



Research article

Nutritional profile of wild, pond-, *gher*- and cage-cultured tilapia in BangladeshShabiha Islam^a, Shuva Bhowmik^{a,*}, Priyanka Rani Majumdar^a, George Srzednicki^b, Matiur Rahman^c, Md. Abul Hossain^a^a Department of Fisheries and Marine Science, Noakhali Science and Technology University, Noakhali 3814, Bangladesh^b School of Chemical Engineering, The University of New South Wales, Sydney, Australia^c National Food Safety Laboratory, Institute of Public Health, Mohakhali, Dhaka 1212, Bangladesh

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ABSTRACT

The proximate, minerals, amino acid and fatty acid composition of wild, pond-, *gher*- and cage-cultured tilapia in Bangladesh were evaluated and varied significantly ($p < 0.05$). The major component of the tilapia was moisture (79.12%–81.36%), followed by protein (14.93%–16.03%), lipid (0.59%–2.35%), carbohydrate (1.23%–1.51%), fibre (0.47%–0.88%), ash (0.31%–0.53%); the energy value was between 97.62 and 126.73 kcal/100 g. Macro-nutrients and micro-nutrients were detected in following order: $K > Na > Mg > Ca$ and $Fe > Mn$, respectively in all the tilapia and the ratio of Na/K was < 1 . Essential amino acids, leucine (1.47–1.56 g/100 g) and lysine (1.66–1.74 g/100 g), were the predominant amino acids in tilapia, followed by non-essential amino acids, aspartic acid (1.72–1.84 g/100 g) and glutamic acid (2.88–3.07 g/100 g). Saturated palmitic acid (25.4%–35.54%), monounsaturated elaidic acid (31.51%–35.63%) and polyunsaturated linolenic acid (17.69%–22.57%) were the main fatty acids found in tilapia. The desirable protein percentage, Na/K ratio, the presence of essential amino acids, leucine and lysine, n-3 and n-6 fatty acid contents proved that the consumption of wild, pond-, *gher*- and cage-cultured tilapia are beneficial to human health and could be recommended to prevent different diseases particularly of cardiovascular type.

1. Introduction

Global fish production is increasing day by day and almost 50% of the total fish production is used for human consumption (FAO, 2014; Linhartová et al., 2018). Fish consumption has increased significantly over the last two decades and the demand for fish in the world market has increased due to the robust growth of the world population (FAO, 2016; Tilami et al., 2018). In Bangladesh, fish is widely used as part of human diet and approximately 60% of animal proteins come from fish, the proliferation of aquaculture, mainly various freshwater fish species, contributes to sustainable growth of fish production and tilapia is one of them (Belton et al., 2014; Bogard et al., 2015). The annual production rate of tilapia exceeds 384,737 tonnes and the amount of consumption is increasing in Bangladesh due to low price (DoF, 2018; Biswas et al., 2018). There are various culture systems such as pond-cultured, *gher*-cultured (pond dug in the rice field used in traditional farming in Bangladesh) and cage-cultured practiced in Bangladesh for the

production of tilapia and wild tilapia are commonly found in open water bodies (Haque et al., 2016; Wang and Lu, 2016; Biswas et al., 2018). However, the nutrition composition of fish greatly varies between species, individuals of the same fish species, types of culture system, size and weight of fish, seasons, geographical locations and sex (Usyodus et al., 2011; Jim et al., 2017; Matos et al., 2019). Besides, consumer claims that wild fishes are of superior quality in terms of nutritional value rather than cultured fish and hence wild fish are sold at a higher price on the market compared to cultured fish (Vanhonacker et al., 2013; Carlucci et al., 2015; Lingam et al., 2019).

