

**PROXIMATE COMPOSITION, AMINO ACIDS AND FATTY ACIDS PROFILES
OF WILD AND CULTURED CLIMBING PERCH, ANABAS TESTUDINEUS
(BLOCH, 1795)**

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Abstract: The availability and compositions of foods in the aquatic system have a direct influence on nutritional compositions of fish muscle. This research aimed to determine the nutritional compositions of wild and cultured climbing perch, *Anabas testudineus*, between pre-monsoon and post-monsoon. The proximate compositions, total amino acid, and fatty acid profiles were determined by AOAC, HPLC and GC, respectively. The results indicated that proximate (e.g., moisture, ash, protein and lipid), amino acid and fatty acid profile varied significantly ($p < 0.05$) between wild and cultured fishes depend on season. The highest amount of moisture ($79.62 \pm 0.92\%$) was found in wild *A. testudineus* and lowest amount of ash ($2.50 \pm 0.09\%$) was found in cultured *A. testudineus* during pre-monsoon. For both cultured and wild *A. testudineus*, amount of protein was higher in post-monsoon than in pre-monsoon period. The protein and amino acids contents as well as lipid and fatty acids of the fish species showed a significant ($p < 0.05$) seasonal variations. Among the 14 recorded amino acids the major amino acids in the total crude protein were histidine, methionine, isoleucine, lysine, glutamic acid, and glycine. The ratio of Essential Amino Acid (EA)/Non-Essential Amino Acid (NEA) was highest (0.34) in cultured fish of post-monsoon season and lowest (0.25) in wild fish of pre-monsoon season. The major fatty acid so wild and cultured *A. testudineus* were oleic acid (18:1), palmitic acid (16:0), linoleic acid (18:2), stearic acid (18:0), palmitoleic acid (16:1), and myristic acid (14:0). Some fatty acids [Lauric acid (C12:0), Pentad cyclic acid (C15:0), Arachidic acid (C20:0)] were not detected in cultured fish but present in wild fish. The n-3/n-6 ratio was highest (0.48) in wild fish of post-monsoon season and lowest (0.14) in cultured fish of pre-monsoon season. Therefore, a comprehensive study on wild and cultured climbing perch is required for further confirmation of the result of the present study.

Key words: Seasonal variation, Nutritional compositions, Amino acid ratio, n-3/n-6 ratio, Climbing perch

INTRODUCTION

Fish is an animal-source food comprising about 60% of protein intake in the diet of millions of Bangladeshi peoples at the rate of 18.1 kg per person per

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©2020 Zoological Society of Bangladesh DOI: <https://doi.org/10.3329/bjz.v48i2.52376>

year (Belton *et al.*, 2014). Fisheries and aquaculture plays an imperative role in Bangladesh economy as it strengthens food security, reduces poverty, and promotes employment and foreign trade opportunities. Bangladesh currently ranks 3rd in inland fishing production and 5th in aquaculture production worldwide (FAO, 2018). Inland fish farming of native and exotic carp species, especially Pangas, Tilapia, Thai/Vietnam Koi has increased significantly in the last two decades. Furthermore, there has also been an increasing interest in aquaculture focusing the small indigenous fish species like Gulsha, Koi, Magur, Mola, Pabda etc. since these species have a high consumer demand and have a greater contribution to the nutrition supply at household level (FRSS, 2015). The contribution of the *Anabas testudineus*, commonly known as 'Koi' in Bengali and climbing perch in English (both the indigenous and Thai/Vietnam variety) to the national fish production is about 4–5% (DoF, 2015). Now-a-days commercial Koi fish farming in pond is prevalent to meet increasing demand. Koi farming is very easy and profitable because of its commercial and nutritional importance.

The most edible part of fish is muscle that contains protein, lipid, carbohydrate, moisture, ash, minerals etc. The main constituent of fish flesh is moisture (about 80 per cent) (Murra and Burt, 2001). Fish is typically an ideal source of protein owing to amino acid composition and digestibility. The protein in the fish flesh ranges between 15–20% (Murra and Burt, 2001). Fat content of fish varies with the species, feeding, size, age, season, physiological status and geographical location (Exler, 1975).

