Fishery Technology 59 (2022) : 270 - 279

Nutritional Composition of Breast and Claw Meat from Economically Important Crab Species from Brackish water and Marine ecosystems

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Abstract

The proximate analysis of the meat from edible crabs of marine (*Portunus pelagicus* and *Portunus sanguinolentus*) and brackish water (*Scylla serrata* and *Scylla olivacea*) ecosystems indicated appreciable levels of protein, fat, carbohydrate, fibre and minerals in the fresh meat besides the essential amino acids (Arg, Leu, Trp and Met) and polyunsaturated fatty acids (C22:6, C20:5 and C20:4). High myofibrillar protein (50-57 g/100g) and low stroma protein (2 g/100g of total protein) make it a nutritionally valuable food. Sodium, potassium, calcium and phosphorous were present at significant levels. Low toxic elements (arsenic, cadmium, lead) indicated the absence of food safety concerns.

Keywords: Crabs, proximate composition, minerals, amino acids, Fatty acids

Introduction

The human consumption of seafood has increased over the years owing primarily to its health benefits which increased its trade demand Skonberg & Perkins, 2002; USDA, 2003). In many developing maritime countries, particularly in India, seafood contributes significantly to foreign exchange earnings (MPEDA, 2019). A total annual fish production of 3.56 million tons have been reported in India during 2019 indicating a 2.10 % increase in landings compared to the previous year (CMFRI, 2020). India had exported 12,89,651 million tonnes of seafood worth 6678.69 million USD (Rs 46,662.9 crore Indian rupees) during 2019-20 (MPEDA, 2019).

Received 28 May 2022; Revised 12 October 2022; Accepted 21 October 2022

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These highly diverse brachyuran crabs comprise of about 700 genera and 5000 species worldwide. About 640 species of crabs have been reported in Indian waters, among which 12 species inhabiting the coastal waters and adjoining brackish water environment are considered as commercially important (Devi et al., 2015). On account of their export potential and high nutritive value, crabs occupy an important place in crustacean fisheries and mud crab farming, fattening and soft-shell crab production are now emerging as feasible business opportunities globally.

As rich in vitamins, glycogen, protein, fats and minerals, crab meat is not inferior to any seafood. There are reports available on the biochemical compositions of crab species from different countries (Krzynowek et al., 1982; Naczk et al., 2004; Skonberg and Perkins, 2002; Premarathna, et al., 2015). Since variation in composition occurs based on the species and ecosystems, a fundamental knowledge on the commercially important crab species is required to facilitate processing and utilizing. The aim of this study is to profile and compare the nutritional parameters in fresh and cooked edible meat (the form generally consumed) of selected economically important marine crabs, namely *Portunus pelagicus* (Linnaeus, 1758) (Flower crab), *Portunus sanguinolentus* (Herbst, 1783) (Three-spot swimming crab) and brackish water crab species *Scylla serrata* (Forsskal, 1775) (Giant mud crab) and *Scylla olivacea* (Orange mud crab) (Herbst, 1796) from the Kerala coast of India.

Materials and Methods

Fresh samples of edible adult crabs such as *Scylla serrata, Scylla olivacea, Portunus pelagicus* and *Portunus sanguinolentus* (Fig. 1.) were collected in fresh condition from Thoppumpady and Vypin markets,

Cochin, Kerala, India and transported to the laboratory in ice. The crabs were washed well under running tap water, meat (from claw and body) was separated, minced together with a laboratory blender (KEMI, India) maintaining a temperature between 4-5°C and taken as fresh samples. For cooked samples the crab meat was cooked in steam for 10 minutes, cooled and used for analysis.

The proximate composition – moisture (AOAC 950.46), ash (AOAC 920.15), crude protein (AOAC 981.10), fat (AOAC 960.39) and fibre (AOAC 962.09) - was carried out by the methods of AOAC (2019). Dried meat samples after moisture estimation were powdered, packed in self-sealing bags and stored in a desiccator for pending analysis. Crude protein content was determined by micro kjeldahl method by the conversion factor of 6.25. Total carbohydrates were determined by subtracting the sum of the protein, fat and ash contents from 100 (Onyeike et al., 2000).

The nitrogen in the meat was fractionated as described by Sankar & Ramachandran (2000). The minced meat was homogenized with 10 volumes of $NaHCO_3$ buffer (pH 7.5, Ionic strength 0.05) and centrifuged (5000g for 15 minutes, 4°C) to collect the supernatant as sarcoplasmic protein nitrogen (SPN). The non-protein nitrogen from the sarcoplasmic protein fraction was precipitated by adding trichloroacetic acid to 5 % level. The residue after removal of SPN was homogenized with 10 volumes of buffer (I-0.5, pH 7.5) containing 0.48M NaCl and 0.02M $NaHCO_3$ buffer and centrifuged as above to collect the myofibrillar nitrogen (MFN) fraction. The residue was extracted overnight by stirring with 0.1N NaOH and centrifuged as above to collect alkali-soluble nitrogen fraction and the precipitate as stroma nitrogen fraction. All extractions were carried out at 4°C, twice and the combined extract was processed further. The fractions were estimated by micro-kjeldahl method (AOAC, 981.10).

The protein amino acids in the meat were released by acid digestion following the method of Ishida et al. (1981). The digest was made acid free by repeated evaporation using a vacuum flash evaporator and made up to 10 ml with 0.05M HCl. Approximately 1 ml was filtered using 0.45µm syringe filters and injected into the HPLC system for separation and quantification of amino acids.

High-Performance Liquid Chromatographic system: (Hitachi L-2130 Elite La Chrom) equipped with auto

Fig. 1. Economically important crab species selected for the study

sampler (L-2200), column oven (L-2350); column Shodex, CX Pak (P-4215), two channel peristaltic pump and a fluorescence detector (FL-2485) was used for the analysis. Mobile phase contains Buffer A: Sodium citrate and ethanol (pH-3.2) and Buffer B: Sodium citrate and NaOH (pH-10). The flow rate was constant at 0.4 ml/min, and the column temperature was set at 60p C. The eluted amino acids are derivatized post column with O-phthaldehyde (OPA) and estimated by fluorescence detector (wavelengths - excitation 340 nm and emission 450 nm) and quantified by comparison with those of standards (Sigma Stock No: AA-S-18).

