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Seasonal variations in nutritional profile of the freshwater mud eel, *Monopterus cuchia* (Hamilton, 1822)

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Abstract
Seasonal variations of proximate compositions, amino acids, and fatty acids contents of *Monopterus cuchia* were studied for the first time in Bangladesh. The fat and fatty acid, protein and amino acid contents showed a significant seasonal dependency. Lipid contents showed the wider variation than the protein contents. Among the 14 recorded amino acids, the primary amino acids were lysine, glutamic acid, arginine, glycine and aspartic acid. The ratio of essential and non-essential amino acids was higher in the post-monsoon season (0.69) than pre-monsoon (0.68) and monsoon season (0.68) and did not show seasonal discrepancies. The amount of fatty acids were found in order of saturated fatty acids (SFA) > mono unsaturated fatty acids (MUFA) > polyunsaturated fatty acids (PUFA). The predominant fatty acids were palmitic and stearic acids of SFAs, oleic and palmitoleic acid of MUFAs and linoleic and α linolenic acids of PUFAs group. The combined value of EPA+DHA varied from 1.44 – 5.34% depending on the season, with the highest in monsoon season. However, the n-6/n-3 ratios were notably lower (0.58 – 2.51) throughout the season than the greatest esteem of 4. Therefore, *M. cuchia* may be consumed as healthy as safe food with reference to n-6/n-3 ratio, irrespective of catching seasons.

Keywords: Proximate composition; amino acid; fatty acid; EFA; NEFA; n-6/n-3 ratio; *Monopterus cuchia*; mud eel

1 | INTRODUCTION

Principal components especially protein, fat and moisture contents in fish muscle are necessary to the consumers, researchers and food processors from various aspects including nutritional value, seasonal differences, and issues concerning food processing. Traditionally, fish has been recognised as the cheapest source of high-quality animal protein in the human diet around the world (Jabeen and Chaudhry 2011). Amino acids in protein and fatty acids in fish oil are the best indicators that reflect the quality of fish flesh, as the flesh is the major edible part of a fish (Periago *et al.* 2005). Amino acids are the building blocks of proteins which act as a precursor for synthesizing nucleotides, neurotransmitters, and peptide hormones (Mohanty *et al.* 2014). They also serve as intermediaries in various metabolic pathways that are necessary for growth and physiological functioning of the human body (Takahashi *et al.* 2011). Moreover, amino acids like glycine, glutamic acid and aspartic acid have proven their importance in the human diet to speed up the wound healing process and must be supplemented externally in the diet as food or by any other means as they cannot be synthesised by the human body (Chyun and Griminger 1984). Fish is also known to be an excellent source of polyunsaturated fatty acids (PUFAs) of n (or omega) series and the clinical benefits of PUFAs to prevent and treatment of numerous diseases are well documented (Ristić-Medić *et al.* 2013). Two essential fatty acid (EFA) of PUFA group that cannot be produced in the human body and must be obtained from diet are linoleic acid (18:2n-6; LA) and α-linolenic acid (18:3n-3; ALA) (Rubio-Rodríguez *et al.* 2010). LA has shown to have a positive effect on atherosclerosis, cardiovascular heart disease (CHD) and type 2 diabetes (Harris *et al.* 2009). Moreover, it can be converted to arachidonic acid (20:4n-6; AA), an important source of prostaglandins which are regulatory compounds, spark healing process as well as stimulate and formation of a blood clot in the human body. On the other hand, consumption of ALA has additionally been recommended to lessen the risk of heart diseases (Mozaffarian 2005). Human body is also capable to convert ALA into eicosapentaenoic acid (20:5n-3; EPA), docosapentaenoic acid (22:5n-3; DPA) and docosahexaenoic acid (22:6n-3; DHA). These n-3 (omega 3) fatty acids are also treated as EFAs in parallel to LA and ALA since the conversion of ALA into EPA, DPA, and DHA is low (Rubio-Rodríguez *et al.* 2010). Therefore, both of n-3 and n-6 fatty acid is mostly derived from food and essential for human health. More specifically, the EPA and DHA and their health benefits are well studied across the world. Documented benefits are the prevention of cardiovascular diseases, arthritis, cancers, autoimmune diseases like multiple sclerosis, Crohn's disease, lupus erythematosus and psoriasis, development and maintenance of normal brain functioning, reducing thrombosis and lowering serum triacylglycerol levels (Simopoulos 2002). Moreover, considering the numerous health benefits of fish, the American Heart Association suggests consumption of any fish at least twice a week for the general population (Kris-Etherton *et al.* 2002). Even though the nutritional properties of fish and fish products make them valuable foodstuffs that are positively attributed to health, the food values of fish are not constant throughout the year due to environmental changes and found to differ between species, age, sex, habitat, reproduction stage, and geographical locations (Çelik *et al.* 2005, Li *et al.* 2011).