Amino acids are the chemical substances that make up protein. There are about twenty types of essential and non-essential amino acids. The essential amino acids cannot be synthesized by human body and it must take from the diet. Fish protein is an excellent source of these amino acids, especially lysine and methionine, in contrast to cereal and meat proteins. Fatty acid is a carboxylic acid that is either saturated or unsaturated and has a long aliphatic chain. Fatty acids are considered as the essential sources of fuel because they produce significant amounts of ATP (adenosine triphosphate) when metabolized.

The inter specific and intraspecific differences in the composition of nutrients in fish are likely caused by intrinsic biological factors (e.g., age, size, sex) coupled with some endogenous (e.g., composition of feed) and exogenous drivers (e.g., environment, seasons, salinity) (Huss, 1995; Celik *et al.*, 2005; Li *et al.*, 2011). Body constituents and energy resources may considerably be varied with seasonal life cycles (Puwastien *et al.*, 1999).

However, external feeding is less likely to affect flesh protein contents because protein contents in fish muscle rely primarily on the culture

environment, species of fish, and the size of the individual (Shearer, 1994). While the cultured fish are supplied with nutrient-rich supplementary feeds; however, it is commonly perceived that the acceptability of fish captured from wild is considered to be greater than that of farmed fish. In contrast, wild fish, may rely fully on natural foods for their sustenance.

A good number of works has already been done on proximate composition of different freshwater and marine fishes (Mazumder *et al.*, 2008, Hossain *et al.*, 2015). Moreover, Onyia *et al.* (2013) made a thorough study on a variation on proximate composition depending on cultured environments. Yeganeh *et al.* (2012), Hassan *et al.* (2010) worked on amino acid and fatty acid profiles and their distribution among fish living in different habitat. Both the aquatic environment and seasons have a substantial influence on the nutrients profile in fish muscle. However, previous studies have focused either of culture environment or seasons to elucidate the variations in nutritional compositions of fishes.

Therefore, this study was designed to determine seasonal variations of the proximate, amino acid and fatty acid profile of cultured and wild climbing perch, *Anabas testudineus*.

MATERIAL AND METHODS

Sampling: Wild Koi fish was collected from Jhapabaor (22°59'1.34"N, 89° 9'36.39"E) and the cultured Koi (Thai koi) fish was collected from Matri Fish Hatchery and Integrated Farm, Monirampur, Jessore, Bangladesh in two seasons; pre-monsoon (March–May, 2015) and post-monsoon (September–November, 2015). The biometric data of wild and cultured *A. testudineus* are provided in the Table 1. For the wild *A. testudineus*, total length was 8.72±1.08 cm, and total weight was 25.11±2.87 g (n=10) in pre-monsoon, whereas 11.99±1.38 cm and 30.00± 2.18 g in post-monsoon, respectively. In case of cultured *A. testudineus*, total length was 9.25±0.93 cm, and total weight was 38.21±3.06g in pre-monsoon time, whereas 10.49±1.91 cm and 47.90±4.62 g (n=10) in the post-monsoon period, respectively. The collected samples were transported to laboratory by insulated ice box and refrigerated until analysis.

Sample preparation and determination of nutritional compositions: After biometric measurements, fish specimens (n=10) were decapitated, eviscerated, and filleted. The fish muscle was then taken 3–5 g in triplicate to determine proximate composition. For amino acid and fatty acid analysis, fish muscle was taken from each sample to make a homogenized pooled sample. From pooled sample final analysis of amino acid and fatty acid were done in triplicate. The

moisture, ash, crude protein content of sampled fish were determined by oven drying method), gravimetric method, and Micro-Kjeldhal method, respectively

Table 1: Biometric data of wild and cultured *A. testudineus* used in this study (n=10)

