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Exposing Proximate Components of Some Selected Fishes Available in Coast of the Bay of Bengal

Skeikh Mustafizur Rahman[1]*, Mst. Shirin Sharmin Khan[1], Yousef Ahmed Alkhamis[2,3], Roshmon Thomas Mathew[2], Md. Moshiur Rahman[1], Mohammed Monirul Islam[4], Md. Asadujjaman[5] and Md. Golam Sarower[1]

[1]*Fisheries and Marine Resource Technology Discipline, Khulna University, Khulna-9208, Bangladesh*
[2]*Fish Resources Research Center, King Faisal University, Hofuf-420, Al-Ahsa, Kingdom of Saudi Arabia*
[3]*Agriculture and Food Sciences College, King Faisal University, Hofuf-420, Al-Ahsa, Kingdom of Saudi Arabia*
[4]*College of Clinical Pharmacy, King Faisal University, Hofuf-420, Al-Ahsa-31982, Kingdom of Saudi Arabia*
[5]*Fisheries and Ocean Sciences, Khulna Agricultural University, Khulna-9100, Bangladesh*

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Authors' Contribution
SMR, MMR designed the experiment. SSK conducted the experiment and collected the data. MMR, RTM, YAA and MMI performed the data analysis. MMR, MA, MMI, MGS, RTM, YAA and SMR prepared the draft manuscript, and also provided extensive support and feedback on further data analysis and finalized the manuscript. All authors commented manuscript drafts.

Key words
Marine fish, Biochemical composition, Processed fish, Fish price

ABSTRACT

Fish is a valued source of heath-benefiting protein and other indispensable nutrients. This study aimed to investigate the proximate components (e.g. protein, lipid, moisture and ash) of eleven non-commercial marine fish species namely *Johnius argentatus*, *Harpodon nehereus*, *Cynoglossus lingua*, *Johnius elongatus*, *Sillaginopsis panijus*, *Pomadasys hasta*, *Setipinna phasa*, *Megalaspis cordyla*, *Rita rita*, *Gonialosa manmina* and *Scatophagus argus* obtained from the Bay of Bengal. The samples were collected from raw fish (as a whole), different body parts (head, middle and tail) and processed fish (boiled and dried). This study further compared the nutrition values in relation to the price of individual species. Protein content (13.27–33.56%) between species and methods of cooking varied considerably. The highest amounts of protein (19.18 to 33.55%) were found in the fried fish, while the raw and boiled fish contained almost similar amount (protein, 14.00 to 19.57%). Fat content differed between species ranged from 0.38 to 4% in raw fish, 0.78 to 3.43% in boiled fish, and 15.72 to 33.78% in fried fish. The ash content also differed among raw (1.05 to 3.76%), boiled (0.51 to 3.00%) and fried (1.72 to 9.06%) fishes. Lowest moisture content was observed in fried fish (28.6 to 53.30%), while raw and boiled fishes showed higher moisture content (71.00 to 84.85%). Between body parts, lipid and ash values were marginally high in middle and tail muscle respectively, while protein and moisture values were comparable. The regression analysis revealed that fish price increased with the increase of their protein contents. The study has provided the nutritional information of these selected fishes which are mostly consumed by the general coastal inhabitants in Bangladesh.

INTRODUCTION

From the ancient time, fish has been regarded as a source of high-grade protein, lipids, vitamins as well as essential micronutrients for the human beings. Fish, mainly obtained from marine environment, contain several functional components that are not available in land-based animals and therefore, fish is widely recognized as nature's super food. Marine fish including crustacean, molluscan shellfish, and echinoderms inevitably offer numerous dietetic elements helpful for human diet such as n-3 long chain polyunsaturated fatty acids (n-3 LC-PUFAs), eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), and other essential components like selenium and iodine, high levels of potassium and low levels of sodium, and vitamins A, B (12), D, and E, and taurine (2-aminoethanesulfonic acid) (Oehlenschläger, 2012). Regular consumption of marine fish reduces the threat

* Corresponding author: mustafizfmrt@yahoo.com
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of heart attack and preserves body fitness, regulates prostaglandin synthesis, decreases threat of type 2 diabetes mellitus, Dementia, and Alzheimer's diseases, prevents the cardiovascular and human coronary artery diseases, and reduces the risk of cancer including colon, breast and prostate, lessens rheumatoid arthritis, multiple scelerosis, asthma, psoriasis, inflammatory bowel disease (Sidhu, 2003; Oehlenschläger, 2012; Schmedes *et al*., 2018). Besides, the consumption of lean-fish once or more per week is related to reduced postprandial triacylglycerol and improved high-density lipoprotein cholesterol levels, and in men a slimmed waist circumference as well as controlled blood pressure (Schmedes *et al*., 2018).