About 300 mg of finely homogenized crab meat in a test tube was digested with 10 ml of 5 % NaOH under nitrogen at 110 for 24 h in an oven. The contents were neutralized to pH 7 using 6 N HCl. Total volume was made to 100 ml, filtered through Whatman No.1 filter paper and estimated spectrophotometrically as described by Sastry & Tammuru (1985).

The lipid in the fresh meat was extracted by the method of Folch et al. (1957). The fatty acid methyl esters (FAME) were prepared according to Metcalfe & Schmitz (1961**)** and quantified using Gas Chromatograph (Perkin Elmer Clarus 580) fitted with an Elite – 225 capillary column (30 m × 0.25 mm id, 0.25 μm film thickness, Perkin Elmer, USA) using nitrogen as carrier gas at a flow rate of 0.6 ml / min. Injector (spitless) and Flame Ionization Detector (FID) were maintained at 265p C and 275p C respectively; the oven temperature was programmed as follows: holding at initial 110°C for 4 min, increasing at a rate of 2.7°C/min to 240°C, and holding 220°C for 5 min. Sample (10 ul) was injected in spitless mode and fatty acids were identified by retention time by comparing with respective standards using Chromcard software; area of each component is obtained from the computer-generated data and concentration calculated using the software by external standard method (Supelco, Cat.No: 18919-1AMP, 37 component FAME mix).

Approximately 1 g of dried meat sample was digested with 8 ml of Trace element grade Nitric acid and 2 ml of H_2O_2 in a microwave digestion equipment (Milestone-Start D, Italy). The digest was made up to 100 ml in a standard flask with deionized water, filtered through a membrane filter (0.45μm). Samples were analyzed using ICP-OES (ICAP 6000 Duo View, Thermofisher, USA). Two sets of standards, namely, ICP-multi-element standard solution VII and VIII (Thermofisher) were used for arsenic calibration with 95 % recovery at mg/kg level. Working standard solutions were prepared from commercial stock standards at 1000 mg/ kg. The concentration of minerals is calculated according to the equation given below,

Mineral (mg/Kg) = Reading of mineral in ICP × 100 (made-up volume) / Weight of the sample (g)

All experiments were performed in triplicate and the results were expressed as the means ± standard deviation (SD). Duncan's multiple range test was used as the means separation procedure. When necessary logarithmic transformation was performed prior to analysis especially for the mineral analysis. The data were then statistically analyzed in a completely randomized experimental design (two-way analysis of variance, two-way ANOVA) with species as fixed factors. $P<0.05$ was regarded as the statistically significant level. The data were analyzed using the Statistical Package for Social Sciences (IBM® SPSS® Statistics for Windows version 20).

Results and Discussion

The brackish water crabs *S. serratae* and *S. olivacea* were of 1000±50g in size and that of marine species *P. pelagicus* and *P. sanguinolentus* were 70±10g. The amount of total meat in the brackish water species were 200 ±20g and that of marine species were 50±5g.

The results of proximate composition of fresh and cooked samples of brackish water and marine species are given in Fig. 2. on wet weight basis. The average moisture content in the samples ranged between 73.00 g/100g and 80.00 g/100g across the species. The moisture in the cooked samples of all species showed a decrease with 3 g/100g and 10 g/ 100g respectively for the marine and brackish water species. The protein and fat contents in the brackish water species were significantly higher than the marine species (12.30 - 14.01 g/100g against 11.00 - 13.68 g/100g and 1.54 - 1.60 g/100g against 0.70 to 1.83 g/100g) ($P<0.05$). The ash content varied between 5-6 g/100g across the species except in the brackish water species *S. serrata,* which showed a much lower ash content (1.60 g/100g).

The results are in line with earlier studies in *Portunus pelagicus* species (Premarathna, 2015**)**. The moisture contents were reported to be compara-

tively higher in green crabs (Srinivasagam, 1979), *Portunus sanguinolentus* (Wilson et al., 2017), green crab (*Carcinus mediterraneus*) (Cherif et al., 2008) and green crab (*Carcinus maenas*) (Naczk et al., 2004). Higher protein contents were reported in *S. serrata* (14.01±0.85), *S. brockii* (29.71%) (Rajagopal et al. 2016), *Carcinus mediterraneus* (Cherif et al., 2008) and the lower in *P. pelagicus* (11.02 ±0.61). The value for lipids compared well with the earlier studies in *S. serrata* (Prasad & Neelakantan 1989). The ash content in this study is comparable to the values reported by Sudhakar et al. (2009) but higher ash contents were reported in *S. tranquebarica* (Manivannan et al., 2010). In the same way higher crude fiber was reported in *S.olivacea* (2.93±0.62 %) and lower in *S. serrata* (1.16±0.09 %). Earlier studies indicated a carbohydrate content of 5% in *S. serrata* (Prasad & Neelakantan 1989) and 7.76 % in *S. tranquebarica* (Thirunavukkarasu, 2005**)**. The nutritional composition of biological samples, is subjected to variations and depends highly on the season, temperature, ecosystems and other geographical conditions. The fat, protein, ash, carbohydrate and fiber contents showed an increase in cooked samples probably due to the loss of water during cooking. A significant difference was identified in proximate components among the species (P<0.05) from different ecosystems. With increased digestibility and acceptability, crab protein is reported to have high biological value due to its growth promoting capacity (Wilson et al., 2017).