	Pre-monsoon		Post-monsoon	
	Wild	Cultured	Wild	Cultured
Total Length (cm)				
Mean (\pm SD)	8.72 \pm 1.08	9.25 \pm 0.93	11.99 \pm 1.38	10.49 \pm 1.91
Maximum	10.30	10.60	13.80	13.80
Minimum	7.10	7.80	9.80	7.10
Weight (g)				
Mean (\pm SD)	25.11 \pm 2.87	38.21 \pm 3.06	30.00 \pm 2.18	47.90 \pm 4.62
Maximum	28.84	42.76	2.61	52.84
Minimum	20.31	33.81	26.82	41.56

(AOAC, 1995). The lipid content was determined by Folch & Stanley method (1957). Amino acid profile and fatty acid profile were done by High Performance Liquid Chromatography (HPLC) (Anonymous, 1993) and Gas Chromatographic (GC) analysis (Nichols *et al.*, 1993), respectively.

Statistical analysis: Statistical analysis was performed with the Statistical Package for the Social Sciences (SPSS) v. 20.0 (SPSS, SAS Institute Inc. Gary, USA) and Microsoft office excel 2007. Multiple comparisons were done with Tukey HSD test with one way ANOVA (Analysis of Variance) at 5% level of significance. The descriptive statistics such as mean, standard deviation (SD), maximum and minimum values were used to represent our findings.

RESULTS AND DISCUSSION

A comparative analysis was performed to determine the moisture, ash, protein, lipid, amino acid, and fatty acid profile in wild and cultured climbing perch of Jashore district, Bangladesh. Based on the season, the findings revealed a wide variation in the nutritional compositions in terms of proximate, amino acid, and fatty acid contents of wild and cultured Koi fish.

Proximate Composition: Moisture content in our analysis, seasonal variation was observed in moisture content of both wild and cultured Koi fish. Moisture content (Mean \pm SD) of the wild *A. testudineus* was 79.62 \pm 0.29% and 75.27 \pm 0.15% between pre-monsoon and post-monsoon whereas in cultured fish the amount was 74.04 \pm 0.57% and 73.91 \pm 0.49%, respectively (Table 2). Result also represented that moisture content differed significantly ($p < 0.05$) in both season between wild and cultured Koi fish. Wild fish contained higher amount of moisture (79.62 \pm 0.92%) than cultured fish (73.91 \pm 0.49%) (Table 2). The highest

amount of moisture ($79.62 \pm 0.92\%$) was reported in wild fish during pre-monsoon.

Ash content: In pre-monsoon, it was found that the wild and cultured Koi contained $3.62 \pm 0.05\%$ and $2.50 \pm 0.09\%$ ash, respectively; on the contrary, in post-monsoon, the amount was $3.02 \pm 0.04\%$ and $2.90 \pm 0.03\%$, respectively (Table 2). Our finding revealed that a significant difference was observed ($p < 0.05$) in both season (pre-monsoon and post-monsoon) between wild and cultured *A. testudineus*. Wild fish contained higher amount of ash when compared with cultured fish in both seasons.

Crude protein content: Crude protein content of wild Koi in pre-monsoon and post-monsoon was found to $12.13 \pm 0.04\%$ and $14.74 \pm 0.05\%$, respectively (Table 2). On the other hand, cultured fish contained $16.04 \pm 0.07\%$ of crude protein in pre-monsoon and $17.92 \pm 0.05\%$ in the post-monsoon period. The highest value was recorded in post-monsoon cultured fish ($17.92 \pm 0.05\%$) and the lowest value in wild fish ($12.13 \pm 0.04\%$) of pre-monsoon. Result of crude protein content stated that significant difference ($p < 0.05$) remains in wild and cultured fish of both seasons.