The Bay of Bengal is a treasure of fish and fisheries resources. Based on an earlier survey report, there is a total of 475 fish species recognized in the Bay of Bengal, while according to the more recent FAO fisheries index, 629 fish species have been identified so far. In spite of having so much enriched fisheries biodiversity, customers demand for marine fish in Bangladesh, especially fish inhabiting the upper layers of the open sea, including the major portion of which is supplied by small-scale conventional fishermen, is quite occasional. It has long been a tradition of Bangladeshi people to consume freshwater fish although they overlook consuming marine fish because of a number of factors including its peculiar flavor, rough texture, unidentified traits for human health. As the cost of marine fish is quite less compared to freshwater fish, the consumption of marine fish on the part of the undernourished poor people could be encouraging.

Nutritional quality of fish may be influenced by how it is processed and cooked. Studies related to the effects of various processing and preparation methods on nutritive values of various fish species have already been performed (Puwastien *et al*., 1999; Gokoglu *et al*., 2004; Gladyshev *et al*., 2007; Türkkan *et al*., 2008; Bordin *et al*., 2013; Farid *et al*., 2014; Abraha *et al*., 2018). Anatomical position of fish flesh sampled plays a significant role as nutrients are not consistently dispensed throughout the entire body parts of fish. As can be seen, lipid content fluctuates between 2% and nearly 30% on the basis of the part of the body sampled (Porter *et al*., 1992). It has been also noticed that red or blood fish meat contains more lipid and less protein than white meat (Geiger and Borgstrom, 1962). The bulk amount of minerals is deposited in the skeleton tissues of the fish body (Karunarathna and Attygalle, 2012).

The information about proximate composition of fish in Bangladesh is only available for the most commercially important species (Barua *et al*., 2012; Bogard *et al*., 2015), scarce or little of low economic value marine fish species. It is an invaluable instrument for perceiving the nutrient composition of essential foods in order to understand the bonds between food cultivation, access and nutrient consumption, and to formulate strategies and programmes, for example, development of improved production technologies (Thilsted and Wahab, 2014), so as to establish the fulfillment of nutrient requirements of common people. Thus, the proximate composition (protein, lipid, moisture and ash) of fish from raw condition (as a whole), from different body parts (head, middle and tail) and also from fish processed differently (boiled and dried), was determined for eleven small non-commercial marine fish species namely *Johnius argentatus*, *Harpodon nehereus*, *Cynoglossus lingua*, *Johnius elongatus*, *Sillaginopsis panijus*, *Pomadasys hasta*, *Setipinna phasa*, *Megalaspis cordyla*, *Rita rita*, *Gonialosa manmina* and *Scatophagus argus* obtained from the Bay of Bengal. This study further compared the nutrition values in relation to the price of individual species. These databases will help build perceptions among the customers, promote the financial value of food ingredients, and afford standardized calculation procedures, all of which are necessary for global studies on nutrition and disease to determine nutrient ingestion around the world.

MATERIALS AND METHODS

Sample collection

In this study, eleven marine fishes were collected from the local markets (Rupsa and Gollamari) in Khulna city, Bangladesh. These fishes were obtained from the southern coast of the Bay of Bengal and landed in Khulna city for local consumers. Immediately after collection, samples were kept in boxes contained crushed ice and returned to the Fish Nutrition Laboratory, Khulna University, Bangladesh. At the laboratory, the collected fishes were washed several times with tap water and processed using common household handling practices (eviscerating, beheading, and washing) and then stored in refrigerator at -18°C until the laboratory analysis. The price of fish species was considered as wholesale values and data was taken from three consecutive days. The sizes of the experimental fishes were ranged between 250 and 500gm.

Sample preparation

The proximate components were analyzed using the fish meat obtained from different body parts and differently cooked fish (e.g. boiled and fried). In case of body parts, fish meat was taken from head portion (hereafter termed as head muscle), middle portion (hereafter termed as dorsal muscle) and tail portion (hereafter termed as tail muscle). For boiling, the whole fish was dipped in boiling water for about 10 min, while the whole fish was fried using the soybean oil for about 10 min for fried fish samples. The whole fish, without boiling or frying, was considered as raw or control samples. Bones and skins of raw, boiled and fried fish were removed and homogenized with a household blender for the determination of proximate components.

Determination of proximate components

Proximate components of collected fishes under various conditions were determined according to the standard protocols described in Association of Official Analytical Chemists (AOAC, 2000). The moisture content was determined by oven drying at 105ºC until a constant weight was achieved. The protein values were determined by calculating the total Nitrogen by Kjeldahl method and the protein content was determined by multiplying total nitrogen by 6.25 factors (AOAC, 2000). Lipid content was measured through AOAC (2000) using the Soxhlet system. Total ash content was obtained by using the muffle furnace at 550ºC. Sample, when turned into white in color, was taken out and the ash content was measured. Each experiment was conducted with the replication of three. All values were represented as mean ± SE.