The percentage of different nitrogen fractions present in the samples and the proportions of different protein fractions are given in Table 1. In the crab species studied, the myofibrillar nitrogen ranged between 53 - 57 g/100g with significantly higher content in the brackish water species (P<0.05). The sarcoplasmic proteins nitrogen ranged from 30 to 35 g/100g with higher values for marine species. The stroma protein was very low in crab meat with 1-2 g/100g. The alkali soluble nitrogen which indicates the level of denatured protein due to post-mortem handling and ranged from 0.05 to 7.60 g/100g across the species with the highest proportion in the marine species (6.40-7.60 g/100g) followed by the brackish water species (4.70- 5.50 g/100g). The stroma protein contributes to only 2.50 g/100g reflecting its easy digestibility. The nonprotein nitrogen accounts for just 3 g/100g of the total nitrogen. The nitrogen levels significantly increased (P<0.05) in the cooked samples, again due to loss of water from the meat during the process. In fish, myofibrillar proteins constitute 65-75 % of the total muscle proteins which includes the contractile proteins and regulatory proteins and sarcoplasmic proteins, or water-soluble proteins, constitute between 20 and 30 % of total proteins which includes the enzymes involved in metabolic processes (Medina and Pazos 2010). Myofibrillar and sarcoplasmic proteins were reported to be the major protein in shrimp muscles as well (Sriket et al., 2007). Shamsundar and Prakash (1994) reported a higher myofibrillar protein content in the range of 80–82% in *Metapenaeus dobsoni* while Laly et al. (2019) reported a lower level of 76.63 % in the same shrimp from Cochin coast, India. The myofibrillar and sarcoplasmic proteins contents in the crabs studied were lower than the reported values in fish and shrimp.

Amino acids, the building block of proteins, plays a major role in metabolism and nutrition. Quality of a Protein, is basically decided by the composition

Table 1. Percentage of different nitrogen fractions in fresh and cooked samples of all the four species.

	Scylla olivacea		*Scylla serrata*		*Portunus sanguinolentus*		*Portunus pelagicus*	
	Raw (n=3)	Cooked (n=3)	Raw (n=3)	Cooked (n=3)	Raw (n=3)	Cooked (n=3)	Raw (n=3)	Cooked (n=3)
TN	1.99 ± 0.41 ^{b}	2.34 ± 0.29 ^{d}	2.32 ± 0.46 ^{d}	2.85 ± 0.63 ^{e}	2.10 ± 0.27 ^{c}	2.34 ± 0.03 ^{d}	1.85 ± 0.24 ^{a}	2.13 ± 0.19 ^{c}
NPN	0.07 ± 0.02 ^{b}	0.13 ± 0.02 ^{e}	0.08 ± 0.04 ^{cd}	0.13 ± 0.02 ^{de}	0.04 ± 0.03 ^{a}	0.07 ± 0.02^{bc}	0.03 ± 0.01 ^{a}	0.05 ± 0.02 ^{ab}
SPN	0.6 ± 0.01 ^{a}	0.6 ± 0.05 ^{a}	0.7 ± 0.04 ^{a}	0.74 ± 0.03 ^{a}	0.7 ± 0.03 ^{a}	0.75 ± 0.01 ^{a}	0.56 ± 0.04 ^{a}	0.62 ± 0.03 ^{a}
MPN	1.12 ± 0.05 ^{b}	1.19 ± 0.05 ^{d}	1.34 ± 0.02 ^{e}	1.42 ± 0.03 ^{f}	1.13 ± 0.08 ^{b}	1.15 ± 0.01 ^{c}	1.04 ± 0.13 ^{a}	1.06 ± 0.02 ^{a}
ASN	0.11 ± 0.007 ^{a}	0.31 ± 0.008 ^{c}	0.11 ± 0.02 ^{a}	0.51 ± 0.005 ^{d}	0.16 ± 0.10 ^{b}	0.3 ± 0.004 ^{c}	0.12 ± 0.07 ^{a}	0.31 ± 0.01 ^{c}
SN	0.04 ± 0.006 ^{a}	0.04 ± 0.01 ^{a}	0.06 ± 0.03 ^{a}	0.04 ± 0.02 ^{a}	0.05 ± 0.02 ^{a}	0.03 ± 0.01 ^{a}	0.02 ± 0.005 ^{a}	0.02 ± 0.01 ^{a}

Values are presented as means ±SD. n: number of replicates. Values of a same row that do not share a same superscript are significantly different (P<0.05).TN- total nitrogen; NPN-Non-protein nitrogen; SPN-Sarcoplasmic protein nitrogen; MPN-myofibrillar protein nitrogen; ASN- alkali soluble nitrogen; SN-Stroma nitrogen.

and arrangement of amino acids (Farr, 2002). The total amino acid content (TAA) for the species analyzed ranged from 8 to 17 mg/100g meat with highest value for the brackish water species *Scylla serrate* and the lowest for the marine species *Portunus sanguinolentus* (Table 2). The total Essential Amino acids (EAA) content ranged from 5 to 11 mg /100g, accounting about 60% of the amino acid pool and is about 80% in the case of *S. olivacea*. Among EAAs, Arg, Leu and Trp were present in significantly high levels in the species analyzed with higher values for the marine species ($P<0.05$). Besides, *Portunus pelagicus*s howed higher content of Leu as well. The brackish water species were found to have higher level of Arg, Thr, Met and Ile compared to their marine counterparts. The level of Non-Essential Amino acids (NEAA) ranged from 2.6 to 6.4 mg / 100g meat with higher values for the species *Portunus pelagicus* followed by *Scylla olivacea, Scylla serrate* and *Portunus sanguinolentus* in that order. The marine species were good in Gln and the brackish water species were high in Ser, Gln, Ala and Tyr.

The amount of His in the selected species were more or less similar to the values reported in marine crab from the Southeast coast of India (Ramamoorthy et al., 2016) and in Chinese mud crab *Eriocheir sinensis* (Chen et al., 2007). His is involved in many metabolic functions including production of histamines during allergic reactions. Lys was found to regulate the blood sugar level. The level of amino acids in the species compared well with the values in *Charybdis natator* (Soundrapadiyan & Singh 2008). The NEAA are assumed to be synthesized adequately in the body as substrates to meet the needs for protein synthesis. Some of the NEAA (e.g., Gln, Glu, and Arg) play important roles in regulating gene expression, cell signaling, antioxidative responses, and immunity. Additionally, Glu, Gln, and Asp are major metabolic fuels for the small intestine and they, along with Gly, regulate

Table 2. The amino acid composition of all the samples is tabulated below (mg/100g).