Lipid content: Lipid content showed variation between pre-monsoon and post-monsoon (Table 2). In pre-monsoon, lipid content was $3.82 \pm 0.07\%$ and $5.14 \pm 0.02\%$ in wild and cultured fish, respectively; on the contrary, in post-monsoon the amount were $3.61 \pm 0.06\%$ and $5.56 \pm 0.03\%$ in wild and cultured fish, respectively. Significant difference ($p < 0.05$) was found in wild and cultured fish of both season. Total amount of lipid is higher in cultured fish than wild.

Table 2: Seasonal variation in proximate composition (%) of wild and cultured *A. testudineus*

Proximate composition (%)	Pre-monsoon		Post-monsoon	
	Wild	Cultured	Wild	Cultured
Moisture	79.62 ± 0.92^a	74.04 ± 0.57^{cd}	75.27 ± 0.15^b	73.91 ± 0.49^d
Ash	3.62 ± 0.05^a	2.50 ± 0.09^c	3.02 ± 0.04^b	2.90 ± 0.11^d
Protein	12.13 ± 0.04^a	16.04 ± 0.07^c	14.74 ± 0.05^b	17.92 ± 0.05^d
Lipid	3.82 ± 0.07^a	5.14 ± 0.02^c	3.61 ± 0.06^b	5.56 ± 0.03^d

Data are expressed as mean \pm SD. Mean values followed by different letters within a row denote significant differences ($p < 0.05$).

FAO (1991) stated that fish typically contains 72% water, 19% protein, 8% fat, 0.5% calcium, 0.25% phosphorus and 0.1% vitamin A, D, B etc. The percentage of proximate composition showed a wide variation in wild and cultured fish. Alemu *et al.* (2013) showed that both exogenous and endogenous factors influence fish body composition.

In general, moisture content range fall between 60–80% in many fish (Murra and Burt, 2001). In our study, seasonal variation was observed in moisture content of wild and cultured fish. The moisture content varied from 73.06–80.62%. The highest value was found in wild Koi fish during pre-monsoon, 79.62 ± 0.29 %, and the lowest value was in cultured fish during post-monsoon season 73.91 ± 0.16 %. Hossain *et al.* (2015) analyzed proximate composition of *A. testudineus* collected from fish market. They found 72.60 ± 0.17 % moisture in Koi fish.

Ash content was found to vary from 2.37 to 3.71%. In pre-monsoon, wild and cultured fish illustrated that they contained 3.62 ± 0.02 % and 2.50 ± 0.03 % ash, respectively; on the contrary, in post-monsoon, the amounts were 3.02 ± 0.01 % and 2.90 ± 0.03 %, respectively. Hossain *et al.* (2015) described that *A. testudineus* contained 3.02 ± 1.12 % ash.

The protein in the fish flesh ranges between 15–20% (Murra and Burt, 2001). Hossain *et al.*, (2015) described that *A. testudineus* contained 16.18 ± 0.13 % protein. The present study coincides with the work. Lipid content ranged from 3.56 to 5.61% in pre-monsoon and post-monsoon. Similar result was shown that *A.* contained 5.31 ± 0.37 % lipid (Hossain *et al.*, 2015).

Amino Acids Profile: Amount of amino acid in protein varied seasonally in both wild and cultured fish (Table 3). A total of 14 amino acids—six essential amino acids (EAs) and eight non-essential amino acids (NEAs)—were found in the present study. EAs that were present include threonine, valine, methionine, isoleucine, leucine and lysine; and NEAs include aspartic acid, serine, glutamic acid, glycine, alanine, histidine, tyrosine, and arginine.

Threonine: In pre-monsoon, amount of threonine was 0.277 ± 0.006 % and 0.437 ± 0.006 % in wild and cultured fish, respectively; on the contrary, in post-monsoon, the amount was 0.320 ± 0.02 % and 0.460 ± 0.04 %, respectively. Significant difference ($p < 0.05$) resides in wild and cultured fish of both seasons; but irrespective of the season, no such significant difference ($p > 0.05$) was found within the wild and cultured Koi.

