1.04) is in accordance with the results of the studies that evaluate the nutrient composition of fish varieties of Lakshadweep (Dhaneesh *et al*., 2012). The total ash and carbohydrate contents in the fish, *Terapon jarbua*, were detected in very low quantities during the monsoon season which is similar to the results of the investigation by Dhaneesh *et al*., (2012). The moisture content of the fish species varied along with the seasonal changes and it ranged between the values of 64.22 ± 0.55 % to 78.22 ± 0.63 %. *Pangasianodon hypophthalmus* and *Puntius javanicus* also exhibited moisture content at the same level ranging from 64.53±0.68 to 74.88±0.66 and 65.75±1.10 to 77.28±0.2 respectively. The total ash content in the fish was noticed to be the least with 1.03 ± 0.12 % in the monsoon season which is in correlation to the percentage of protein content. The highest concentration of ash, 1.99 ± 0.12 % was observed during the post-monsoon season. A higher concentration of ash content in *Terapon jarbua* than other perciforme fishes like *Pristipoma maculatum* and *Terapon quadrilineatus* was reported by Thomas and Manju. (2015). Similar total ash concentration was noticed in other fish species such as *Thunnus albacares (13.69%), Parupeneus bifasciatus (6.12%), Hyporhamphus dussumieri (6.97%) and T. albacares (1.65%)* (Dhaneesh *et al*., 2012). The sufficient amount of ash contents denotes the availability of food required for the development of fish in the environment as well as the presence of good quantities of mineral contents in the fish which again reveals the nutritional potential of the fish (Shabir *et al*., 2018).

Total fat content in *Terapon jarbua* also showed a seasonal fluctuation during the two years of study. Monsoon season showed a low concentration (9.16 ± 1.33 %) of ash and the highest percentage (12.73 ± 0.21 %) of fat was recorded in the pre-monsoon season. Lipid content is greatly influenced by the diet conditions, and size of the fish (Hickling, 1945). Fat content is more aligned with the direct food availability of the fish species from its environment (Shalders *et al*., 2022).

In the present study, the composition of minerals, namely iron, sodium, potassium, calcium, magnesium and phosphorous was estimated to uncover the nutritional significance of *Terapon jarbua*. Since the high incidence of the minerals such as calcium and phosphorous in bony fishes is associated with their increased nutritional value, the present results regarding the seasonal deviation in the percentage of each mineral make an ample contribution to the scientific field (Martínez-Valverde *et al*., 2000). Though iron concentration varies with each fish species, high content (14.43 ± 4.1 mg) of iron was reported from *Amblypharyngodon mola* in a previous study (Wheal *et al*., 2016). In the present study, iron content remained stably high with a concentration of 9.84 ± 0.25 mg in the pre-monsoon season consistently throughout the two years, denoting that *Terapon jarbua* is rich in iron.

Sodium, being a vital component for the proper function of muscles is a major constituent mineral in the fish muscle. A sodium concentration of 482.02 mg was detected in this investigation during the post-monsoon season. The sodium content ranges from 30 to 381 mg/100g within both freshwater and marine fish species indicating the fish as an ample source of sodium (Masamba *et al*., 2015).

The maximum magnesium content in the fish was obtained during the post-monsoon season of the year, 2017 with a concentration of 473.14 ± 3.45 mg. Based on the results of the study, magnesium levels are significantly higher than those of previous studies that indicated low magnesium content, up to 34 - 58 mg/100g (Adeniyi *et al*., 2012).

Fish is generally believed as a good source of calcium and *Terapon jarbua* has been observed to have a maximum range of 482.02 ± 16.15 mg calcium present in it during the post-monsoon season. Fish species such as *Brycinus lateralis* and *Barbus poechii* had increased calcium contents of 959 mg/100 g and 1290 mg/100 g respectively (Masamba *et al*., 2015).

Phosphorus marked high quantities in the fish, *Terapon jarbua* with a maximum value of 2276.69 ± 8.73 mg and 2240.69 ± 19.23 mg in the pre -monsoon season of 2016 and 2017 respectively. Similarly magnesium level was also reported at a high concentration of 1375mg/100g from *Barbus poechii* which is a small-sized fish variety (Masamba *et al*., 2015).

For proper body metabolism, vitamins play a vital role, and fish products provide a good supply of vitamins especially vitamins A and D. The study exhibited maximum vitamin concentration of 0.47 ± 0.01 mg during the pre-monsoon season of 2017. As per the results of a similar previous study, high quantities of vitamins are present in the fish species, *Hyporhamphus dussumieri* (5.29 mg/100 gm) during pre-monsoon months (Dhaneesh *et al*., 2012).