Moreover, the nutritional composition of fish such as proteins, minerals, amino and fatty acids profile are very important for fish consumption (Lund, 2013; Njinkoue et al., 2016; Mohanty et al., 2019; Zhang et al., 2020). Minerals can play pivotal role in maintaining acid-base and water balance, formation teeth structure and bones, and accelerating metabolic reaction in human body (Duran et al., 2010; Gharibzahedi and Jafari, 2017; Adeyeye et al., 2019). Fish skeleton

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contains more minerals compared to fish muscle (Ersoy and Özeren, 2009; Nurnadia et al., 2013; Elsadin et al., 2019). In addition, fish proteins are rich in essential amino acids, especially lysine, methionine and taurine, which are insufficient in other sources of animal muscle, and some of other amino acids such as glycine, alanine, aspartic acid and glutamic acid that are responsible to produce the flavor and taste (Doğan and Ertan, 2017; Man et al., 2019; Kim, 2020). Besides, fish muscle protein is very useful in repairing the tissue and proper growth of tissue (Oluwaniyi et al., 2010; Venkatesan et al., 2017). Apart from this, fish provide many health benefits such as high content of n-3 long-chain polyunsaturated fatty acids, docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) are useful to prevent inflammation, rheumatoid arthritis, cancers and cardiovascular diseases (Raatz et al., 2013; Mat-suoka et al., 2017; Jiao et al., 2020). European Food Safety Authority suggests almost 200 mg DHA + EPA for regular consumption are useful to prevent cardiovascular diseases and n-6/n-3 ratio of 2–5/1 also useful for the prevention of several types of diseases (EFSA, 2010; Tufan et al., 2018).

Nowadays consumers are wondering whether the nutritional composition of fish in terms of proximate composition, minerals, amino acid and fatty acid profile in wild and cultured fish is superior or equivalent (Carlucci et al., 2015; Dayal et al., 2019). Although several studies provide nutritional profile of tilapia fish, the information about nutritional value of tilapia on the basis of culture system is still limited. Therefore, the main objective of the study is to evaluate nutritional value of wild, pond-, *gher*- and cage-cultured tilapia that would promote knowledge of the industrial process and ensure an excellent choice for the consumers in terms of improving their health.

2. Materials and methods

2.1. Sample collection

A total 108 tilapia (*Oreochromis niloticus*) samples were collected from four different available sources (wild, pond, *gher* and cage) in different geographic locations of Bangladesh (Figure 1) with the help of local fishermen. The range of weight of collected wild, pond-, *gher*- and cage-

cultured tilapia were 80–130 g, 95–115 g, 88–110 g and 105–150 g respectively. In addition, the range of length were 13–16 cm, 14–17 cm, 12–16 cm and 15–19 cm in wild, pond-, *gher*- and cage-cultured tilapia respectively. A single pooled wild tilapia sample was collected from Brahmaputra River, Mymensingh, followed by pond-cultured tilapia from a commercial fish farm of Trishal in Mymensingh, cage-cultured tilapia from Dakatia River of Chandpur and *gher*-cultured tilapia from Batiaghata of Khulna respectively in the months of April to June, 2018. After collection, samples were kept in polyethylene bags within an insulated ice box and transported to the laboratory.

2.2. Sample preparation

Fish samples were pooled and labelled, based on the four different available sources (wild, pond, *gher* and cage), and stored in a freezer at $-20\text{ }^{\circ}\text{C}$ until analysed. A cleaned sharp stainless-steel knife was used to dissect, eviscerate and fillet these fish samples. These fillet samples were prepared for analysis by pounding thoroughly in a blender to make a homogenous pulp and analysed. Then the samples were packed into labelled sterilized polythene bags and stored in the freezer at $-20\text{ }^{\circ}\text{C}$ for further analysis. All samples were analysed in triplicate.

2.3. Proximate composition analysis

The moisture content of tilapia samples was determined by evaluating the loss of weight after drying the sample in hot air oven at $105\text{ }^{\circ}\text{C}$ overnight until weight became stable (AOAC, 1990). Ash content of was determined in moisture free dry samples in a muffle furnace at $550\text{ }^{\circ}\text{C}$ for 20 h until all organic components of sample were incinerated completely (AOAC, 1990). Crude protein content of tilapia samples was determined by multiplying the nitrogen content obtained by Kjeldahl's method by the conversion factor 6.25 (AOAC, 1990). Crude lipid content of tilapia sample was determined by extracting fat using Soxhlet method (AOAC, 1990). The crude fibre content of sample was determined as the loss of weight by digestion of fat free fish sample with 1.25% (0.26 N) H_2SO_4 and 1.25% (0.23 N) NaOH and followed by drying overnight in an oven at $105\text{ }^{\circ}\text{C}$ and then for 3 h in a muffle furnace at $550\text{ }^{\circ}\text{C}$ (AOAC, 1980).