Bangladesh, a South Asian country, is taken into account as the most suitable region for fisheries aquaculture and one of the world's leading inland fisheries producer across the world. Fish consumption is common in Bangladesh, and it contributes about 60% to the animal protein intake annually which is almost four times higher than the global population's intake of animal protein (DoF 2017). Bangladesh is blessed with huge inland open water resources that are inhabited by the variety of fish species. Freshwater swamp eel, *Monopterus cuchia*, locally known as 'Kuchia' or 'Kuicha' belongs to the family Synbrachidae of the order Synbranchiformes (Rosen and Greemwood 1976), is one of the most important fish species of Bangladesh regarding its high export demand (Islam 2017). This fish is also occurs in the freshwater of Pakistan, Myanmar, Nepal and throughout India. While they prefer freshwater, they can also tolerate the saline water. In Bangladesh, *M. cuchia* inhabit in the wetland ecosystem particularly in mud-holes, swamps, paddy field, floodplains, canals etc. (Rahman 1989). Kuchia is often distributed throughout the country, however, abundantly harvested in the Chattogram, Mymensingh, Kishorgonj, Tangail, Netrokona, Shylet, Sunamgonj, Naogaon, Bogura, Pabna, Khulna, Dinajpur and Barishal districts of Bangladesh (Imteazzaman and Galib 2013; Chaki *et al.* 2014; Chakraborty 2018). The annual landing of *M. cuchia* depends on capture fishery since there is no culture system yet to operate for freshwater mud eel in Bangladesh. Bangladesh government has started few projects to introduce the culture techniques for *M. cuchia* considering its high demand in the international market (Chakraborty 2018). Bangladesh exports live Kuchia to more than 15 countries with high demand in China, Thailand, Japan, Malaysia, South Korea, Taiwan, Hong Kong and Singapore (Hasan *et al.* 2012). In 2016–2017, Bangladesh earns 25.37 million USD (1 USD = ~80 BDT) by exporting almost 1.3 million metric tons of *M. cuchia*, contributing around 5% and 20% to total export value and export quantity of fish and fishery products respectively (DoF 2017). There are few reports focused on the reproductive and population biology (Nasar 1989, Narejo *et al.* 2003a; Sultana 2008; Jahan *et al.* 2014), reproductive physiology (Alam *et al.* 2012), harvesting techniques and co-management aspects (Chakraborty *et al.* 2010, Barman *et al.* 2013), molecular identification and sexual differentiation (Miah *et al.* 2013a), genetic variability (Miah *et al.* 2013b), respiratory adaptation and mechanisms (Singh *et al.* 1989), haematology (Salehin *et al.* 2013), growth performances (Narejo *et al.* 2003b), marketing and export potentiality (Hasan *et al.* 2012; Islam 2017) of *M. cuchia* are available in literature. Moreover, there is only one study (Islam 2017) determining the proximate composition of *M. cuchia* in Bangladesh. Even though it is proven that nutritional quality of fish flesh differs among seasons due to environmental changes (Bandarra *et al.* 1997, Ali *et al.* 2013, Som and Radhakrishnan 2013, Chrisolite *et al.* 2016, Maqbool *et al.* 2017, Kosker *et al.* 2018), but to the best of authors' knowledge, no study has ever investigated to determine the proximate composition, fatty acids and amino acid profile of *M. cuchia* depending on harvesting seasons in Bangladesh and elsewhere. In view of the above facts, the present study aimed to determine the proximate, fatty acid and amino acid composition of freshwater mud eel in relation to the seasonal changes. Since the information related to the nutritional values of fish is particularly important to ensure that they meet prerequisites of man's diet, therefore, it is expected that this study will provide the fundamental information concerning the nutritional values of *M. cuchia* to its consumers and the nutritionist working on diet table.