Statistical analysis

All analyses were performed using 'R' version 3.6.1. The descriptive statistics (means, SD, SEs, etc.) were calculated using the 'psych' package. First, the multivariate analysis canonical variates analysis (CVA) was performed considering the proximate components of raw fish together by using the 'MASS' package to find out whether the species were significantly different. Then the generalized linear model (GLM) with 'quasi-poisson' family option and 'log' link function was applied using 'pscl' package for the 'percentage data' (proximate components) which did not comply with the assumptions of any parametric model. The 'quasi-poisson' regression is not only flexible with data assumptions but also allows for over-dispersion in the dependent variable. In the model, each proximate component was included as a response variable, while body part or cooking method was fitted as a fixed factor. The post-hoc test was performed using the 'emmeans' package to check out where the variation lied. The linear regression analysis was done using the 'car' package to check the association between price and proximate components. Finally, all graphs were made using 'ggplot2' package.

RESULTS AND DISCUSSION

The CVA analysis showed that most of the species were significantly different when all proximate components of raw fish were taken together (Fig. 1A and B). Then the subsequent individual GLM model revealed these differences among species based on proximate components (%) in raw fish (Table I, Fig. 2) and cooked fish (Table I).

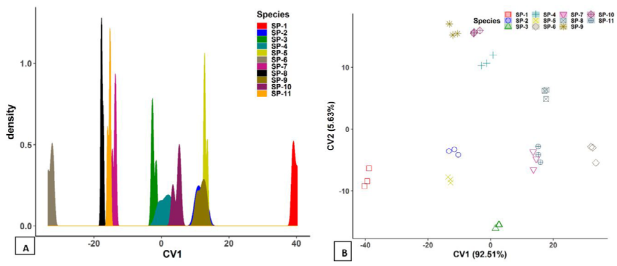

Fig. 1. The Canonical Variates Analysis (CVA) of proximate components of raw fish of 11 different species collected from the coastal regions of Bangladesh. A. density plot showing their distribution based on all proximate components and B. the biplots of the canonical variates scores based on these proximate components. For names of species of fish, see Table I.

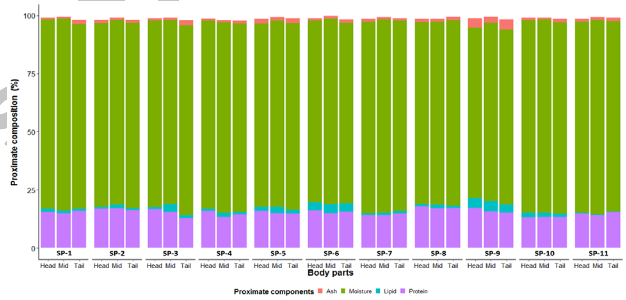

Fig. 2. Proximate components (%) of raw fish of 11 species collected from the coastal regions of Bangladesh. The figure also shows the variation in proximate composition among different body parts within a species. For names of species of fish, see Table I.

The nutritive quality of fish, regarded as a food source, which is acquired from its biochemical substance, greatly differs from species to species, feeding habits, size, sex, environment and season (Canli and Atli, 2003; Celik, 2008; Mohamed, 2013). Variations in biochemical composition in fish muscles may also appear within the same species subject to the location and season of fishing, maturity and gender of the individual and breeding performance (Mohamed, 2013). It reveals that dietary composition cannot be universalized for a specific group of organisms and therefore, requires comprehensive study in order to investigate the prospect of individual species for the sake of fitness and nutrimental protection. This study observed the nutritional quality of eleven non-commercial coastal and marine species that were obtained from the southern coast of the Bay of Bengal.

Table I. Proximate components of raw, boiled and fried fish of different species collected from the coastal regions of Bangladesh. All values represent as mean±SE of three replicates. Differences in small letters indicate significant variation between species at P < 0.05 level of significance. Here, Species-1, *Johnius argentatus*; Species-2, *Sillaginopsis panijus*; Species-3, *Johnius elongates*; Species-4, *Pomadasys hasta*; Species-5, *Setipinna phasa*; Species-6, *Megalaspis cordyla*; Species-7, *Rita rita*; Species-8, *Gonialosa manmina*; Species-9, *Scatophagus argus*; Species-10, *Harpodon nehereus*; Species-11, *Cynoglossus lingua.*