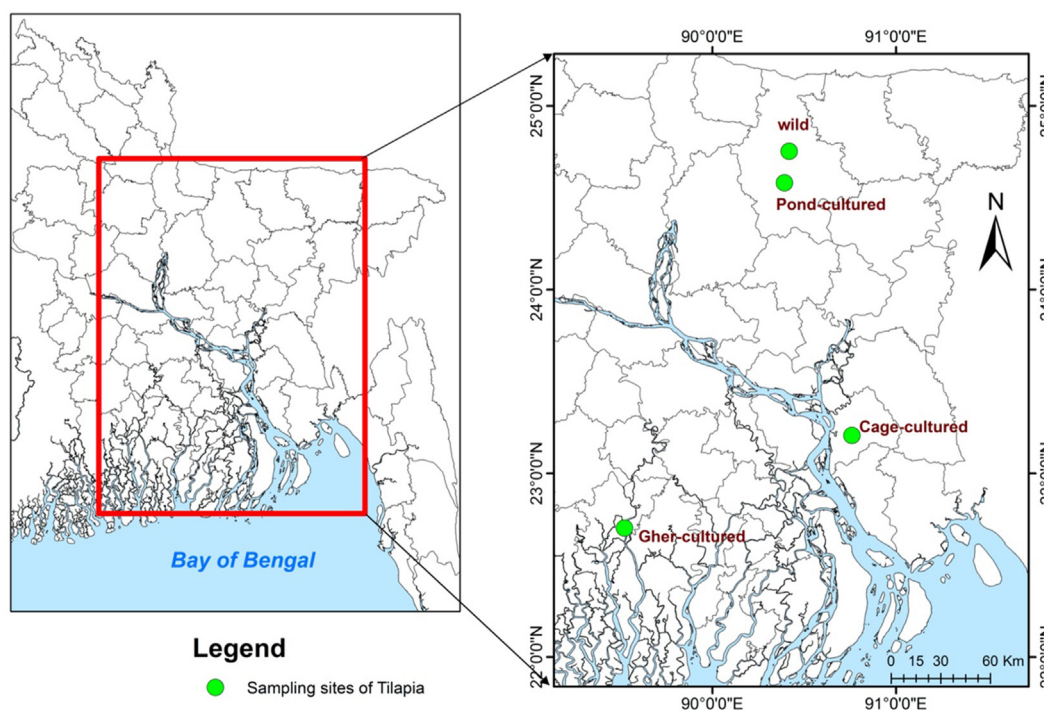


Figure 1. Sampling sites of wild, pond-, *gher*- and cage-cultured tilapia.

Total carbohydrates or nitrogen free extract (NFE) of sample were calculated by subtracting the sum of percentages of moisture, crude protein, ash, crude lipid and crude fibre in the sample from 100 (Castell and Tiews, 1980). The energy value was determined by multiplying the crude protein, carbohydrate and crude lipid content of tilapia sample with its respective energy values of 4, 4 and 9 kcal per gram weight of fish following the method described in Jabeen and Chaudhry (2011).

2.4. Mineral content

To determine the mineral content, fish muscle samples were dissolved and digested with HNO₃ at 200 °C for 2 h (AOAC, 1995). Calcium (Ca), magnesium (Mg), manganese (Mn) and iron (Fe) contents in fish muscle sample were determined by atomic absorption spectroscopy method using atomic absorption spectrophotometer model AA-7000 (Gokoglu et al., 2004) while sodium (Na) and potassium (K) contents were analyzed by using flame photometry method (Junsomboon and Jakmunee, 2011).

2.5. Amino acid determination

The profiling of amino acids from the wild, pond-, *gher*- and cage-cultured tilapia samples was conducted using high performance thin layer chromatographic (HPTLC) method (Nilima and Kunda, 2014). For amino acid analysis, the pasted tilapia fish samples were hydrolysed in acidic solution of 6 N HCl at 110 °C for 22–24 h. The samples were evaporated in a water bath to remove the acid content completely. Then the individual amino acids of samples were quantified and identified based on the retention time and peak area of the amino acids standards in HPTLC (Vijayan et al., 2016).