2 | METHODOLOGY

2.1 Sample collection and measurements

The local fishermen at Bagha union (Figure 1) of Golabganj Upazilla (sub-district) in Sylhet district of Bangladesh are usually engaged in catching and trading of wild *M. cuchia*. In this study, fish specimens were purchased directly from the collector in three seasons: pre-monsoon (March – May), monsoon (June – August) and post-monsoon (September – November) in 2017.

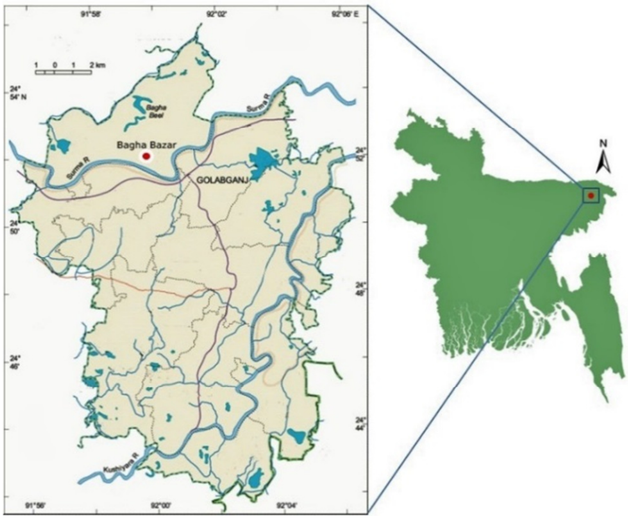

FIGURE 1 Map showing the sampling location

Monopterus cuchia were identified morphologically according to the taxonomic keys (after Rahman 1989). Fish specimens (n = 10) from each season were selected based on the size normally caught and sold by the local Kuchia collector. Immediately after collection, fish specimens were kept alive and transported to the laboratory, where the biometric measurements (wet weight and length) of each of these fish were carried out. The mean total length and weight (mean ± SD, range) of the sampled fish were 57.7 ± 6.7 cm (51 – 64.4) and 216.1 ± 65.0 g (151.1 – 281.1 g) in pre-monsoon, 64.9 ± 7.9 cm (57.0 – 72.8 cm) and 296.6 ± 4.7 g (291.9 – 301.3 g) in monsoon and 61.2 ± 6.0 cm (55.2 – 67.2 cm) and 291.1 ± 81.9 g (209.3 –373.0 g) in post-monsoon season respectively.

2.2 Sample preparation

After length-weight measurements, fish were beheaded, gutted and filleted. Afterward, the fish muscles were kept in sterilized plastic bags and stored in the deep freezer at –18˚C for 6 days before further analysis. Proximate compositions were performed in triplicate. For amino acids and fatty acids analyses, edible parts of fish muscles from all fish samples were homogenized to make a pooled sample, and final analysis was done in triplicate from the homogenized pooled sample.

2.3 Determination of proximate composition

All prepared samples were subjected to ash and moisture analysis following standard methods (AOAC 2000). Total nitrogen (N) contents of fish muscle samples were determined by using of Micro-Kjeldhal technique. The crude protein contents were calculated by multiplying the nitrogen value by 6.25. Total crude fat from fish muscle tissues was determined with the help of soxhlet apparatus using the non-polar organic solvent petroleum ether (Boiling point = 40 – 60˚C, Fisher Limited UK).

2.4 Amino acids determination

Amino acid determinations were carried out in the Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka, Bangladesh. The analysis of amino acids in the fish sample was done by high performance lipid chromatography (HPLC) in an amino acid analyser (SKYAM s4300, Germany). In details, 0.2 g of prepared fish muscle was hydrolysed with 25 ml of 7N HCl at 120˚C for 22 – 24 hours under a nitrogen atmosphere. HCl was neutralized with 7.5N NaOH, and the solution was prepared up to 250 ml volume with sample dilution buffer (pH 3.4), and the solution was filtered by 0.45 mm membrane filter prior to analysis. Subsequently, 100 ul of sample was taken in a vial and added 900 ul sample dilution buffer (pH 3.4) to make to the volume of 1 ml. Standard amino acids were analysed simultaneously and each of the amino acid in the unknown sample was identified based on the retention time and peak area of the standard amino acids. Tryptophan was not estimated in this study as it is destroyed upon acid hydrolysis.