Components	Species-1	Species-2	Species-3	Species-4	Species-5	Species-6	Species-7	Species-8	Species-9	Species-10	Species-11
Raw fish											
Protein (%)	15.40±0.22^{bcd}	16.73±0.26^{ab}	14.90±0.64^{cd}	14.56±0.37^{defg}	15.20±0.22^{cde}	15.57±0.21^{bcd}	14.33±0.15^{defg}	17.40±0.19^{a}	16.04±0.32^{abcd}	13.27±0.25^{g}	14.73±0.42^{cdef}
Lipid (%)	1.18±0.08^{efg}	1.08±0.13^{fg}	1.92±0.40^{cd}	1.27±0.13^{defg}	2.08±0.16^{c}	3.71±0.08^{ab}	1.06±0.03^{fg}	1.21±0.10^{ef}	4.00±0.18^{a}	1.76±0.12^{cde}	0.38±0.04^{h}
Moisture (%)	81.14±0.52^{ab}	79.41±0.34^{bc}	80.35±0.45^{bc}	81.26±0.51^{ab}	79.72±0.41^{bc}	78.47±0.42^{cd}	82.46±0.43^{a}	78.85±0.28^{c}	75.08±0.56^{e}	82.77±0.20^{a}	82.59 ±0.37^{a}
Ash (%)	1.19±0.18^{cd}	1.21±0.12^{cd}	1.43±0.25^{cd}	1.09±0.07^{de}	1.82±0.11^{bc}	1.19±0.08^{cd}	1.00±0.04^{de}	1.37±0.08^{bcd}	3.73±0.30^{a}	1.06±0.11^{de}	1.19±0.07^{cd}
Boiled fish											
Protein (%)	15.57±0.41^{fg}	19.41±0.41^{bcd}	19.62±0.32^{bc}	16.80±0.30^{ef}	17.95±0.14^{de}	21.52±0.42^{a}	16.16±0.25^{ef}	17.34±0.26^{e}	16.73±0.29^{ef}	13.95±0.19^{h}	18.85±0.43^{cd}
Lipid (%)	0.95±0.09^{ef}	1.33±0.09^{dx}	0.78±0.04^{fg}	2.58±0.04^{bc}	1.11±0.06^{ex}	2.38±0.06^{c}	1.50±0.03^{d}	2.43±0.06^{b}	3.43±0.15^{a}	2.67±0.13^{bc}	0.80±0.01^{f}
Moisture (%)	82.78±0.91^{a}	76.12±0.51^{cdef}	77.31±1.15^{cde}	77.98±0.26^{bcd}	78.77±0.34^{bc}	74.47±1.22^{ef}	80.73±0.52^{ab}	78.08±0.72^{bcd}	74.91±0.53^{def}	80.85±0.69^{ab}	78.21±0.58^{bc}
Ash (%)	0.61±0.09^{fg}	1.83±0.05^{c}	0.52±0.09^{g}	2.12±0.10^{bc}	1.37±0.03^{d}	0.93±0.05^{e}	0.97±0.03^{e}	0.89±0.07^{e}	2.99±0.01^{a}	1.03±0.08^{de}	0.88±0.03^{ef}
Fried fish											
Protein (%)	30.50±0.51^{bc}	27.81±0.45^{d}	31.40±0.34^{ab}	26.42±0.32^{de}	28.74±0.49^{cd}	31.34±0.71^{ab}	33.56±1.09^{a}	24.65±0.46^{ef}	23.11±0.71^{fg}	21.19±0.30^{g}	23.19±0.16^{fg}
Lipid (%)	33.78±0.85^{a}	23.24±0.46^{b}	24.84±0.31^{b}	17.30±0.55^{cd}	24.35±0.20^{b}	16.37±0.40^{d}	18.68±0.25^{c}	16.39±0.13^{d}	15.72±0.26^{de}	18.68±0.28^{c}	16.68±0.21^{d}
Moisture (%)	31.71±0.80^{h}	44.59±0.74^{de}	38.71±0.59^{fg}	52.45±0.97^{c}	40.82±0.21^{fg}	47.68±0.88^{d}	42.09±1.13^{ef}	54.63±0.71^{bc}	55.52±0.33^{bc}	56.72±1.38^{ab}	57.62±0.41^{ab}
Ash (%)	2.79±0.03^{de}	2.90±0.04^{cde}	3.87±0.13^{ab}	2.48±0.04^{e}	4.47±0.47^{a}	2.75±0.03^{ed}	3.87±0.13^{ab}	3.35±0.16^{bcd}	3.91±0.15^{ab}	2.60±0.15^{e}	1.72±0.15^{f}

Table II. Variation in proximate components among different body parts within the same species. Differences in small letters indicate significant variation between species at P < 0.05 level of significance.