	R-Ss (n=3)	C-Ss (n=3)	R-So (n=3)	C-So (n=3)	R-Ps (n=3)	C-Ps (n=3)	R-Pp (n=3)	C-Pp (n=3)
Threonine (EAA)	1.97 ±0.01^{e}	2.19±0.02^{f}	1.67±0.02^{d}	1.95±0.02^{e}	0.27±0.01^{b}	0.34±0.04^{c}	0.20±0.02^{a}	0.34±0.02^{c}
Valine (EAA)	0.46±0.02^{c}	0.48±0.01^{c}	0.58±0.02^{d}	0.64±0.01^{e}	0.32±0.02^{b}	0.75±0.03^{f}	0.23±0.02^{a}	0.26±0.03 ^{a}
Methionine (EAA)	0.95±0.03^{c}	0.99±0.02^{ab}	0.87±0.02^{c}	0.99±0.02^{c}	0.09±0.01^{a}	0.13±0.03^{ab}	0.36±0.02^{ab}	0.46±0.01^{b}
Isoleucine (EAA)	0.57±0.03^{c}	0.85±0.02^{e}	0.68±0.03^{d}	0.9±0.02^{e}	0.19±0.01^{a}	0.24±0.03^{b}	0.15±0.04^{a}	0.16±0.03^{a}
Leucine (EAA)	0.53±0.02^{abc}	1.41±0.05^{e}	0.62±0.03^{bc}	0.9±0.02^{d}	0.5±0.36^{ab}	0.76±0.02 ^{cd}	0.31±0.03 ^{a}	0.50±0.02 ^{ab}
Phenylalanine (EAA)	0.48±0.02^{b}	0.76±0.15 ^{c}	0.68±0.02 ^{c}	0.90±0.02 ^{d}	0.17±0.01 ^{a}	0.18±0.02 ^{a}	0.23±0.02 ^{a}	0.25±0.03 ^{a}
Histidine (EAA)	1.18±0.03^{d}	1.92±0.07 ^{e}	1.03±0.01^{c}	1.93±0.03^{e}	0.32±0.02 ^{b}	0.37±0.03 ^{b}	0.23±0.01 ^{a}	0.35±0.03 ^{b}
Lysine (EAA)	0.74±0.01^{b}	2.47±0.04 ^{d}	0.81±0.02 ^{b}	1.06±0.01 ^{c}	0.38±0.01 ^{a}	0.45±0.02 ^{a}	3.06±0.25 ^{e}	3.30±0.04 ^{f}
Arginine (EAA)	1.53±0.25^{b}	2.42±0.02 ^{e}	1.83±0.01 ^{c}	2.07±0.02 ^{d}	0.99±0.06 ^{a}	1.47±0.06 ^{b}	3.88±0.19 ^{f}	6.06±0.01 ^{g}
Tryptophan (EAA)	2.5±0.3^{b}	3.16±0.01 ^{c}	2.08±0.02 ^{a}	3.81±0.06 ^{d}	2.11±0.03 ^{a}	3.70±0.05 ^{d}	2.48±0.05 ^{d}	3.61±0.01 ^{c}
Aspartate (NEAA)	0.60 ±0.3^{b}	1.91±0.07 ^{d}	1.21±0.02 ^{c}	1.98±0.02 ^{d}	0.37±0.02 ^{a}	0.48±0.01 ^{ab}	0.53±0.01 ^{ab}	0.66±0.02 ^{b}
serine (NEAA)	1.05±0.03^{e}	1.06±0.02 ^{e}	0.21±0.02^{a}	1.03±0.01^{e}	0.31±0.02 ^{b}	0.44±0.02 ^{d}	0.18±0.01 ^{a}	0.36±0.05 ^{c}
Proline (NEAA)	0.32 ±0.02^{bc}	0.38±0.01 ^{c}	0.21±0.02 ^{a}	0.83±0.02 ^{d}	0.22±0.02 ^{a}	0.29±0.07 ^{b}	ND	ND
Glutamine (NEAA)	1.67±0.44^{ab}	4.18±0.02 ^{c}	1.69±0.52 ^{ab}	4.22±0.04 ^{c}	1.47±0.03 ^{a}	1.88± 0.18 ^{b}	1.38±0.02 ^{a}	1.45±0.04 ^{a}
Glycine (NEAA)	0.71±0.21^{c}	1.69±0.57 ^{d}	0.69±0.02 ^{c}	1.75±0.01 ^{c}	0.48±0.02 ^{b}	0.67±0.02 ^{c}	0.32±0.02 ^{a}	0.37±0.03 ^{ab}
Alanine (NEAA)	0.96±0.06^{d}	1.03±0.02 ^{e}	0.84±0.04 ^{c}	0.93±0.01 ^{d}	0.27±0.01 ^{b}	0.28±0.01 ^{b}	0.13±0.02 ^{a}	0.16±0.02 ^{a}
Tyrosine (NEAA)	1.11±0.02^{e}	1.28±0.02 ^{f}	1.03±0.01 ^{d}	1.07±0.01 ^{b}	0.19±0.02 ^{a}	0.20±0.04 ^{a}	0.17±0.02 ^{a}	0.71±0.03 ^{c}
"EAA	10.94±0.09^{c}	16.68±0.27 ^{g}	11.77±0.09 ^{d}	14.27±0.20 ^{e}	5.38±0.34 ^{a}	8.42±0.33 ^{b}	11.16±0.65 ^{c}	15.34±0.21 ^{f}
"NEAA	6.44±0.82^{e}	11.55±0.04 ^{f}	5.05±0.10 ^{d}	5.73±0.08 ^{d}	3.32±0.10 ^{b}	4.26±0.26 ^{c}	2.73±0.09 ^{a}	3.73±0.19
TAA	17.38 ±0.92^{d}	27.64± 0.23^{f}	16.85±0.19^{d}	20.01±0.28^{e}	8.71±0.36^{a}	12.69±0.57^{b}	13.89±0.71^{c}	19.07±0.40^{e}
EAA/TAA	0.62 ± 0.03^{b}	0.57 ±0.005^{a}	0.69 ±0.005^{d}	0.71±0.005^{e}	0.61 ±0.01^{b}	0.66 ±0.007^{c}	0.80 ±0.006^{f}	0.80 ±0.006^{f}

Values are presented as means ±SD. n: number of replicates. ND: value not detected. Values of a same row that do not share a same superscript are significantly different (PÂ0.05).EAA-Essential amino acid, NEAA-Non-Essential amino acid, TAA – Total amino acids.