2.6. Fatty acid determination

Total lipids and fatty acids are extracted from tilapia samples by hydrolytic method. The fatty acids were obtained from saponification of total lipids of tilapia sample with NaOH and were converted into fatty acid methyl esters (FAMES) by methylation using HCl and methanol

mixture. The composition of fatty acids in wild, pond, *gher* and cage-cultured tilapia sample was determined by gas chromatographic (GC) method (Kocatepe and Turan, 2012). The comparison of the retention times and peak areas with the respective peak areas of the relevant fatty acids' standard was used to identify and quantify the individual fatty acids (Mohanty et al., 2019).

2.7. Ethical considerations

All procedures performed in this study were approved by the post-graduate research ethics committee of the Department of Fisheries and Marine Science at Noakhali Science and Technology University.

2.8. Statistical analysis

All the analysed results were presented as mean ± standard deviation (SD). Statistical analyses were conducted by using SPSS version 20 to understand the differences between the variables and significance level at $p < 0.05$.

3. Results and discussion

3.1. Proximate composition

The proximate composition of wild, pond-, *gher*- and cage-cultured tilapia is presented in Table 1. Moisture content varied from 79.12% (cage-cultured) to 81.36% (pond-cultured), lipid content varied from 0.59% (wild) to 2.35% (cage-cultured), protein content varied from 14.93% (pond-cultured) to 16.03% (cage-cultured), ash content varied from 0.31% (*gher*-cultured) to 0.53% (cage-cultured). The highest fibre content was found in pond-cultured tilapia (0.88%) and lowest in cage-cultured tilapia (0.47%). The highest carbohydrate content was found in wild tilapia (1.51%) while the lowest was found in pond-cultured tilapia (1.23%). Finally, the highest energy value was calculated for cage-cultured tilapia (126.73 kcal/100 g) and lowest in wild tilapia (97.62 kcal/100 g). Similar results for tilapia collected from Mymensingh in Bangladesh were presented by Bogard et al. (2015) who reported 390

Table 1. Proximate composition (% moisture basis) and energy values in the wild (n = 23), pond (n = 27), *gher*- (n = 26) and cage-cultured (n = 32) tilapia.

Proximate composition	Wild	Pond-cultured	<i>Gher</i> -cultured	Cage-cultured
Moisture%	80.97 ± 3.47 ^a	81.36 ± 1.86 ^a	80.92 ± 0.86 ^a	79.12 ± 0.57 ^b
Crude Lipid %	0.59 ± 0.09 ^c	1.08 ± 0.43 ^b	1.02 ± 0.52 ^b	2.35 ± 0.2 ^a
Crude Protein%	15.87 ± 0.015 ^b	14.93 ± 1.73 ^c	15.65 ± 0.58 ^b	16.03 ± 0.94 ^a
Ash%	0.34 ± 0.14 ^b	0.52 ± 0.015 ^a	0.31 ± 0.18 ^b	0.53 ± 0.18 ^a
Crude fiber%	0.72 ± 0.17 ^b	0.88 ± 0.21 ^a	0.78 ± 0.01 ^b	0.47 ± 0.17 ^c
Carbohydrate%	1.51 ± 0.01 ^a	1.23 ± 0.17 ^c	1.32 ± 0.22 ^b	1.5 ± 0.36 ^a
Energy value (kcal/100g)	97.62 ± 5.25 ^c	102.28 ± 6.42 ^b	104.82 ± 4.15 ^b	126.73 ± 2.55 ^a

Values are mean ± SD, Values within same rows with different superscripts are statistically different at $P < 0.05$.

Table 2. Concentrations of minerals (mg/kg) in wild, pond-, *gher*- and cage-cultured tilapia.