The current investigation suggests that *Terapon jarbua* is a nutritious fish that can supplement diets with adequate amounts of protein, minerals, and vitamins.

5. Conclusion

The present study unveiled the dietary significance of *Terapon jarbua* by summarizing the nutritional status of the fish. The findings evidently indicated that the candidate fish as a rich source of proteins, minerals and vitamins. The outcomes from the investigation emphasized the well-adjusted proportion of the mineral contents such as iron, calcium, magnesium, phosphorus, and sodium as well as the presence of vitamins. This study contributed to a deeper comprehension of the nutritional value of this species, which currently occupies only a small proportion of catch selection. The likely season with the highest nutritional value was determined by the nutritional evaluation performed in three different seasons. Thus the study highlighted the significance of *Terapon jarbua* as a good dietary fish and thereby exemplified the commercial importance of the species.

Acknowledgement

The authors are thankful to the authorities of Mar Ivanios College (Autonomous), Nalanchira for providing all research facilities for the study. The authors thankfully acknowledge the support of SGS laboratory, Chennai for analytical testing.

6. References

Adeniyi, S. A., Orjiekwe, C. L., Ehiagbonare, J. E. and Josiah, S. J., 2012. Nutritional composition of three different fishes (*Clarias gariepinus*, *Malapterurus electricus* and *Tilapia guineensis*). Pakistan Journal of Nutrition, *11*(9), 793.

Ahmed, I., Jan, K., Fatma, S. and Dawood, M. A., 2022. Muscle proximate composition of various food fish species and their nutritional significance: A review. Journal of Animal Physiology and Animal Nutrition, 106(3), 690-719; https://doi.org/10.1111/jpn.13711.

AOAC, H. W. (2000). International A: Official Methods of Analysis of the AOAC International. The Association: Arlington County, VA, USA.

Ashraf, S. A., Adnan, M., Patel, M., Siddiqui, A. J., Sachidanandan, M., Snoussi, M. and Hadi, S., 2020. Fish-based bioactives as potent nutraceuticals: Exploring the therapeutic perspective of sustainable food from the sea. Marine drugs, 18(5), 265; https://doi.org/10.3390/md18050265.

Béné, C., Arthur, R., Norbury, H., Allison, E. H., Beveridge, M., Bush, S. and Williams, M. 2016., Contribution of fisheries and aquaculture to food security and poverty reduction: assessing the current evidence. World development, 79, 177-196; https://doi.org/10.1016/j.worlddev.2015.11.007.

Chatzimichalakis, P. F., Samanidou, V. F. and Papadoyannis, I. N., 2004. Development of a validated liquid chromatography method for the simultaneous determination of eight fat-soluble vitamins in biological fluids after solid-phase extraction. Journal of Chromatography B, 805(2), 289-296; https://doi.org/10.1016/j.jchromb.2004.03.009

Chauhan, R., Awasthi, S., Srivastava, S., Dwivedi, S., Pilon-Smits, E. A., Dhankher, O. P. and Tripathi, R. D., 2019. Understanding selenium metabolism in plants and its role as a beneficial element. Critical Reviews in Environmental Science and Technology, 49(21), 1937-1958; https://doi.org/10.1080/10643389.2019.1598240

Devi, J. R. and Thangam, E. B., 2012. Mechanisms of anticancer activity of sulforaphane from *Brassica oleracea* in HEp-2 human epithelial carcinoma cell line. Asian Pacific Journal of Cancer Prevention, 13(5), 2095-2100; http://dx.doi.org/10.7314/APJCP.2012.13.5.2095

Dhaneesh, K. V., Noushad, K. M. and Ajith Kumar, T. T., 2012. Nutritional evaluation of commercially important fish species of Lakshadweep archipelago, India. PLoS ONE 2012, 7, e45439; https://doi.org/10.1371/journal.pone.0045439.

Dlamini, C.S., 2020. Contribution of Forest Ecosystem Services toward Food Security and Nutrition. In: Leal Filho, W., Azul, A.M., Brandli, L., Özuyar, P.G., Wall, T. (eds) Zero Hunger. Encyclopedia of the UN Sustainable Development Goals. Springer, Cham. https://doi.org/10.1007/978-3-319-95675-6_67

Gladyshev, M., Arts, M., Sushchik, N., 2009. Preliminary estimates of the export of omega-3 highly unsaturated fatty acids (EPA+DHA) from aquatic to terrestrial ecosystems. In: Kainz, M., Brett, M., Arts, M. (eds) Lipids in Aquatic Ecosystems. Springer, New York, NY; https://doi.org/10.1007/978-0-387-89366-2_8.

Guéguen, L. and Pointillart, A., 2000. The bioavailability of dietary calcium. Journal of the American College of Nutrition, 19(sup2), 119S-136S; https://doi.org/10.1080/07315724.2000.10718083.