Table 3. The table shows the fatty acid composition of brackish water and marine crabs (mg/100g)

	R-So (mg/100g)	C-So (mg/100g)	R-Ss (mg/100g)	C-Ss (mg/100g)	R-Ps (mg/100g)	C-Ps (mg/100g)	R-Pp (mg/100g)	C-Pp (mg/100g)
Myristic acid (C14:0)	27.83 ± 0.26^{b}	35.53 ± 0.42^{d}	32.55 ± 0.40^{c}	51.58 ± 0.37^{f}	43.22 ± 0.30^{e}	54.53 ± 0.46^{g}	8.55 ± 0.40^{a}	67.57 ± 0.37^{h}
Pentadecanoic acid (C15:0)	5.41 ± 0.51^{b}	6.55 ± 0.39^{c}	9.49 ± 0.40^{d}	14.53 ± 0.48^{e}	14.24 ± 0.30^{e}	17.60 ± 0.39^{f}	3.60 ± 0.36^{a}	14.62 ± 0.31^{e}
Palmitic acid (C16:0)	206.48 ± 0.49^{b}	272.49 ± 0.49^{c}	543.56 ± 0.30^{g}	879.59 ± 0.44^{h}	301.26 ± 0.31^{d}	528.54 ± 0.45^{f}	63.53 ± 0.41^{a}	328.50 ± 0.34^{e}
Heptadecanoic acid (C17:0)	9.60 ± 0.51^{c}	12.47 ± 0.46^{d}	3.44 ± 0.34^{a}	30.58 ± 0.35^{h}	18.40 ± 0.38^{e}	25.37 ± 0.34^{f}	5.52 ± 0.47^{b}	26.50 ± 0.47^{g}
Stearic acid (C18:0)	69.49 ± 0.42^{b}	92.55 ± 0.45^{c}	199.55 ± 0.41^{g}	400.62 ± 0.44^{h}	112.67 ± 0.29^{d}	161.52 ± 0.46^{f}	27.58 ± 0.42^{a}	147.48 ± 0.32^{e}
Arachidic acid (C20:0)	3.53 ± 0.47^{b}	4.47 ± 0.46^{c}	8.54 ± 0.41^{d}	20.55 ± 0.40^{h}	10.56 ± 0.50^{e}	15.51 ± 0.39^{g}	1.37 ± 0.29^{a}	13.55 ± 0.41^{f}
Behenic acid (C22:0)	2.53 ± 0.44^{c}	_	1.51 ± 0.38^{b}	8.42 ± 0.40^{e}	3.49 ± 0.47^{d}	9.37 ± 0.34^{f}	0.42 ± 0.26^{a}	1.56 ± 0.43^{b}
Tricosanoic acid (C23:0)	9.50 ± 0.49^{c}	11.58 ± 0.36^{d}	2.51 ± 0.40^{a}	23.57 ± 0.34^{f}	15.53 ± 0.40^{e}	29.46 ± 0.38^{g}	2.52 ± 0.44^{a}	4.53 ± 0.39^{b}
Lignoceric acid(C24:0)	2.59 ± 0.42^{b}	_	6.53 ± 0.36^{e}	9.42 ± 0.40^{f}	3.45 ± 0.42^{c}	5.64 ± 0.35^{d}	_	0.54 ± 0.16^{a}
Myristoleic acid (C14:1)	_	_	_	_	6.52 ± 0.47^{d}	3.58 ± 0.40^{c}	0.48 ± 0.35^{a}	1.62 ± 0.30^{b}
Palmitoleic acid (C16:1)	58.52 ± 0.49^{b}	72.47 ± 0.30^{d}	91.58 ± 0.32^{f}	147.59 ± 0.31^{h}	64.57 ± 0.39^{c}	120.55 ± 0.40^{g}	15.47 ± 0.32^{a}	82.63 ± 0.31^{e}
cis-10-Heptadecanoic acid (C17:1)	2.48 ± 0.46 ^{b}	3.55 ± 0.38 ^{c}	4.54 ± 0.35 ^{d}	11.48 ± 0.46 ^{e}	4.48 ± 0.43 ^{d}	16.53 ± 0.39 ^{f}	1.51 ± 0.47 ^{a}	3.56 ± 0.40 ^{c}
Oleic acid (C18:1n9c)	118.02 ± 0.13 ^{d}	150.55 ± 0.37 ^{e}	616.43 ± 0.38 ^{g}	1000.15 ± 0.30 ^{h}	114.47 ± 0.45 ^{c}	163.54 ± 0.47 ^{f}	33.50 ± 0.47 ^{a}	48.54 ± 0.41 ^{b}
cis-11-Eicosenoic acid (C20:1)	9.60 ± 0.46 ^{a}	10.52 ± 0.45 ^{b}	19.48 ± 0.35 ^{f}	22.52 ± 0.45 ^{g}	14.48 ± 0.47 ^{c}	18.58 ± 0.40 ^{e}	14.59 ± 0.34 ^{c}	17.55 ± 0.41 ^{d}
Erucic acid (C22:1)	0.04 ± 0.02 ^{a}	_	0.15 ± 0.05 ^{b}	_	0.05 ± 0.04 ^{a}	0.15 ± 0.04 ^{b}	_	0.05 ± 0.04 ^{a}
Nervonic acid (C24:1)	_	_	3.53 ± 0.45 ^{b}	6.44 ± 0.36 ^{d}	4.51 ± 0.45 ^{c}	8.47 ± 0.36 ^{e}	_	1.40 ± 0.26 ^{a}
Linolelaidic acid (C18:2n6t)	56.52 ± 0.42 ^{d}	68.63 ± 0.40 ^{e}	320.53 ± 0.39 ^{g}	325.56 ± 0.38 ^{h}	38.48 ± 0.41 ^{c}	89.48 ± 0.39 ^{f}	6.56 ± 0.40 ^{a}	33.58 ± 0.31^{b}
Ò-Linolenic acid (C18:3n6)	3.69 ± 0.23 ^{b}	4.54 ± 0.41 ^{c}	1.53 ± 0.35 ^{a}	23.55 ± 0.36 ^{f}	4.52 ± 0.37 ^{c}	10.50 ± 0.49 ^{e}	1.50 ± 0.48 ^{a}	5.53 ± 0.40 ^{d}
cis-11,14-Eicosadienoic acid (C20:2)	8.42 ± 0.40 ^{d}	9.55 ± 0.28 ^{e}	2.53 ± 0.35 ^{b}	15.52 ± 0.46 ^{f}	1.51 ± 0.45 ^{a}	2.48 ± 0.41 ^{b}	1.47 ± 0.47 ^{a}	6.47 ± 0.31 ^{c}
cis-8,11,14-Eicosatrienoic acid (C20:3)	5.51 ± 0.30 ^{c}	7.57 ± 0.39 ^{d}	7.49 ± 0.40 ^{d}	10.47 ± 0.43 ^{f}	2.59 ± 0.48 ^{b}	8.43 ± 0.38 ^{e}	1.57 ± 0.41 ^{a}	1.58 ± 0.29 ^{a}
Arachidonic acid (C20:4)	24.47 ± 0.43 ^{c}	29.44 ± 0.30 ^{d}	66.48 ± 0.36 ^{f}	74.04 ± 0.10 ^{g}	52.49 ± 0.44 ^{e}	100.75 ± 0.20 ^{h}	14.49 ± 0.42 ^{a}	15.52 ± 0.39 ^{b}
cis-5,8,11,14,17 - Eicosapentaenoic acid (C20:5n3)	20.81 ± 0.27 ^{a}	25.03 ± 0.09 ^{b}	60.55 ± 0.37 ^{c}	104.53 ± 0.40 ^{f}	89.45 ±0.47 ^{d}	149.45 ± 0.47 ^{g}	94.60 ± 0.34 ^{e}	198.62 ± 0.42 ^{h}
cis-13,16-Docosadienoic acid (C22:2)	_	_	_	_	7.51 ± 0.45 ^{a}	8.53 ± 0.25 ^{b}	_	_
cis-4,7,10,13,16,19-Docosahexaenoic acid (C22:6n3)	35.84 ± 0.26 ^{a}	42.59 ± 0.57 ^{b}	117.49 ± 0.31 ^{d}	196.57 ± 0.47 ^{f}	146.54 ± 0.42 ^{e}	240.43 ± 0.48 ^{h}	113.63 ± 0.37 ^{c}	228.55 ± 0.42 ^{g}
SFA	337.01 ± 0.90 ^{b}	435.64 ± 2.09 ^{c}	807.68 ± 1.66 ^{f}	1438.87 ± 2.79 ^{h}	522.83 ± 3.36 ^{d}	847.54 ± 3.57 ^{g}	118.64 ± 1.69 ^{a}	604.83 ± 0.15 ^{e}
MUFA	188.68 ± 0.30 ^{c}	237.09 ± 0.78 ^{e}	735.70 ± 0.95 ^{g}	1188.19 ± 1.05 ^{h}	209.07 ± 1.61 ^{d}	331.40 ± 2.07 ^{f}	65.55 ± 0.48 ^{a}	155.35 ± 0.39 ^{b}
PUFA	155.30 ± 0.59 ^{a}	187.35 ± 0.68 ^{b}	576.58 ± 1.69 ^{f}	750.22 ± 2.07 ^{h}	343.08 ± 2.83 ^{d}	610.05 ± 1.31 ^{g}	233.83 ± 1.68 ^{c}	489.84 ± 0.91 ^{e}
TFA	681.01 ± 1.76 ^{b}	860.08 ± 4. 46 ^{c}	2119.96 ± 4.10 ^{g}	3377.28 ± 5.90 ^{h}	1074.99 ± 5.56 ^{d}	1788.98 ± 3.50 ^{f}	418.03 ± 3.61 ^{a}	1250.01 ± 0.95 ^{e}
EPA/DHA	0.58 ± 0.01 ^{c}	0.59 ± 0.01 ^{d}	0.52 ± 0.01 ^{a}	0.53 ± 0.01 ^{b}	0.61 ± 0.01 ^{e}	0.62 ± 0.01 ^{f}	0.83 ± 0.01 ^{g}	0.87 ± 0.01 ^{h}