Valine: Content of valine in wild *A. testudineus* in pre-monsoon and post-monsoon were 0.090 ± 0.02 % and 0.100 ± 0.01 %, respectively. On the other hand, cultured fish contains 0.110 ± 0.017 % and 0.140 ± 0.03 % valine in pre-monsoon and post-monsoon, respectively. The highest value was recorded in cultured fish during post-monsoon and the lowest value in wild fish during pre-monsoon. The amount of valine content did not varied significantly ($p > 0.05$) between seasons and habitats.

Methionine: Amount of methionine in wild fish was 0.313 ± 0.029 % and 0.35 ± 0.02 % in pre-monsoon and post-monsoon whereas in cultured fish the

amount was $0.457 \pm 0.023\%$ and $0.490 \pm 0.03\%$, respectively. Significant difference was observed ($p < 0.05$) between wild and cultured *A. testudineus* of both seasons but no significant variation ($p > 0.05$) in both wild and cultured fishes between seasons.

Isoleucine: Isoleucine content of the wild *A. testudineus* was $0.527 \pm 0.032\%$ and $0.620 \pm 0.04\%$ in pre-monsoon and post-monsoon season whereas in cultured fish the amounts were $0.8433 \pm 0.05\%$ and $0.907 \pm 0.035\%$, respectively. The mean values of isoleucine content varied significantly ($p < 0.05$) between wild and cultured fish of both seasons.

Leucine: In pre-monsoon, wild and cultured fish contained $0.133 \pm 0.021\%$ and $0.170 \pm 0.02\%$ leucine, respectively; on the contrary, in post-monsoon, the amount were $0.170 \pm 0.017\%$ and $0.210 \pm 0.01\%$, respectively. The values of leucine content differ significantly between the wild Koi of pre-monsoon and culture Koi of post-monsoon season.

Lysine: In pre-monsoon, wild and cultured Koi fish contained $0.300 \pm 0.026\%$ and $0.367 \pm 0.012\%$ lysine, respectively; and in post-monsoon, the amount was $0.370 \pm 0.02\%$ and $0.440 \pm 0.03\%$. The variation in lysine content between the wild and cultured Koi fish of both seasons was statistically significant ($p < 0.05$).

Aspartic acid: In pre-monsoon, amount of aspartic acid in wild and cultured fish was $0.737 \pm 0.012\%$ and $0.890 \pm 0.017\%$ whereas in post-monsoon the amount was $0.760 \pm 0.03\%$ and $0.930 \pm 0.01\%$, respectively. A significant variation in aspartic acid content was observed ($p < 0.05$) among wild and cultured fish of both seasons

Serine: Cultured koi fish contained $0.463 \pm 0.006\%$ and $0.490 \pm 0.01\%$ serine in pre-monsoon and post-monsoon whereas in case of wild fish the amounts were $0.323 \pm 0.015\%$ and $0.360 \pm 0.04\%$, respectively. Likewise aspartic acid, the amount of serine varied significantly between wild and cultured fish of both seasons.

Glutamic Acid: In pre-monsoon, amount of glutamic acid was $0.990 \pm 0.026\%$ and $1.147 \pm 0.025\%$ in wild and cultured Koi, respectively. On the other hand, in post monsoon, the amount were $1.040 \pm 0.04\%$ and $1.260 \pm 0.03\%$, respectively. Glutamic acid contents varied significantly ($p < 0.05$) between the culture fish of pre-monsoon and post-monsoon; however, no such variation was found in wild fish of both seasons. **Glycine:** Amounts of glycine in wild fishes in pre-monsoon and post-monsoon were $1.290 \pm 0.026\%$ and $1.380 \pm 0.02\%$, respectively. Moreover, cultured fish contained $1.450 \pm 0.02\%$ glycine in pre-monsoon and $1.580 \pm 0.03\%$ in post-monsoon. Result represented that glycine content differed significantly ($p < 0.05$) in both seasons between wild and cultured Koi fish.