Species	Protein (%)			Lipid (%)			Moisture (%)			Ash (%)		
	Head	**Middle**	**Tail**	**Head**	**Middle**	**Tail**	**Head**	**Middle**	**Tail**	**Head**	**Middle**	**Tail**
Species-1	15.35±0.37^{a}	15.02±0.16^{a}	15.84±0.48^{a}	1.46±0.05^{a}	1.09±0.03^{b}	0.98±0.04^{b}	81.46±0.56^{a}	82.48±0.46^{a}	79.49±0.68^{b}	0.85±0.05^{b}	0.83±0.06^{b}	1.89±0.08^{a}
Species-2	16.9±0.70^{a}	17.07±0.12^{a}	16.24±0.37^{a}	0.76±0.05^{b}	1.55±0.20^{a}	0.97±0.21^{b}	78.93±0.97^{a}	79.56±0.34^{a}	79.73±0.33^{a}	1.52±0.25^{a}	0.93±0.01^{b}	1.18±0.11^{ab}
Species-3	16.55±0.33^{a}	15.29±0.78^{a}	12.86±0.83^{b}	1.05±0.26^{b}	3.48±0.06^{a}	1.27±0.15^{b}	80.10±0.65^{ab}	79.31±0.77^{a}	81.63±0.18^{b}	1.09±0.07^{b}	0.94±0.02^{b}	2.27±0.44^{a}
Species-4	15.89±0.23^{a}	13.44±0.12^{c}	14.36±0.21^{b}	0.95±0.09^{b}	1.77±0.04^{a}	1.07±0.05^{b}	80.86±0.37^{a}	81.80±0.92^{a}	81.13±1.35^{a}	1.01±0.04^{a}	1.02±0.11^{a}	1.24±0.15^{a}
Species-5	15.82±0.36^{a}	14.97±0.35^{ab}	14.82±0.08^{b}	1.85±0.07^{b}	2.68±0.08^{a}	1.71±0.02^{b}	78.90±0.52^{a}	80.13±0.66^{a}	80.13±0.87^{a}	1.86±0.03^{b}	1.44±0.05^{c}	2.17±0.09^{a}
Species-6	16.16±0.22^{a}	15.04±0.18^{b}	15.51±0.36^{ab}	3.53±0.05^{a}	3.88±0.11^{a}	3.72±0.16^{a}	78.01±0.34^{b}	79.83±0.41^{a}	77.58±0.65^{b}	1.13±0.06^{ab}	1.0±0.05^{a}	1.42±0.15^{b}
Species-7	14.08±0.19^{b}	14.07±0.15^{b}	14.83±0.16^{a}	0.99±0.05^{a}	1.15±0.05^{a}	1.03±0.04^{a}	82.41±0.41^{a}	83.16±0.10^{a}	81.82±0.58^{a}	0.96±0.04^{b}	0.91±0.05^{b}	1.13±0.05^{a}
Species-8	17.96±0.14^{a}	16.99±0.19^{b}	17.24±0.33^{ab}	0.96±0.04^{b}	1.58±0.05^{a}	1.1±0.07^{b}	78.22±0.26^{a}	78.80±0.59^{a}	79.52±0.34^{a}	1.42±0.05^{a}	1.12±0.06^{b}	1.57±0.10^{a}
Species-9	17.19±0.19^{a}	15.75±0.22^{b}	15.18±0.25^{b}	4.13±0.20^{a}	4.43±0.20^{a}	3.45±0.21^{b}	73.26±0.35^{b}	76.67±0.66 ^{a}	75.30±0.56^{a}	4.20±0.17^{a}	2.6±0.09^{b}	4.37±0.26^{a}
Species-10	13.12±0.16^{a}	13.41±0.72^{a}	13.3±0.42^{a}	2.11±0.03^{a}	1.75±0.06^{ab}	1.45±0.26^{b}	82.78±0.19^{a}	83.13±0.49^{a}	82.39±0.27^{a}	1.13±0.09^{a}	0.67±0.03^{b}	1.37±0.15^{a}
Species-11	14.76±1.11^{a}	14.14±0.43^{a}	15.29±0.55^{a}	0.34±0.02^{a}	0.34±0.02^{a}	0.45±0.10^{a}	82.31±0.18^{ab}	83.66±0.67^{a}	81.79±0.51^{b}	1.09±0.09^{b}	1.06±0.08^{b}	1.43±0.05^{a}

For names of species see Table I.

Protein acquired from fish has ever been taken into account as a great value for nutrient. Sea food contains more amount of protein than domestic meats. Besides, marine fish is greatly digestible and filled with some types of peptides and essential amino acids, while domestic meat protein lacks such components like methionine and lysine as specified by Tacon and Metian (2013). Proteins are highly essential for the growth of hormone and enzyme (Wilson, 1986) as well as a vital source of energy (Halver and Hardy, 2002). The protein content of raw muscle of eleven fish species is presented in Table I. Protein values in raw fish ranged from 13.27% to 17.40% consistent with the findings of other marine fish species published elsewhere (Puwastien *et al*., 1999; Nurnadia *et al*., 2011; Barua *et al*., 2012; Kumar *et al*., 2014; Fernandes *et al*., 2014; Bogard *et al*., 2015). The highest and lowest values were obtained in *G. manmina* and *H. nehereus*, respectively. According to FAO (www.fao.org/fishery/topic/1239/en) studies, fish contained protein from 11.9 to 20.6% is considered the high protein fish category and therefore, the fish species available in the Bay of Bengal are healthy.