2.5 Fatty acids determination

A hydrolytic method was employed for the extraction of fat and fatty acids. Fat was extracted into ether and then methylated to fatty acid methyl esters (FAMEs). Gas chromatography (GC) was used to measure FAMEs quantitatively. The fatty acids profile was completed following gas chromatographic method (after Chowdhury *et al.*

2003). Fatty acids were obtained from lipids by saponification using NaOH dissolved in methanol H_2O mixture (hydrolysis with alkali).

2.6 Statistical analysis

The Statistical Package for the Social Sciences (SPSS, version 20.0) software package (SPSS, SAS Institute Inc. Gary, USA) and Microsoft Office Excel 2010 were used for statistical analysis. The data were analysed to determine the descriptive statistics such as mean, standard error of mean and standard deviation. For multiple comparisons in proximate compositions, fatty acids and amino acids profile among the samples studied in different seasons; all data were subjected to Tukey HSD test with one way ANOVA (Analysis of Variance) at 5% level of significance.

3 | RESULTS

3.1 Proximate composition

Chemical compositions of *M. cuchia*, depending on the seasons, are shown in Figure 2. It was found that mean moisture contents were 78.9 ± 0.1%, 79.6 ± 0.1% and 79.9 ± 0.1% in pre-monsoon, monsoon and post-monsoon season respectively (Figure 2). Moisture content in fish fillet in pre-monsoon season varied significantly from monsoon and post-monsoon samples, but no such significant variation was obtained between monsoon and post-monsoon season.

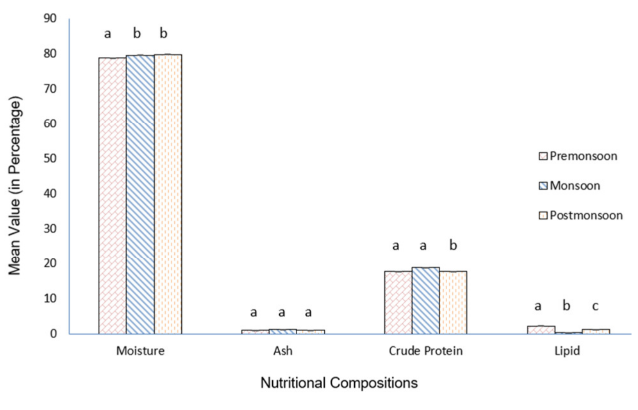

FIGURE 2 Nutritional compositions of *Monopterus cuchia* fillets collected in three different seasons. Different letters within the same content of nutritional composition denote significant differences ($p < 0.05$) among seasons. Data are expressed as mean ± standard error of the mean.

In pre-monsoon, it was found that *M. cuchia* contains 1.1 ± 0.01% ash and on the contrary, 1.2 ± 0.03% and 1.1 ± 0.03% ash were found in monsoon and post-monsoon seasons respectively (Figure 2). Seasonally the mean highest ash content was recorded 1.2 ± 0.03% in monsoon, and the lowest value was found 1.1 ± 0.01% in pre-monsoon season. Analysis of the data also revealed no significant difference ($p > 0.05$) in ash content among observed seasons.

Seasonally crude protein content varied from 17.3 – 19.3%. The highest crude protein (18.8 ± 0.1%) was found in the monsoon season, while the post-monsoon season represented the lowest value (17.7 ± 0.1%). There was no significant difference ($p > 0.05$) in protein contents between pre-monsoon and monsoon seasons. However, it varied significantly between monsoon and post-monsoon as well as between monsoon and pre-monsoon season (both $p < 0.05$). Fat contents showed significant seasonal dependency and varied from 0.3 – 2.4%. The mean fat content was found to be 2.2 ± 0.02% in pre-monsoon, 0.3 ± 0.01% in monsoon and 1.3 ± 0.02% in the post-monsoon season respectively.

3.2 Amino acids profile

Amount of amino acids in crude protein of *M. cuchia* varied seasonally (Table 1). The results obtained from this analysis showed that the predominant amino acids in fish protein were lysine followed by glutamic acid. In addition, arginine, glycine and aspartic acid were found to be higher in concentration than other amino acids analysed during this study, also showed the significant seasonal dependency.