Alanine: Amount of alanine in wild Koi fish were $0.397\pm 0.012\%$ and $0.420\pm 0.017\%$ during pre-monsoon and post-monsoon, respectively. On the contrary, the amounts were $0.490\pm 0.01\%$ and $0.550\pm 0.029\%$ in cultured Koi fish, respectively. The highest value was recorded in post-monsoon cultured fish, and the lowest value in wild fish of pre-monsoon and significant difference ($p < 0.05$) was found between cultured and wild Koi of both seasons.

Histidine: Cultured fish contained $1.823\pm 0.025\%$ and $1.870\pm 0.01\%$ histidine in pre-monsoon and post-monsoon, whereas in the case of wild fish the amount was $2.023\pm 0.084\%$ and $2.240\pm 0.02\%$, respectively. Significant difference was observed ($p < 0.05$) between cultured fish of both seasons.

Tyrosine: In pre-monsoon, wild and cultured Koi fish contained $0.383\pm 0.015\%$ and $0.473\pm 0.012\%$ tyrosine, respectively; on the contrary, in post-monsoon, the amount was $0.440\pm 0.02\%$ and $0.55\pm 0.04\%$, respectively. No significant difference ($p > 0.05$) lies between wild fish but cultured Koi fish exhibited significant difference ($p < 0.05$).

Arginine: Arginine content of the wild *A. testudineus* were $0.407\pm 0.015\%$ and $0.47\pm 0.01\%$ in pre-monsoon and post-monsoon seasons whereas in cultured fish, the amounts were $0.52\pm 0.026\%$ and $0.58\pm 0.04\%$, respectively.

Table: 3 Amino Acids composition (%) of wild and cultured *A. testudineus*

Amino Acids	Pre-monsoon		Post-monsoon	
	Wild	Cultured	Wild	Cultured
Essential amino acids (EAs)				
Threonine	0.277 ± 0.006^a	0.437 ± 0.006^b	0.320 ± 0.020^a	0.460 ± 0.040^b
Valine	0.090 ± 0.020^a	0.110 ± 0.017^a	0.100 ± 0.010^a	0.140 ± 0.030^a
Methionine	0.313 ± 0.029^a	0.457 ± 0.023^b	0.350 ± 0.020^a	0.490 ± 0.030^b
Isoleucine	0.527 ± 0.032^a	0.8433 ± 0.050^b	0.620 ± 0.040^a	0.907 ± 0.035^b
Leucine	0.133 ± 0.021^a	0.170 ± 0.017^{ab}	0.170 ± 0.020^{ab}	0.210 ± 0.010^b
Lysine	0.300 ± 0.026^a	0.367 ± 0.012^b	0.370 ± 0.020^b	0.440 ± 0.030^c
Non-essential amino acids (NEAs)				
Aspartic Acid	0.737 ± 0.012^a	0.890 ± 0.017^b	0.760 ± 0.030^a	0.930 ± 0.010^b
Serine	0.323 ± 0.015^a	0.463 ± 0.006^b	0.360 ± 0.040^a	0.490 ± 0.010^b
Glutamic Acid	0.990 ± 0.026^a	1.147 ± 0.025^b	1.040 ± 0.040^a	1.260 ± 0.030^c
Glycine	1.290 ± 0.026^a	1.450 ± 0.020^c	1.380 ± 0.020^b	1.580 ± 0.030^d
Alanine	0.397 ± 0.021^a	0.490 ± 0.017^{bc}	0.420 ± 0.030^{ab}	0.550 ± 0.050^c
Histidine	2.023 ± 0.084^a	1.823 ± 0.025^b	2.240 ± 0.040^a	1.870 ± 0.010^c
Tyrosine	0.383 ± 0.015^a	0.473 ± 0.012^b	0.440 ± 0.020^{ab}	0.550 ± 0.040^c
Arginine	0.407 ± 0.015^a	0.520 ± 0.026^{bc}	0.470 ± 0.010^{ab}	0.580 ± 0.040^c
EA/NEA	0.25	0.33	0.27	0.34

Data are expressed as mean \pm SD. Different letters within a row denote significant differences ($p < 0.05$).