Values are presented as means ±SD. Number of replicates=3. Values of a same row that do not share a same superscript are significantly different (P<0.05). SFA-Saturated fatty acids, MUFA-Monounsaturated fatty acids, PUFA – Polyunsaturated fatty acids, TFA -Total fatty acids, EPA/DHA-Eicosapentaenoic acid/Docosahexaenoic acid

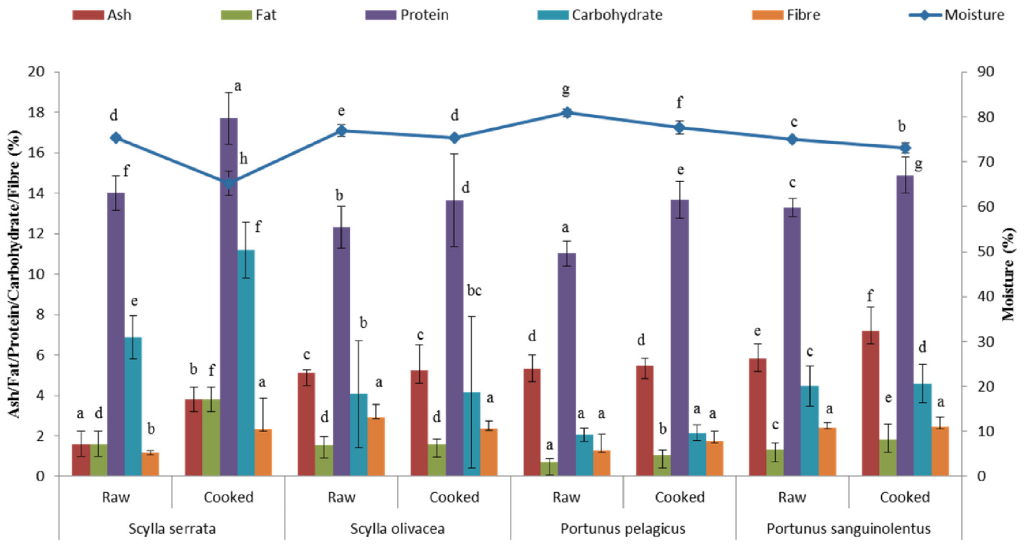

Fig. 2. Comparison of proximate composition of fresh and cooked samples of brackish water sp. (*S. olivacea, S.serrata*) and marine sp. (*P. pelagicus, P.sanguinolentus*) crabs.Data are represented as mean ±SD, Number of replicates=3. Values of same components that do not share a same superscript are significantly different (P<0.05).

neurological function. Among EAA, Leu activates mammalian target of rapamycin to stimulate protein synthesis and inhibit proteolysis and tryptophan modulates neurological and immunological functions through multiple metabolites such as serotonin and melatonin. A significant difference in each of the essential and non-essential amino acids across the crab species from different ecosystems is understandable from Table 2 (P<0.05). The amino acids in general, were found to be increased in cooked samples probably due to the loss of water during the cooking of the meat.