TABLE 1 Amino acids profile (%) of *Monopterus cuchia* captured in different seasons

Amino acids	*Pre-monsoon*	*Monsoon*	*Post-monsoon*
Threonone^{EAA}	1.25 ± 0.02^{a}	0.63 ± 0.02^{b}	0.54 ± 0.02^{c}
Valine^{EAA}	1.68 ± 0.03^{a}	0.72 ± 0.02^{b}	0.65 ± 0.02^{b}
Methionine^{EAA}	2.15 ± 0.02^{a}	0.97 ± 0.02^{b}	0.93 ± 0.02^{b}
Isoleucine^{EAA}	1.85 ± 0.02^{a}	0.88 ± 0.02^{b}	0.82 ± 0.03^{b}
Leucine^{EAA}	2.19 ± 0.02^{a}	0.87 ± 0.03^{b}	0.84 ± 0.02^{c}
Lysine^{EAA}	3.88 ± 0.02^{a}	1.76 ± 0.02^{b}	1.68 ± 0.02^{c}
ΣEAAs	12.99	5.82	5.46
Aspartic Acid^{NEAA}	2.24 ± 0.02^{a}	0.95 ± 0.02^{b}	0.95 ± 0.02^{c}
Serine^{NEAAs}	1.62 ± 0.02^{a}	0.74 ± 0.02^{b}	0.74 ± 0.03^{b}
Glutamic Acid^{NEA}	3.60 ± 0.03^{a}	1.56 ± 0.02^{b}	1.26 ± 0.03^{c}
Glycine^{NEAAs}	3.11 ± 0.02^{a}	1.46 ± 0.02^{b}	1.31 ± 0.02^{c}
Alanine^{NEAAs}	1.68 ± 0.02^{a}	0.76 ± 0.02^{b}	0.65 ± 0.02^{c}
Histidine^{NEAAs}	1.89 ± 0.03^{a}	0.85 ± 0.04^{b}	0.88 ± 0.03^{b}
Tyrosine^{NEAAs}	1.64 ± 0.03^{a}	0.78 ± 0.02^{b}	0.67 ± 0.03^{c}
Arginine^{NEAAs}	3.36 ± 0.02^{a}	1.53 ± 0.02^{b}	1.47 ± 0.02^{b}
ΣNEAAs	19.13	8.62	7.91
EAAs/NEAAs	0.68	0.68	0.69

EEAs, Essential Amino Acids; NEAAs, Non-essential Amino Acids. The values are given as mean±standard deviation from the pooled sample with triplicate. Different letters within a row denote significant differences (p < 0.05).

Among 14 amino acids (EAAs = 6, NAAAs = 8), the highest values were marked in pre-monsoon season as the lowest were in post-monsoon season. The ratio of EAA/NEAA was observed 0.68, 0.68 and 0.69 in tested samples in pre-monsoon, monsoon and post-monsoon respectively. Despite the seasonal variations of amino acids in the protein, findings showed more or less similar EAA/NEAA ratio during the study seasons.

3.3 Fatty acids profile

The fatty acid concentrations (in percentage) in fish lipid are shown in Table 2. Twenty five fatty acids were found in analysed fish oil. The total saturated fatty acids (SFAs) contents of lipids in tested fish samples were 55.8% in pre-monsoon, 42.8% in monsoon and 33.9% in monsoon season. Total SFAs concentration was found to be higher in comparison to monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs) throughout the year. Among all detected SFAs, palmitic acid (C16:0) was the primary SFA. Results showed that *M. cuchia* contains 19.81±0.002%, 22.10±0.067% and 15.98±0.002% palmitic acid in pre-monsoon, monsoon and post-monsoon season respectively. Moreover, all analysed SFAs showed the significant seasonal dependency.

For MUFAs, the highest value was found in the post-monsoon season followed by monsoon and lowest in the pre-monsoon season. PUFAs followed the same trend as MUFAs in terms of total concentration. Oleic acid (C18:1) and palmitoleic acid (C16:1) were the predominant MUFAs. Analysis of all monounsaturated fatty acids revealed that significant differences existed ($p < 0.05$) among the seasons.

Among all PUFAs, the most abundant fatty acid was linoleic acid (C18:2), mean range varied from 5.41 ± 002% to 17.79 ± 0.001%. A quite substantial percentage of α linolenic acid (C18:3) and arachidonic acid (C20:4) were also found. All detected PUFAs, showed the significant differences depending upon the seasons. Eicosapentaenoic acid (C20:5, EPA) was not detected in pre-monsoon season whereas analysed fish muscle tissues represented the existence of docosahexaenoic acid (C22:6, DHA) in all seasons. Moreover, DHA content was higher than EPA. As can be seen in Table 2, the combined values of EPA and DHA was found to be higher in monsoon season (5.44%) followed by 1.44% and 1.91% in post-monsoon and pre-monsoon season, respectively. The ratio of n-6 and n-3 fatty acids was to be calculated as 1.29 in pre-monsoon, 0.58 in monsoon and 2.51 in post-monsoon season.