Minerals (mg/kg)	Wild	Pond-cultured	<i>Gher</i> -cultured	Cage-cultured
Essential minerals (macro-nutrients)				
Potassium(K)	13237.46 ± 178.33 ^a	12079.09 ± 334.73 ^c	10965.12 ± 202.07 ^d	
Sodium (Na)	2137.36 ± 60.12 ^b	1869.59 ± 79.10 ^c	2432.67 ± 62.67 ^a	
Magnesium (Mg)	716.42 ± 11.65 ^c	819.39 ± 79.06 ^a	744.64 ± 60.22 ^b	
Calcium (Ca)	430.48 ± 29.69 ^d	800.31 ± 128.73 ^a	569.91 ± 53.36 ^b	
Trace elements (micro-nutrients)				
Iron (Fe)	9.24 ± 1.61 ^b	25.83 ± 12.18 ^a	8.92 ± 1.25 ^c	9.50 ± 3.63 ^b
Manganese (Mn)	1.99 ± 0.18 ^b	4.11 ± 0.80 ^a	1.02 ± 0.21 ^d	
Na/K	0.2	0.2	0.2	0.1

Values are mean ± SD, Values within same rows with different superscripts are statistically different at $P < 0.05$, Na/K = Sodium to potassium ratio.

kJ/100 g energy content, 19.5% protein, 2% fat, 77.6% moisture and 1.8 % ash. Besides, Biswas et al. (2018) reported 21.22% protein, 2.07% fat, 68.09% moisture and 1.83% ash in tilapia collected from Dekar haor in Bangladesh. Likewise, Jim et al. (2017) reported 13.86%–17.12% protein, 1.73%–3.17% fat and 1.76%–3.30% ash for tilapia collected from different lakes in Zimbabwe. Usydus et al. (2011) reported 2% lipid, 16.4% protein, 81.2% moisture and 0.5% ash in tilapias collected from local fish markets in Poland. In addition, Matos et al. (2019) reported 77.8%–79.7% moisture, 18.1%–18.8% protein, 1%–3.6% lipid and 0.9%–1.2% ash in cage- and pond-cultured tilapia respectively. The significant variations of proximate composition in wild, pond-, gher- and cage-cultured tilapia might be due to life cycle variations, types of cultured system, environmental condition, season and types of diet during the time of sampling (Ondo-Azi et al., 2013; Khitouni et al., 2014). However, in our study a considerable amount of protein detected in tilapia fish that would be suitable diet for human health. There are several beneficial health effects of fish protein such as reduced obesity, decreased oxidative stress of adipose tissue, decreased tumor necrosis factor, controlled type 2 diabetes, improved resolution of inflammation and lowering the cardiovascular risk (Tilami and Sampels, 2018).

3.2. Mineral composition

The minerals composition of wild, pond-, gher- and cage-cultured tilapia is shown in Table 2. Potassium (K) content varied considerably within a range from 10,965.12 mg/kg (gher-cultured) to 13,237.46 mg/kg (wild), sodium (Na) concentration varied significantly from 1,405.35 mg/kg (cage-cultured) to 2,432.67 mg/kg (gher-cultured), magnesium (Mg) content ranged from 716.42 mg/kg (wild) to 819.39 mg/kg (pond-cultured), calcium (Ca) content varied from 430.48 mg/kg (wild) to 800.31 mg/kg (pond-cultured), iron (Fe) content varied significantly from 8.92 mg/kg (gher-cultured) to 25.83 mg/kg (pond-cultured), manganese (Mn) content ranged from 1.02 mg/kg (gher-cultured) to 4.11 mg/kg (pond-cultured) and similar Na/K ratio (0.2) was found in wild, pond- and gher-cultured tilapia except cage-cultured tilapia (0.1). These findings did not match those by Bogard et al. (2015) who reported 2,800 mg/kg K, 810 mg/kg Na, 260 mg/kg Mg, 950 mg/kg Ca, 11 mg/kg Fe and 0.52 mg/kg Mn. This might be due to variations of sampling sites and

seasons of collection during the study period. However, the findings of the present study agreed with those by Njinkoue et al. (2016) who claimed that higher values of K and lower amount of Na in fish were good for human health, particularly in order to avoid cardiovascular diseases. Subsequently, since the Na/K ratio found in all tilapia fish analysed in this study was less than 1 it indicates that wild, pond-, gher- and cage-cultured fish are safe for human consumption. To reinforce this claim it may be worthwhile mentioning that Bu et al. (2012) claimed that the ratio of Na/K > 1 in any food material may be harmful to human health. The macro-nutrients and micro-nutrients concentration in tilapia fish in wild and cultured system were listed in following order, K > Na > Mg > Ca and Fe > Mn, respectively. A similar trend was reported by Łuczyńska et al. (2009) in freshwater fish species collected from different lakes in north-eastern Poland. The findings of minerals value in fish in mentioned areas significantly varied and the variations of macro- and micro-nutrients composition in fish depends on length and weight of fish, feeding type, age, environmental conditions and types of culture system (Łuczyńska et al., 2009; Njinkoue et al., 2016).