The fatty acid composition of the crab meats analyzed showed 26-51% saturated fatty acids (SFA), 13- 35 % monounsaturated fatty acids (MUFA) and 20 to 57 % polyunsaturated fatty acids (PUFA) with higher proportions for the marine species (Table 3). C16 and C18 predominated in all the species analyzed regardless of the brackish water and marine ecosystems. Oleic acid (C18:1) and palmitoleic acid (C16:1) were the major acids MUFA, with higher proportions for the freshwater species. C24:1, nervonic acid was detected in trace amounts in both the species from marine origin. Eicosapentaenoic acid (EPA) (20-94 mg /100g of lipid) and docosahexaenoic acid (DHA) (35 - 146 mg/100g fat) were the major PUFA found in the crab species across the habitat with higher proportions for the marine species. Linoleic acid (C18:2) was the third major fatty acid present in the crab meat in appreciable levels in the brackish water species compared to marine species studied. Fatty acids in lipids decide the quality of fat present in a food.

The values in the species analyzed are comparable with the reported values in marine crab from the Southeast coast of India Ramamoorthy et al. (2016) and a lower level of stearic acid was reported in the blue crab (*Callinectes sapidus*) in the North Eastern Mediterranean Sea (Çelik et al., 2004). Ayas & Ozogul (2011) reported a higher level of oleic acid than that reported in the present study. Celiket al. (2004) alsoreported a comparable oleic acid and palmitoleic acid in *Callinectes sapidus* in male and female crabs respectively. Studies across the globe recommend crab meat as a rich source of EPA and DHA (Cherif et al., 2008; Naczk et al., 2004). Dunstan et al. (2007) has reported that omega-3-long chain fatty acids including EPA and DHA are dietary fats with an immense health benefit including fetal development.

The mineral content of the marine and brackish water crab species studied are given in Table 4. Among 20 elements analyzed, phosphorous, sodium, potassium and calcium constitute the major elements which makes the crab meat a healthy diet. This along with microelements such as selenium, iron and zinc play a key role in human nutrition.

Table 4. The data shows different macro and micro elements quantified in (mg/Kg) fresh and cooked samples of four species

	R- Pp	C- Pp	R- Ps	C- Ps	R- Ss	C- Ss	R- So	C- So
Na	923.02±0.96 ^{a}	947.05±1.71 ^{a}	1213.12±1.25 ^{d}	1329.28±1.35 ^{e}	1122.84±1.23 ^{b}	1674.76±2.66 ^{f}	1157.35±6.66^{bc}	1171.91±1.23 ^{cd}
K	1186.06±9.57 ^{a}	1387.56±11.19 ^{b}	1681.43±12.45 ^{c}	1859.55±13.48 ^{de}	1879.61±12.29 ^{d}	2120.97±17.39 ^{f}	1687.96±6.66 ^{c}	1924.46±7.11 ^{e}
Ca	283.12±0.96 ^{a}	336.45±1.71 ^{c}	376.14±1.25 ^{d}	412.34±1.35 ^{e}	332.31±4.34 ^{c}	473.74±1.23 ^{f}	291.45±1.76 ^{b}	316.37±1.23 ^{c}
P	1942.29±1.45 ^{a}	2763.03±0.96 ^{b}	2703.17±1.30 ^{b}	3496.68±1.78 ^{d}	3766.11±1.40 ^{e}	5274.28±1.64 ^{f}	2937.05±1.70 ^{c}	3504.45±1.69 ^{d}
Mn	1.15±0.03 ^{ab}	1.67±0.02 ^{a}	1.67±0.04 ^{a}	2.88±0.03 ^{c}	2.15±0.01 ^{b}	3.49±0.02 ^{d}	2.67±0.04 ^{c}	3.37±0.04 ^{d}
Li	0.19±0.01 ^{a}	0.24±0.01 ^{a}	0.33±0.03 ^{b}	0.67±0.03 ^{c}	0.23±0.03 ^{a}	0.30±0.01 ^{b}	0.22±0.07 ^{a}	0.26±0.07 ^{ab}
V	0.22±0.01 ^{cd}	0.26±0.01^{bc}	0.30±0.02^{bcd}	0.38±0.01 ^{de}	0.18±0.02 ^{a}	0.42±0.04 ^{e}	0.14±0.01 ^{a}	0.21±0.02 ^{ab}
Cr	0.38±0.02^{bc}	0.57±0.01 ^{cd}	0.76±0.03 ^{cd}	0.78 ±0.02 ^{e}	0.42±0.03 ^{ab}	0.64±0.01 ^{d}	0.39±0.01 ^{a}	0.53±0.03 ^{cd}
Fe	38.63±0.69 ^{a}	49.46±0.14 ^{b}	93.36±0.09 ^{e}	98.57±0.28 ^{e}	70.51±0.23 ^{c}	80.97±0.21 ^{d}	57.91±0.06 ^{b}	87.46±0.59 ^{d}
Ni	0.34±0.01 ^{a}	0.43±0.03 ^{b}	0.64±0.03 ^{c}	0.84±0.01 ^{d}	0.44±0.01 ^{b}	0.97±0.02 ^{e}	0.38±0.02 ^{a}	0.58±0.02 ^{c}
Co	0.15±0.01 ^{cd}	0.17±0.02 ^{d}	0.06±0.01 ^{a}	0.08±0.01 ^{ab}	0.10±0.01^{bc}	0.12±0.01 ^{cd}	0.07±0.02 ^{a}	0.08±0.01 ^{ab}
Cu	17.53±0.46 ^{c}	21.88±0.36 ^{d}	11.53±0.49 ^{a}	26.74±0.29 ^{ab}	12.63±0.45 ^{a}	14.73±0.31 ^{b}	14.80±0.20 ^{b}	16.55±0.42 ^{c}
Zn	14.6±0.13 ^{a}	24.86±0.16 ^{d}	15.75±0.18 ^{a}	20.81±0.07^{bc}	24.69±0.36 ^{cd}	32.28±0.35 ^{e}	21.72±0.19 ^{b}	26.58±0.37 ^{d}
As	0.83±0.08 ^{b}	0.90±0.21 ^{c}	0.40±0.03 ^{d}	0.92±0.19 ^{e}	0.73±0.07 ^{a}	0.77±0.09 ^{a}	0.81±0.06 ^{a}	0.82±0.05 ^{a}
Se	0.56±0.08 ^{a}	0.83±0.19 ^{c}	0.51±0.19 ^{ab}	1.72±0.18 ^{d}	0.65±0.29 ^{ab}	0.81±0.21 ^{c}	0.56±0.13 ^{a}	0.69±0.22 ^{b}
Mo	0.07±0.12 ^{a}	0.10±0.02 ^{b}	0.07±0.02 ^{a}	0.08±0.01 ^{a}	0.05±0.01 ^{a}	0.07±0.01 ^{a}	0.05±0.01 ^{a}	0.06±0.03 ^{a}
Cd	0.46±0.16 ^{c}	0.74±0.13 ^{d}	0.57±0.11 ^{a}	0.68±0.09 ^{c}	0.46±0.14 ^{c}	0.58±0.09 ^{c}	0.61±0.05 ^{b}	0.80±0.07 ^{b}
Sn	0.04±0.01 ^{a}	0.05±0.01 ^{ab}	0.05±0.01 ^{ab}	0.06±0.02 ^{ab}	0.06±0.03 ^{ab}	0.07±0.03 ^{ab}	0.04±0.01 ^{a}	0.06±0.02 ^{b}
Hg	0.44±0.08 ^{a}	0.77±0.16 ^{c}	0.48±0.13 ^{a}	0.63±0.08 ^{b}	0.88±0.06 ^{c}	1.02±0.07 ^{d}	0.50±0.05 ^{ab}	0.62±0.17 ^{c}
Pb	0.29±0.01 ^{a}	0.40±0.03 ^{b}	0.30±0.02 ^{a}	0.31±0.01 ^{a}	0.29±0.01 ^{a}	0.31±0.02 ^{a}	0.29±0.02 ^{a}	0.32±0.04 ^{a}