Hickling, C. F., 1945. The seasonal cycle in the Cornish pilchard, *Sardina pilchardus Walbaum*. Journal of the marine Biological Association of the United Kingdom, 26(2), 115-138; doi: 10.1017/S0025315400011796

Jennings, S., Stentiford, G. D., Leocadio, A. M., Jeffery, K. R., Metcalfe, J. D., Katsiadaki, I. and Verner-Jeffreys, D. W., 2016. Aquatic food security: insights into challenges and solutions from an analysis of interactions between fisheries, aquaculture, food safety, human health, fish and human welfare, economy and environment. Fish and Fisheries, 17(4), 893-938; https://doi.org/10.1111/faf.12152.

Kutty Ayyappan, M. P., Shenoy, A. V.and Gopakumar, K., 1976. Proximate composition of 17 species of Indian fish. http://hdl.handle.net/1834/33714.

Lall, S. P., 2002. The minerals–In: Fish Nutrition, (Eds) JE Halver, and RW Hardy.pp. 259-308.

Langer, S. E. E. M. A., Samyal, A. N. S. H. U. and Bakhtiyar, Y. A. H. Y. A., 2008. Studies on ovarian development of *Macrobrachium dayanum* (Hend.) in relation to Gonadosomatic index and Hepatosomatic index. Biosciences Biotechnology Bioresearch Asia, 5(1), 289-294.

Martínez-Valverde, I., Periago, M. J., Santaella, M. and Ros, G., 2000. The content and nutritional significance of minerals on fish flesh in the presence and absence of bone. Food Chemistry, 71(4), 503-509; https://doi.org/10.1016/S0308-8146 (00)00197-7.

Masamba, W. R., Mosepele, K. and Mogobe, O., 2015. Essential mineral content of common fish species in Chanoga, Okavango Delta, Botswana.*Afr. J. Food Sci*. 9 (9), 480–486; doi:10.5897/ajfs2015.1307

Mohanty, B. P., Ganguly, S., Mahanty, A., Mitra, T., Patra, S., Karunakaran, D. and Ayyappan, S., 2019. Fish in human health and nutrition. Advances in fish research, 7, 189-218.

Mohanty, B. P., Paria, P., Das, D., Ganguly, S., Mitra, P., Verma, A. and Sharma, A. P., 2012. Nutrient profile of giant river-catfish *Sperata seenghala* (Sykes). National Academy Science Letters, 35, 155-161; https://doi.org/10.1007/s40009-012-0014-1.

Shabir, U., Raja, R. and Khan, I. A., 2018. Estimation of proximate composition (moisture and ash content) of some economically important fishes of the valley. International Journal of Advance Research in Science and Engineerig, 7(4), 2046-2053.

Shalders, T. C., Champion, C., Coleman, M. A. and Benkendorff, K., 2022. The nutritional and sensory quality of seafood in a changing climate. Marine Environmental Research, *176*, 105590; https://doi.org/10.1016/j.marenvres.2022.105590.

Sivakami, S., Ayyappan, S., Rahman, M. F. and Govind, B. V., 1986. Biochemical composition of *Cyprinus carpio* (Linnaeus) cultured in cage in relation to maturity. Indian Journal of Fisheries, 33(2), 180-187.

Subasinghe, R., 2017. Regional review on status and trends in aquaculture development in Asia-Pacific-2015. FAO Fisheries and Aquaculture; Circular No. 1135/5. 2007. ISSN: 2070-6065.

Palani kumar, M., Ruba Annathai, A., Jeya Shakila, R. and Shanmugam, S.A., 2014. Proximate and Major Mineral Composition of 23 Medium Sized Marine Fin Fishes Landed in the Thoothukudi Coast of India. Journal of Nutrition and Food Sciences. 4: 259; doi: 10.4172/2155-9600.1000259.

Thomas, A. and Manju, K., 2015. Comparative evaluation of biochemical composition of three perciforme fishes from the south west coast of India. Uttar Pradesh Journal of Zoology, 195-199. Retrieved from https://mbimph.com/index.php/UPJOZ/article/view/599.

Wheal, M. S., DeCourcy-Ireland, E., Bogard, J. R., Thilsted, S. H. and Stangoulis, J. C., 2016. Measurement of haem and total iron in fish, shrimp and prawn using ICP-MS: Implications for dietary iron intake calculations. Food Chemistry, 201, 222-229; https://doi.org/10.1016/j.foodchem.2016.01.080

Williams, G., 1984. The genesis of chronic illness: narrative re-construction. Sociology of health & illness, 6(2), 175-200; https://doi.org/10.1111/1467-9566.ep10778250.