3.3. Amino acid composition

The amino acid profile of wild, pond-, gher- and cage-cultured tilapia is presented in Table 3. In the present study, most abundant amino acids were arginine, leucine, lysine, alanine, aspartic acid and glutamic acid. Total Essential Amino Acids (EAA) varied from 7.65 g/100 g (wild) to 8.13 g/100 g (gher-cultured). Total Flavor Amino Acid (FAA) varied from 5.92 g/100 g (pond-cultured) to 7.2 g/100 g (gher-cultured). Total non-essential amino acids (NAA) ranged considerably from 15.26 g/100 g (wild) to 16.28 g/100 g (gher-cultured) and total amino acids (TAA) varied significantly from 38.17 g/100 g (wild) to 40.69 g/100 g (cage-cultured). Similar results were reported by Moses et al. (2018) with leucine, lysine and aspartic acid being the most abundant amino acids found in tilapia fish collected from different rivers in Nigeria. The concentration of EAA, NAA and TAA ranged from 33.95 to 42.58 g/100 g, 38.61–47.19 g/100 g and almost 65–75 g/100 g, respectively. Additionally, the findings of the study presented in this paper coincide with Adeyeye (2009) who stated that aspartic acid and leucine were the most common amino acids in tilapia. The author also found that NAA, FAA,

Table 3. Amino acid composition (g/100 g protein) of wild, pond-, gher- and cage-cultured tilapia.

Amino acid	Wild	Pond-cultured	Gher-cultured	Cage-cultured
Essential Amino Acid (EAA)				
Arginine	1.28 ± 0.05 ^c	1.3 ± 0.1 ^b	1.34 ± 0.17 ^a	1.37 ± 0.03 ^a
Histidine	0.48 ± 0.12 ^b	0.49 ± 0.16 ^b	0.51 ± 0.08 ^a	0.53 ± 0.07 ^a
Isoleucine	0.87 ± 0.09 ^b	0.88 ± 0.19 ^b	0.9 ± 0.06 ^a	0.92 ± 0.01 ^a
Leucine	1.47 ± 0.09 ^c	1.48 ± 0.16 ^c	1.52 ± 0.09 ^b	1.56 ± 0.25 ^a
Lysine	1.66 ± 0.21 ^c	1.68 ± 0.06 ^c	1.71 ± 0.21 ^b	1.74 ± 0.05 ^a
Methionine	0.43 ± 0.18 ^b	0.43 ± 0.24 ^b	0.44 ± 0.12 ^b	0.45 ± 0.11 ^a
Threonine	0.67 ± 0.19 ^c	0.69 ± 0.09 ^b	0.7 ± 0.15 ^a	0.72 ± 0.08 ^a
Valine	0.79 ± 0.14 ^c	0.79 ± 0.016 ^c	0.81 ± 0.11 ^b	0.84 ± 0.15 ^a
ΣEAA	7.65 ± 1.08	7.74 ± 1.02	8.13 ± 0.76	7.93 ± 0.99
Non-essential Amino Acid (NAA)				
Alanine	1.25 ± 0.15 ^c	1.27 ± 0.08 ^c	1.33 ± 0.07 ^b	1.36 ± 0.15 ^a
Aspartic Acid	1.72 ± 0.17 ^b	1.75 ± 0.19 ^b	1.8 ± 0.56 ^a	1.84 ± 0.04 ^a
Glutamic Acid	2.88 ± 0.09 ^c	2.9 ± 1.00 ^b	2.98 ± 1.00 ^b	3.07 ± 1.71 ^a
Glycine	0.87 ± 0.17 ^c	0.87 ± 0.18 ^c	0.89 ± 0.09 ^b	0.93 ± 0.23 ^a
Serine	0.63 ± 0.18 ^c	0.64 ± 0.14 ^b	0.64 ± 0.09 ^b	0.66 ± 0.015 ^a
Tyrosine	0.26 ± 0.09 ^c	0.27 ± 0.08 ^b	0.27 ± 0.17 ^b	0.29 ± 0.09 ^a
ΣFAA	6.72 ± 0.63	5.92 ± 1.52	7.2 ± 1.99	7 ± 1.75
ΣNAA	15.26 ± 1.95	15.44 ± 2.7	16.28 ± 3.01	15.84 ± 2.97
Total Amino Acid (TAA)	38.17 ± 1.95	38.62 ± 2.70	39.61 ± 3.00	40.69 ± 2.97