Despite the fact that fish is occasionally eaten uncooked in some provisions, for example, sushi and ceviche, it generally goes through a preparation procedure before consumption. This process of preparing fish results in affecting the nutrient composition (Farid *et al*., 2014). Differences in fish species and ways of cooking are likely to be an influential aspect for the chemical formation of the product consumed (García-Arias *et al*., 2003). In fish processing methods, heat is important to enhance taste and flavor as well as prolong shelf life of their products (Abraha *et al*., 2018). The present study clearly observed a significant variation of protein in fried fish, however, such variations were not observed in boiled fish (Table I). The protein content in boiled fish ranged from 13.95 to 21.52% which is similar to that of raw fish. Protein content in fried fish increased about double (21.19-33.56%) in compared to raw and boiled fish (Table I). High protein content in fried fish was also recorded in grouper, red snapper, Florida pompano and Spanish mackerel, sardine, several Thai marine and freshwater teleosts, rainbow trout, sea bass (Puwastien *et al*., 1999; Gokoglu *et al*., 2004; Türkkan *et al*., 2008; Abraha *et al*., 2018). Water reduction through frying process led to more protein content in fried fish compared to raw fish.

As nutrients are not consistently stored throughout the entire body parts of the fish, anatomical position of the sampled meat appears to be a significant issue (Karunarathna and Attygalle, 2012). In the present study, there were hardly any remarkable variations found in the protein content among the different body parts (Table II, Fig. 2). Nevertheless, protein content was marginally higher in head muscle (13.11-17.95%) followed by middle (13.40-17.07%) and tail (12.86-17.23%) muscles in some species (Table II). This study corresponds to the findings of Karunarathna and Attygalle (2012) who reported that the protein contents in tuna species were insignificant among red muscle (20-25%), white muscle (20-23%) and head muscle (20-25%). In another study, Sidwell (1981) showed that the belly flap contains considerably lower protein content (16-17%) compared to the other parts of the body.

The lipid content of raw fish varied widely between fish species, the highest was observed in *S. argus* (4%) and the lowest in *C. lingua* (0.38%) (Table I, Fig. 2). Research done by Ackman (1995) revealed that fish species can be typically classified into four different groups based on the amount of lipid available in the mussel: lean lipid (< 2% lipid), low lipid fish (2-4% lipid), medium lipid fish (4-8% lipid), and high lipid fish (> 8% lipid). In this study, out of eleven species, three fish species (*S. phasa, M. cordyla* and *S. argus*) belong to the low lipid fish category, while the remaining eight fish species (*J. argentatus*, *H. nehereus*, *C. lingua*, *J. elongatus*, *P. hasta*, *S. panijas*, *R. rita*, and *G. manmina*) belong to the very low lipid (lean) fish category (Table I). In a comprehensive study, Kumar *et al*. (2014) reported the proximate values of 23 medium sized marine fish species in the Thoothukudi Coast of India. They revealed that out of 23 fish species, 22 had a medium to lean lipid content (6.83-0.24%). On the other hand, high lipid was observed by Nurnadia *et al*. (2011), Bogard *et al*. (2015), Kumar *et al*. (2014), Gopakumar (1997) in *Hilsa macrura* (23.15%), *Tenualosa ilisha* (18.3%), *Leiognathus dussumieri* (14.725), *Sardinella longiceps* (11.70%), respectively. Differences in lipid content among species may further be affected by some aspects such as feed composition, geological position, age distinction, breeding period, and fishing season (Canli and Atli, 2003; Celik, 2008; Mohamed, 2013). Moisture content is marked as a sign of the comparative amounts of lipid and protein of the fish (Dempson *et al*., 2004): Low moisture in fish contributes high protein and lipid (see also below). Following this, two species, *S. argus* and *M. cordyla* of this study, also had high lipid and low moisture (Table I). Likewise, an inverse relationship between moisture and lipid content was detected by Nurnadia *et al*. (2011).

It has been reported that the concentration of lipid and its composition in fish have been greatly altered during the frying process (Bordin *et al*., 2013). Fried fish contained a greater amount of lipid (15.72 to 33.78%) than uncooked (raw) (0.38 to 4.0%) and boiled (0.78 to 3.43%) conditions (Table I), which could be the consequence of water leaching and lipid absorption by fish during frying (Unlusayin *et al*., 2001). Regarding cooking conditions, lipid values presented in this study are close to those found by Türkkan *et al*. (2008) for seabass (raw: 4.18%, fried: 6.91%), Gokoglu *et al*. (2004) for rainbow trout (raw: 3.44%, fried: 12.7% and boiled: 4.32%), Puwastien *et al*. (1999) for Black pomfret (raw: 3.6%, fried: 18.2%), Malabar red snapper (raw: 0.5%, fried: 10.9% and boiled: 0.7%); Silver pomfret (raw: 6.8%, fried: 12.7% and boiled: 22.7%). On the other hand, Puwastien *et al*. (1999) mentioned that cooking oil penetrated in fish after water lost partly due to evaporation during frying.