TABLE 2 Fatty acid composition (%) of *Monopterus cuchia* captured in different seasons

Fatty acid composition (%)	*Pre-monsoon*	*Monsoon*	*Post-monsoon*
Saturated fatty acids (SFAs)			
Caproic acid (C6:0)	4.67±0.002[a]	1.87±0.002[b]	0.30±0.001[c]
Caprylic acid (C8:0)	8.56±0.004[a]	0.99±0.002[b]	0.84±0.001[c]
Lauric acid (C12:0)	8.27±0.002[a]	3.09±0.012[b]	3.77±0.002[c]
Tridecanoic acid (C13:0)	ND	0.35±0.001[a]	0.49±0.004[b]
Myristic acid (C14:0)	6.15±0.003[a]	4.02±0.019[b]	2.13±0.002[c]
Pentadecyclic acid (C15:0)	0.88±0.001[a]	1.43±0.0004[b]	1.12±0.002[c]
Palmitic acid (C16:0)	19.81±0.002[a]	22.10±0.067[b]	15.98±0.002[c]
Stearic acid (C18:0)	3.98±0.005[a]	5.18±0.001[b]	6.15±0.001[c]
Arachidic acid (C20:0)	1.05±0.005[a]	1.52±0.003[b]	1.76±0.001[c]
Behenic acid (C22:0)	0.66±0.002[a]	ND	0.44±0.002[b]
Lignoceric acid (C24:0)	1.75±0.002[a]	2.21±0.003[b]	0.94±0.005[c]
∑ SFAs	**55.79**	**42.77**	**33.94**
Monounsaturated fatty acids (MUFAs)			
Myristoleic acid (C14:1)	0.37±0.001[a]	1.35±0.001[b]	1.79±0.001[c]
Pentadecenoic acid (C15:1)	ND	0.42±0.002[a]	0.83±0.002[b]
Palmitoleic acid (C16:1)	9.89±0.001[a]	9.62±0.003[b]	8.29±0.001[c]
Oleic acid (C18:1)	18.96±0.003[a]	20.79±0.002[b]	25.99±0.001[c]
Eicosenoic acid (C20:1)	ND	0.31±0.002[a]	0.50±0.002[b]
∑ MUFAs	**29.23**	**32.48**	**37.42**
Polyunsaturated Fatty Acids (PUFAs)			
Hexadecadienoic acid (C16:2); n-3	0.64±0.001[a]	1.38±0.001[b]	0.68±0.001[c]
Hexadecatrienoic acid (C16:3); n-3	ND	2.91±0.001[a]	2.16±0.001[b]
Linoleic acid (C18:2); n-6	6.38±0.001[a]	5.41±0.002[b]	17.79±0.001[c]
α Linolenic acid (C18:3); n-3	3.98±0.0001[a]	1.98±0.001[b]	1.68±0.001[c]
Eicosadienoic acid (C20:2); n-6	ND	0.64±0.002[a]	0.65±0.001[b]
Arachidonic acid (C20:4); n-6	2.07±0.001[a]	3.07±0.001[b]	2.04±0.003[c]
Eicosapentaenoic acid (C20:5, EPA); n-3	ND	0.60±0.001[a]	0.28±0.002[b]
Docosapentanoic acid (C22:5); n-3	ND	4.02±0.001[a]	2.21±0.002[b]
Docosahexaenoic acid (C22:6, DHA); n-3	1.91 ±0.0001[a]	4.74±0.001[b]	1.16±0.001[c]
EPA+DHA	**1.91**	**5.34**	**1.44**
∑ PUFAs	**14.98**	**24.75**	**28.64**
n-6/n-3	**1.29**	**0.58**	**2.51**

ND, Not detected; SFAs, saturated fatty acids; MUFAs, monounsaturated fatty acids; PUFAs, Polyunsaturated fatty acids. The ratio of each group (SFAs, MUFAs and PUFAs) of fatty acids in % was calculated as 100% from the total fatty acids determined. Means (±SD) followed by different letters within the same row are statistically significant (p <0.05).