Values are mean ± SD. Values within same rows with different superscripts are statistically different at P < 0.05, FAA (flavor amino acid) is including aspartic acid, glutamic acid, glycine and alanine.

Table 4. Fatty acid composition (%) of wild, pond-, *gher*- and cage-cultured tilapia.

Fatty acid	Wild	Pond-cultured	<i>Gher</i> -cultured	Cage-cultured
Saturated Fatty Acids (SFA)				
C:14.0, Myristic	2.09 ± 0.03 ^a	1.95 ± 0.04 ^b	0.59 ± 0.16 ^c	2.1 ± 0.2 ^a
C:16.0, Palmitic	35.54 ± 0.05 ^a	27.69 ± 0.08 ^a	17.62 ± 0.01 ^c	25.4 ± 0.3 ^b
C:18.0, Stearic	2.65 ± 0.14 ^c	6.19 ± 0.03 ^a	ND	4.51 ± 0.18 ^b
C:20.0, Arachidic	2.57 ± 0.12 ^b	2.47 ± 0.02 ^b	2.71 ± 0.01 ^a	1.76 ± 0.07 ^c
C:22.0, Behenic	0.71 ± 0.05 ^a	ND	ND	ND
ΣSFA	43.56 ± 0.39	38.3 ± 0.17	20.92 ± 0.18	33.77 ± 0.75
Monounsaturated Fatty Acids (MUFA)				
C:18.1n-9, Elaidic	31.51 ± 0.06 ^b	33.18 ± 0.05 ^b	35.63 ± 0.14 ^a	35.63 ± 0.02 ^a
C:22.1n-9, Erucic	5.2 ± 0.15 ^a	3.49 ± 0.01 ^b	ND	ND
ΣMUFA	36.71 ± 0.21	36.67 ± 0.06	35.63 ± 0.14	35.63 ± 0.02
Polyunsaturated Fatty Acids (PUFA)				
C:18.2n-6, Linoleic	ND	ND	41.42 ± 0.08 ^a	ND
C:18.3n-3, α-Linolenic	17.69 ± 0.17 ^c	22.98 ± 0.02 ^b	ND	27.57 ± 0.01 ^a
ΣPUFA	17.69 ± 0.17	22.98 ± 0.02	41.42 ± 0.08	27.57 ± 0.01
PUFA/SFA	0.40 ± 0.44	0.6 ± 0.12	1.98 ± 0.44	0.82 ± 0.01
Σn-6	ND	ND	41.42 ± 0.08	ND
Σn-3	17.69 ± 0.17	22.98 ± 0.02	ND	27.57 ± 0.01
Total fatty acid (TFA)	97.96 ± 0.77	97.95 ± 0.25	97.97 ± 0.4	96.97 ± 0.78

Values are mean ± SD, ND = Not detected, Values within same rows with different superscripts are statistically different at $P < 0.05$.

NAA and TAA were present in 31.3 g/100 g, 7.2 g/100 g, 31.3 g/100 g and 62.6 g/100 g concentrations respectively. Some studies claim that particular essential amino acids such as arginine play an important role in anti-oxidative reactions, metabolic regulation and neurological functions (Wu, 2013). However, the variations of amino acid content in tilapias may occur due to environmental conditions, types of feed, weight and length of fish (Doğan and Ertan, 2017).