Lipid content is reported to fluctuate between 2% and nearly 30% based on the parts of the sampled body (Porter *et al*., 1992). Red or blood flesh is observed to include higher amount of lipid and lower amount of protein compared with white flesh (Geiger and Borgstrom, 1962). The lipid contents in head and tail muscle were found insignificant, while varied barely in middle muscle for the most studied fishes (Table II, Fig. 2). The total lipid contents in the head muscle, middle muscle and tail muscle ranged from 0.34-4.11%, 0.34-4.44%, and 0.45-3.7%, respectively (Table II), which is in accordance with the findings of Karunarathna and Attygalle (2012) for tuna species. Wide variations in lipid content between body parts were evident for several species. It is reported that salmon's belly flap includes significant proportion of lipid (30-50%) (Ackman, 1995). The Indian oil sardine is found to store up lipid at 27% or over in the skin and merely 6% in the muscles (Nair *et al*., 1978). In case of capelin, the maximum quantity of lipid (35%) was discovered in the belly flap followed by the skin (25%) (Karunarathna and Attygalle, 2012).

It has been reported that moisture content in fish accounts for 70-80% of the total weight (Ackman, 1995). During the present study, the standard moisture contents in raw fish fluctuated between 75 to 82% (Table I), almost identical figures for marine fish were noticed by a number of studies (Puwastien *et al*., 1999; Karunarathna and Attygalle, 2012; Nurnadia *et al*., 2011; Barua *et al*., 2012; Kumar *et al*., 2014; Bogard *et al*., 2015). The maximum moisture content was detected in *H. nehereus* (82.77%) and minimum was detected in *S. argus* (75.4%). The proportion of water available in the composition acts as an excellent marker for the relative energy, protein and lipid content; the lesser the proportion of water, the higher the lipids and protein content, and energy mass of the fish (Aberoumad and Pourshafi, 2010). This study also proved that lower water content in fish contributed to comparatively higher amount of lipid and protein in most fish.

Moisture contents of boiled fish (74.5 to 82.78%) were resembled as raw fish (75.41 to 82.77%) but reduced greatly, depending on species, from 30 to 50% for fried fish (31.71 to 57.62%) (Table I). These results are in agreement with those of (Puwastien *et al*., 1999; Gokoglu *et al*., 2004; Türkkan *et al*., 2008). Lowering the moisture content in fried fish is due to the contribution of heat that evaporates moisture in cell during cooking. Moisture contents between body parts were not as marked as cooking. The moisture contents of head, middle, and tail muscle were ranged from 73.26 to 82.78%, 76 to 83.66%, and 75.30 to 82.39%, respectively (Table II, Fig. 2). Working with several tuna species by Karunarathna and Attygalle (2012) reported varying moisture content in body parts (for example, fish skin recorded between 58 to 60%, while other edible parts between 69 to 74%).

The ash value in fish is the indicator of mineral content: high ash content represents high mineral composition, which is good for human health (Emmanuel *et al*., 2011). In case of the majority of fishes, the standard ash content in the consumable muscle protein has remained within 0.5-1.8% (Sidwell, 1981). Ash levels of raw fish, 1.06-3.73%, were within the other studied marine fish species published elsewhere (Puwastien *et al*., 1999; Gokoglu *et al*., 2004; Nurnadia *et al*., 2011; Kumar *et al*., 2014; Bogard *et al*., 2015). Among the studied fish species, *S. argus* (3.73%) contained higher amount of ash than the remaining species ranged from 1.06 to 1.82% (Table I). The amount of mineral deposits and trace elements, comprising the whole ash content, has been reported to differ in fishes subject to such factors like feeding behaviour, atmosphere, ecosystem, and migration still in the same place (Canli and Atli, 2003).

No marked differences in ash values were observed between raw and boiled fish, while frying caused significant increment (Table II). These results are in a good agreement with those observed by Puwastien *et al*. (1999) for several fish species (tilapia, black pomfret, grouper, silver pomfret, mackerel), Türkkan *et al*. (2008) for seabass, Gokoglu *et al*. (2004) for rainbow trout. Frying stimulates water evaporation in fish, which in turn improves ash values in most fishes (Gladyshev *et al*., 2007). Decreased values were also reported by Gladyshev *et al*. (2009) who indicated a potential drop in ash content due to reduction connected with leaching of these elements that disappeared in the water and dispensed during steaming the muscle. The overall ash content in tail muscle was higher (4.34-1.24%) followed by head muscle (4.2-0.85%) and middle muscle (1.44-0.67%) (Table II). Variations in ash content in different body parts were also observed by Karunarathna and Attygalle (2012) and Sidwell (1981).