4 | DISCUSSION

4.1 Proximate composition

Fish are exposed to considerable environmental changes throughout the year which influenced their proximate muscle composition. Mazumder *et al.* (2008) reported that moisture contents have varied between 65.88 and 78.62% in freshwater fish. Moreover, mean moisture content was measured as 76.57% in *Mastacembelus mastacembelus* (Olgunoğlu 2011), 78.69% in *Cyprinus carpio* and 79.00% in *Labeo rohita* (Jabeen and Chaudhry 2011). In general, the moisture content of the samples analysed in our study is in agreements with the results available on the moisture composition for *Salmo trutta macrostigma* (Ateş *et al.* 2013) and *Carassius gibelio* (Dagtekin *et al.* 2018) depending on seasons.

It was observed that the moisture content of fish decreased with an increase in fat content both in pre-monsoon and post-monsoon season in our study. Previously, the inverse relationship between the fat and moisture content in fish has been reported (Öksüz *et al.* 2011). In monsoon, we found the lowest amount of fat in fish muscle which can be explained by the fact that fish uses their reserve fat during spawning activities (FAO/WHO 1984). Miah *et al.* (2015) studied the breeding biology of freshwater mud eel of Bangladesh, and they found that May – June is the major breeding season of *M. cuchia*. Based on classification proposed by Ackman (1990), *M. cuchia* can be classified as a lean fish (fat less than 2%) according to its lipid content (mean value 1.27%) throughout the year. In this present investigation, lipid contents have varied from 0.3 – 2.24%, which were much lower than the values obtained for *Ilisha elongate*, *Trichiurus japonicus*, *Psenopsis anomala*, *Pneumatophorus japonicus*, *Argyrosomus argentatus*, *Nibea albi* and *Pampus chinensis* (Li *et al.* 2011), *Upeneus moluccensis* and *Mullus surmuletus* (Öksüz *et al.* 2011) of marine origin, but these were within the range of 0.39 – 3.49% for the freshwater fish (Olgunoğlu 2011, Islam 2017). Our result for lipid content compared well with the findings of Li *et al.* (2011) for *Monopterus albus* as well.

In general, most marine fish tended to have higher lipid content than freshwater fish. Moreover, the results showing the seasonal variation in lipid content is in line with the findings of Ozogul *et al.* (2011). No significant differences were observed in ash content among the seasons, which is well comparable with the findings of Dagtekin *et al.* (2018) and the values of ash content were within the range observed by Bogard *et al.* (2015). Based on season, protein content in analysed fish was varied from 17.67 – 18.83%, which coincided well with previous findings (e.g. Zhao *et al.* 2010). Memon *et al.* (2011) reported higher concentration of protein in cultured fish than present investigations. This may be due to the quality of supplementary feeds with rich in protein given for rearing those species in a confined culture area. In this study, protein content was found to be higher in monsoon season than other two seasons. This could be associated with the tendency of heavy feeding for the preparation of spawning by *M. cuchia*. Seasonal variation in protein content for different species has also been acknowledged by other researchers (e.g. Ozogul *et al.* 2011, Ateş *et al.* 2013). *Monopterus cuchia* could be categorised as high protein fish since the value of protein content was greater than 15% irrespective of the season. Fish is like to be considered high protein when its protein value is greater than 15% (Stansby 1962).

4.2 Amino acid profiles

Fish protein includes both essential and non-essential amino acids in fascinating amount for human consumption and they work together to promote human health. Lysine, glutamic acid, arginine, glycine and aspartic acids were the most dominant amino acids in *M. cuchia* tissues. Similarly, aspartic acid, glutamic acid, and lysine were reported as most abundant amino acids in freshwater fishes (Zuraini *et al.* 2006). Glutamic acid, aspartic acid, lysine, arginine, glycine, and leucine were also reported as the major amino acids in the tissues of both the fresh and marine water fishes (Jabeen and Chaudhry 2011, Cieślik *et al.* 2018). However, the quantities and types of amino acids in fish muscle are being affected by catching seasons and habitat (Wesselinova 2000) which coincides well with the present findings.