3.4. Fatty acid composition

The fatty acid (FA) profile of wild, pond-, *gher*- and cage-cultured tilapia are given in Table 4. The fatty acid was measured as the total saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) namely n-3 and n-6 identified during the study. FA composition was varied significantly between the wild, pond-, *gher*- and cage-cultured tilapias. Total SFA varied from 20.92% (*gher*-cultured) to 43.56% (wild), total MUFA was varying from 35.63% (*gher*-cultured) to 36.71% (wild), total PUFA varied considerably from 17.69% (wild) to 41.42% (*gher*-cultured), the ratio of PUFA/SFA ranged 0.4 (wild) to 1.98 (*gher*-cultured), total n-3 was varying from 17.69% (wild) to 27.57% (cage-cultured) and n-6 only detected in *gher*-cultured tilapia (41.42%). The dominant SFA acids were stearic acid and palmitic acid, while elaidic acid and linolenic acid were the major MUFA and PUFA. Similar results were reported by Matos et al. (2019) who found 380 mg/100 g SFA, 300 mg/100 g MUFA, 30 mg/100 g PUFA, 40 mg/100 g n-3 and 10 mg/100 g n-6 in pond-cultured tilapia and 1,250 mg/100 g SFA, 1570 mg/100 g MUFA, 550 mg/100 g PUFA, 60 mg/100 g n-3 and 490 mg/100 g n-6 in cage-cultured tilapia. Similar results for tilapia from the local fish markets in Poland were reported by Usyduş et al. (2011) who found 35.4% SFA, 33.1% MUFA, 31.5% PUFA, 9.9% n-3 and 21.6% n-6. The fatty acid profile of fish dependent on the diet, environmental conditions and production systems (Bogard et al., 2015; González et al., 2017; Matos et al., 2019). The long-chain fatty acid erucic acid detected in wild and pond-cultured tilapia, and the concentration is 5.2% and 3.49% respectively. The amount of erucic acid varies among fish species and individual samples, but highest concentrations found in fish oil, fish liver and oily fish muscle (Sissener et al., 2018). The European Food Safety Authority recommended that tolerable daily intake (TDI) of erucic acid for

humans is 7 mg/kg (EFSA, 2016). The high amount of erucic acid in food is responsible for adverse effects such as lipodosis in the heart muscle, tissue damage and reduced contractility (Bremer and Norum, 1982). In our present study, the concentration of erucic acid in tilapia fish is very low, but consumers should maintain the portion size of fish in their diet. Consumption of 200–300 g portion of oily fish could increase the amount of erucic acid in the human body, which could exceed the TDI set by EFSA (Sissener et al., 2018). However, in our current study we did not analyze the content of EPA and DHA in tilapia due to limited resources, but some research articles indicated that the percentage of EPA and DHA in tilapia varies significantly in the different seasons and the range was 1.2%–1.72% (EPA) and 4.95%–9.83% (DHA) in tilapia (Rasoarahona et al., 2005; Zula and Desta, 2021). The content of EPA and DHA in the human diet, especially fish, has a positive effect such as diminishing liver steatosis and the formation of the nervous system, particularly the retina and the brain of humans (Echeverría et al., 2017; Valenzuela et al., 2020). Nowadays, DHA is used as a critical nutritional element during lactation and pregnancy due to its active role in the development of nervous system in the early stage of human life (Echeverría et al., 2017). Thus, tilapia fish would be a suitable food item for consumers, especially pregnant women.

4. Conclusion

The outcome of the present study indicates that proximate, minerals, amino acid and fatty acid composition of wild, pond-, *gher*- and cage-cultured tilapia varied significantly and the variations of nutritional value of mentioned tilapia depends on localities, composition of feed, biological differences (weight, sex, age and sexual maturity), water temperature and water chemistry. The nutritional data of collected tilapia fish suggest that wild, pond-, *gher*- and cage-cultured tilapia is suitable for human consumption. This finding would be beneficial to national consumers, who bought the fish from fish markets based on wild or modes of culture system, and to promote the consumption of tilapia globally. In future studies, it would be useful to determine the nutritional profile of tilapia feed commonly used in Bangladesh and investigate the impact of feed composition on nutritional profile of tilapia.

Declarations

Author contribution statement

Shabiha Islam, Shuva Bhowmik: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Priyanka Rani Majumdar, George Srzednicki: Analyzed and interpreted the data; Wrote the paper.

Matiur Rahman, Md. Abul Hossain: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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