Amino acids are the building blocks of proteins that act as body builders. The cellular structure and function of body is largely depend on amino acids as it is serve as a source of energy (Babsky *et al.* 1989). Fish protein contains all the ten EAs in desirable quantity for human consumption. Unlike mammalian protein, fish protein is particularly rich in methionine and lysine, and low in tryptophan (Nowsad, 2007).

Nurullah *et al.* (2003) reported that the amount of glutamic acid in fish muscle was quite high while the other amino acids were slightly low. Similarly, Iwasaki and Harada (1985) have stated that the aspartic acid, glutamic acid, and lysine are the primary amino acids in fish muscles. In the present study, the ratio of EA/NEA amino acids were observed 0.25 and 0.27 in wild Koi fish collected in two different period as pre-monsoon and post-monsoon. Moreover the ratios were 0.33 and 0.34 in cultured fish during pre-monsoon and post-monsoon, respectively. Our finding indicated that that cultured Koi fish have a well-balanced and high-quality protein in the respect of EA/NEA ratio in post-monsoon.

Fatty acids profile: Fatty acids are mainly two types- Saturated Fatty Acid (SFA) and Unsaturated Fatty Acid (UFA). The total SFA content of lipids were 40.119% and 39.865% in wild Koi during pre-monsoon, while 39.748% and 37.573% in cultured Koi during post-monsoon, respectively. Wild *A. testudineus* contained 58.674% and 60.029% UFA in pre-monsoon and post-monsoon, respectively. In addition, the amount of UFA in both season were 60.114% and 61.322% in cultured fish.

Saturated Fatty Acid (SFA): The primary SFA was palmitic acid (C16:0). Result showed that wild Koi fish contained 29.377±0.003% and 27.138±0.002% palmitic acid in pre-monsoon and post-monsoon while the cultured Koi fish contained 30.277±0.255% and 27.359±0.007% in pre-monsoon and post-monsoon, respectively (Table 4). Data also expressed that significant variation ($p<0.05$) was observed between wild fish of both seasons as well as cultured fish of both season. Stearic acid (C18:0) is also a major SFA. Amount of stearic acid in wild fishes in pre-monsoon and post-monsoon were 8.550±0.02% and 8.245±0.001%, respectively. On the other hand, cultured fish contained 8.013±0.015% in pre-monsoon and 8.473±0.006% in post-monsoon. The amount of stearic acid varied significantly ($p<0.05$) between wild and cultured fish of both seasons. Capric acid (C10:0) is present in both wild and cultured fish but the amount is minor. Among other SFA, caproic acid (C6:0), enanthic acid (C7:0), caprylic acid (C8:0) were not detected (ND) in cultured fish in pre-monsoon but present in wild fish. Lauric acid (C12:0), pentad cyclic acid (C15:0), arachidic acid (C20:0) were not detected in cultured fish in both

seasons. Behenic acid (C22:0) and margaric acid (C17:0) were not detected in cultured fish as well as wild fish in pre-monsoon, but only present in wild fish during post-monsoon and the amounts were 0.072 ± 0.001 and 0.128 ± 0.001 , respectively.

Unsaturated Fatty Acids: Monounsaturated Fatty Acids (MUFAs): Amount of oleic acid (C18:1) were $44.067 \pm 0.002\%$ and $42.351 \pm 0.008\%$ in wild and cultured fish during pre-monsoon, respectively; on the contrary, in post-monsoon, the amount were $32.764 \pm 0.18\%$ and $44.994 \pm 0.007\%$, respectively. Palmitoleic acid (C16:1) and Eicosenoic acid (C20:1) were present in both wild and cultured fish. The amount of almitoleic acid (C16:1) in wild *A. testudineus* were $4.782 \pm 0.001\%$ and $4.616 \pm 0.007\%$ in pre-monsoon and post-monsoon season, respectively whereas in cultured fish, the amount were $2.707 \pm 0.009\%$ and $1.609 \pm 0.052\%$, respectively.