Values are presented as means ±SD. Number of replicates (n)=3. Values of a same row that do not share a same superscript are significantly different (P<0.05).R-Raw; C-Cooked, Pp-*Portunuspelagicus*; Ps- *Portunussanguinolentus*; Ss- *Scylla serrate*; So-*Scylla olivacea.*

Ojewola and Udom (2005**)** reported higher levels of calcium 473.74±1.23 in cooked samples of *S. serrata*. The calcium content of the crab is in line with the dietary recommendations of 250 mg/100g (FNB, 2002). However, the sodium level in the species analyzed were lower than the reported value in *Ucidescordatus* (1410.37 mg /100g) (Wheaton & Lawson 1985). Among the micro elements iron was present in appreciable amount in marine species and generally semi-terrestrial animals have higher iron content than its aquatic counter parts (Elegbede & Fashina-Bombata 2013). Zinc is good for the prostate health in man and is found to be in appreciable level among the brackish water and marine species. The toxic chemicals like arsenic, mercury, lead, cadmium etc. were seen in ppb levels probably from the environment indicating the contamination levels and are of significance from food safety point of view. From food safety point of view, none of crab meats exceeded the maximum recommended level of 0.3 mg/kg, 2 mg/kg for Pb and Cd respectively (Codex, 2019). For average consumption (200 g), the intake of heavy metal could be in the range of 0.12 – 0.2 mg/Kg which is much below the safety level recommended (0.5 ppm for Pb, Cd and Hg, 0.76 ppm for As and 12 ppm for Cr). The mineral contents of different crab meats are also influenced by a number of factors like biological and seasonal variations, source of food and its rearing environment. The difference in the proportion of food intake also affects the mineral content, which may depend on the physiological needs of invertebrates, endogenous factors and solubility of minerals in food and water. In cooked meat, of course the mineral content showed a marginal increase probably due to moisture loss. Statistical analysis was carried out by the Duncan's test at 95% confidence and statistical significance was accepted at $p < 0.05$.

Conclusion

The study indicated the nutritional significance of crab meat. The average protein content ranged from

11.02 g/100g -14.01 g/100g, with lowest in the marine crab *Portunus pelagicus* (11.02 g/100g) and highest in brackish water species (12-14 g/100g) but comparatively lower than shrimp and fish. The crab meat can be classified as a low-fat commodity with good proportion of n-3 fatty acids including C18:2, C18:3, C20:5, C22:6. C16:1 and C18:1. The crab meat showed a good proportion of EAA with EAA/TAA (total amino acid) above 0.6 mg/100. The carbohydrate content in crabs is comparatively higher among the brackish water species and ranged between 2.07-6.88 g/100g across the four species studied. The comparative analysis between the crabs from different ecosystems, reveals that the brackish water species are more nutritious probably related to the nutritional status of the habitat and no specific quality difference was noticed between the raw and cooked samples. With appreciable levels of protein, unsaturated fatty acids, good amino acid profile and mineral contents, crab can be a good source of nutrition for human.

Acknowledgements

The authors are deeply thankful to Dr. Srinivas Gopal, Professor Chair, CEFPT, KUFOS for providing the lab facilities. The permission and support given by the Director, ICAR-CIFT and Dr. Suseela Mathew, HOD, B&N division, ICAR-CIFT are gratefully acknowledged. The support given by Dr. Geethalakshmi and Dr. Pavan Kumar Dhara for statistical analysis is also acknowledged. The first author is also thankful to the doctoral fellowship provided by Kerala University of fisheries and ocean studies, Panangad, Kochi, India.

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