Fish choices as well as consumption by consumers are directly influenced by a variety of sensory and non-sensory factors. Sensory factors include nutrition, taste, smell, texture etc., while non-sensory includes behavior, beliefs, personal characteristics, risk perception, nutrition, education etc (Honkanen *et al*., 2005). Fish consumption is also influenced by price, convenience, accessibility, availability and healthy concerns (Birch *et al*., 2012). Despite the sustained economic development and improved food production, stunting of children resulting from chronic micronutrient deficiency and undernourished mother remain a major challenge for Bangladesh. Even though the inland production in Bangladesh increased about more than double from 2000 to 2015 (http://bit.ly/2ig7bW0), it is not sufficient to mitigate the nutrient deficiency for the highly populated country like Bangladesh. In Bangladesh, freshwater fish have been highly desirable by the local consumers since long due to taste, custom, and availability, but these fishes are often costly and thus not affordable by low-advanced communities. On the other hand, huge small artisanal marine fish, which are very much neglected still now, could be an alternative nutrient supply for the disadvantaged communities. The regression model revealed that overall fish price increased with the increase of their protein contents ($F_{1,31}$= 24.11, R^2=0.42, *P*<0.001 and Fig. 3) suggesting that people prefer to pay more for the high protein contained fish.

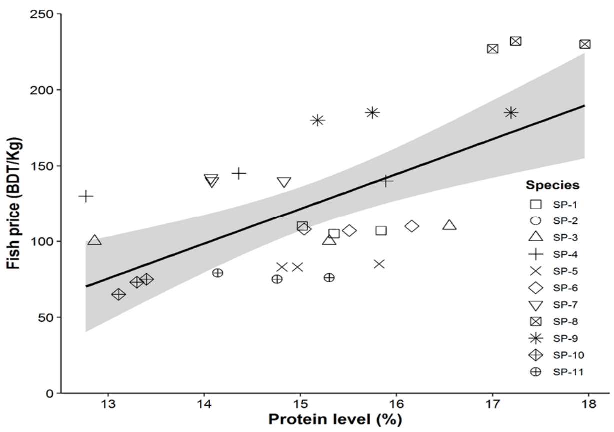

Fig. 3. Regression analysis between fish price and protein level. Each dot represents the value of individual fish, while the solid line indicates the linear fit of data. Fish price was calculated as Bangladesh Taka (BDT). 1 USD = 85 BDT. For names of species of fish, see Table I.

Proteins, organic compounds, are polymers of several free amino acids (FAAs) such as glutamate, glycine, alanine, arginine. These free amino acids, some dipedtides and nucleotides such as inosine 5'- monophosphate (IMP), adenosine 5'-monophosphate (AMP), and guanosine 5'-monophosphate (GMP) are called taste-active components in fish and each amino acid contributes, to differing degrees, to the taste of fish foods (Fuke and Konosu, 1991; Sarower *et al*., 2012). The findings of the present study showed that high priced fish contributed high protein than those of low priced fish (Fig. 3). Glycine and alanine have a pleasant sweet taste, and they are widely presented in large quantity in sea foods (Fuke and Konosu, 1991). Taste-active components in fish vary with various processing methods, species, season, habitat and relative contents of taste-active components (reviewed by Sarower *et al*., 2012). Unfortunately, no studies have been carried out till now regarding this issue and therefore, studies are required to explore why and how test producing FAAs components and other nutrients can influence the prices in relation to their proximate components of some commercially important fish species. However, the study found no significant association between fish price and their lipid contents ($F_{1,31}$= 0.12, R^2=0.004, *P*=0.73). Since very limited numbers of studies were conducted to conclude these findings, further research should be taken to find out the relationships between proximate components and consumers' preferences for taste and price of fish.

CONCLUSION

This study showed that chosen species presented a standard nutritional quality and their quality varied with species, cooking conditions and body parts. Considering the nutritional value, fried fish could be the preferred choice between cooking methods. Highest protein, lipid, moisture, and ash in fried fish were observed at 33.56, 33.78, 57.62, and 4.47%, respectively. In most cases, head muscle, middle muscle, and tail muscle were marginally high in protein, lipid and ash, respectively. Both low and high priced fish contributed almost equally in term of nutritional quality. The conclusions coming out of this study could be beneficial to facilitate the consumers to choose marine fish in terms of their dietary value as well as renew food intake directory. Nevertheless, advance studies related to fatty acid and amino acid compounds of such fish should be conducted in order to produce detailed statistics on nutritional aspects of the fish species mentioned.

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IRB approval

Not applicable for the present work

Ethical statement

No live animals were involved in the present work and the specimens for the research purpose were collected/purchased from the local market.

Statement of conflict of interest

The authors have declared no conflict of interest.

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