The average ratio of essential and nonessential amino acids (EAAs/NEAAs) was reported 0.73 (0.67 – 0.82) for 14 fish (Iwasaki and Harada 1985). Similarly, the EAAs/NEAAs ratio was reported 0.7 for monkfish (*Lophius piscatorim*), 0.71 for both Atlantic cod (*Gadus morhua*) and scup (*Stenotomous chrysops*) and 0.72 for Atlantic whiting (*Merluccius bilinearis*) (Jhaveri *et al.* 1984). It is evident from this study that *M. cuchia*, in general, is well balanced with respect to the EAAs/NEAAs ratio (varied between 0.68 – 0.69) throughout the season, and may be considered a valuable food source of human diet because of having high-quality protein.

4.3 Fatty acid profiles

In general, all the fatty acids detected in this study showed significant seasonal dependency, these are consistent with the findings of Dagtekin *et al.* (2018). Fatty acid composition of freshwater mud eel was dominated by saturated fatty acids, which accounted for 55.8% in pre-monsoon, 42.8% in monsoon and 33.9% in post-monsoon season. A similar finding was reported in freshwater carp (*Chanodichthys erythropterus*) (Kindong *et al.*

2017). Fish oil are characterised by high level of palmitic acid (C16:0), stearic acid (C18:0), palmitoleic acid (C16:1), oleic acid (C18:1), linoleic acid (C18:2), α linolenic acid (C18:3) arachidonic acid (C20:4) eicosapentaenoic acid (C20:5, EPA) and docosahexaenoic acid (C22:6, DHA) (Chrisolite *et al.* 2016). However, the quantity and types of fatty acids of fish can differ depending on several factors such as species, species habitat, water quality (temperature, pH, salinity) age, sex or size of the fish, spawning cycle, abundance of food, geographical location and catching time or season (Bandarra *et al.* 2001). In this study, palmitic acid, oleic acid and palmitoleic acid, and linoleic acids, α Linolenic acid (C18:3), arachidonic acid (C20:4) and docosahexaenoic acid (C22:6, DHA) were the most dominant acids belonging to the group SFA, MUFA and PUFA respectively. Moreover, the higher concentration of DHA than EPA in other freshwater fish species was also reported earlier (Kwetegyeka *et al.* 2008). Since the degree of unsaturation of fatty acids in fish is affected by the water temperature, n-3 PUFA contents of fish in warm regions are lower (Çelik *et al.* 2005). Our finding of higher concentration of DHA+EPA in monsoon season may be associated with the lower water temperature due to heavy rainfall during the monsoon season in Bangladesh (Galib *et al.* 2016, 2018a, 2018b).

Linoleic acid is important in cell signalling also found as a structural component of cell membranes. Therefore, *M. cuchia* can be considered the supplementary food to healthy human diet due to the richness of linoleic and alpha-linolenic acids in fillets. DHA and EPA of the n-3 series fatty acids have been reported owing to their ability to reduce cardiovascular disease. Depending on seasons, 3.8 – 13.9 g of mud eel flesh can have met up the daily requirement of 0.2 g of DHA+EPA recommend by British Nutrition Foundation (1992) for people who are on a balanced and healthy diet. The nutritional value of fish oil is also evaluated by its n-6 and n-3 PUFA ratio. The n-6/n-3 ratio for *M. cuchia* was notably lower (varied from 0.58 – 2.58) throughout the season than the value recommended by Simopoulos (1999). Values higher than the greatest esteem (4 at maximum) are harmful to human health and may expand the risk of many chronic diseases. Therefore, *M. cuchia* can be consumed as healthy as safe food in terms of n-6/n-3 PUFA ratio irrespective of catching seasons.

5 | CONCLUSION

This study has provided the basic information about nutritional values including principal nutrients, fatty acids and amino acids profile of *M. cuchia*, a species with a high potentiality in the international market, for the first time in Bangladesh and elsewhere in respect to seasonal changes. We found a greater variation in lipid content compared to protein, moisture and ash content. Moreover, all detected fatty acids and amino acids showed significant seasonal dependency. Finally, it is concluded with a remark that *M. cuchia* can be consumed as a nutritious food in terms of protein quality, EPA+DHA value and n-6/n-3 PUFA ratio, irrespective of catching seasons. However, we suggest further research on the nutritional composition of *M. cuchia* focusing on micronutrients (vitamins and minerals) and nutritional variation in sexes *i.e.* male and female.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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SR fish specimen collection; **SR & MRH** chemical analysis; **SR & MHF** data analysis; **SR, MHF, MSR, MMEE & MRH** manuscript preparation; **MHF & MSR** research supervision