Polyunsaturated Fatty Acids (PUFAs): In wild Koi, the amount of linoleic acid (C18:2) were $4.384 \pm 0.005\%$ and $10.704 \pm 0.011\%$ during pre-monsoon and post-monsoon, respectively. Conversely, cultured Koi fish contained $11.923 \pm 0.004\%$ linoleic acid in pre-monsoon and $10.028 \pm 0.003\%$ in post-monsoon. Significant variations ($p < 0.05$) existed in wild and cultured Koi between pre-monsoon and post-monsoon.

Cultured *A. testudineus* contained $0.396 \pm 0.007\%$ and $0.583 \pm 0.025\%$ eicosatrienoic acid (C20:3) in pre-monsoon and post-monsoon, whereas in the case of wild fish, the amount were $0.322 \pm 0.001\%$ and $0.527 \pm 0.003\%$, respectively. In wild fishes, amounts of linolenic acid (C18:3) were $1.613 \pm 0.009\%$ and $3.567 \pm 0.008\%$ in pre-monsoon and post-monsoon, respectively. In contrast, cultured Koi fish contained $0.825 \pm 0.006\%$ linolenic acid in pre-monsoon and $1.383 \pm 0.003\%$ in post-monsoon. The amount of arachidonic acid (C20:4) in wild Koi fish were $1.238 \pm 0.002\%$ and $2.173 \pm 0.06\%$ in pre-monsoon and post-monsoon, respectively; on the contrary, the amounts were $0.646 \pm 0.001\%$ and $1.195 \pm 0.055\%$ in cultured Koi fish. Amounts of eicosapentaenoic acid (EPA) (C20:5) in wild fish were $0.062 \pm 0.000\%$ and $0.162 \pm 0.001\%$ in pre-monsoon and post-monsoon, respectively; whereas EPA was not detected in cultured fish during pre-monsoon but in post-monsoon, EPA was detected and the amount was $0.329 \pm 0.001\%$.

Hexadecadienoic acid (C16:2) and hexadecatrienoic acid (HTA) (C16:0) were absent in cultured Koi of both seasons, but present in the wild Koi. Docosatrienoic acid (C22:3) and adrinic acid (C22:4) were not detected in cultured fish during pre-monsoon. In contrast, these two polyunsaturated fatty acids were present in cultured Koi during post-monsoon and in wild fish during

Table 4: Saturated and unsaturated fatty acid composition (%) of wild and cultured *A. testudineus* in two different seasons

Fatty acids	Pre-monsoon		Post-monsoon	
	Wild	Cultured	Wild	Cultured
Saturated Fatty Acids (SFAs)				
Caproic acid (C6:0)	0.077±0.002 ^a	ND	0.673±0.003 ^b	0.181±0.002 ^c
Enanthic acid (C7:0)	0.075±0.004 ^a	ND	0.611±0.003 ^b	0.345±0.001 ^c
Caprylic acid (C8:0)	0.058±0.001 ^a	ND	0.440±0.040 ^b	0.228±0.009 ^c
Capric acid (C10:0)	0.018±0.002 ^a	0.051±0.001 ^c	0.192±0.004 ^b	0.133±0.007 ^d
Lauric acid (C12:0)	0.054±0.003 ^a	ND	0.176±0.001 ^b	ND
Myristic acid (C14:0)	1.630±0.020 ^a	1.524±0.006 ^c	1.595±0.004 ^b	0.854±0.005 ^d
Pentadecylic acid (C15:0)	0.082±0.001 ^a	ND	0.252±0.001 ^b	ND
Palmitic acid (C16:0)	29.377±0.003 ^a	30.277±0.255 ^c	27.138±0.002 ^b	27.359±0.007 ^b
Stearic acid (C18:0)	8.550±0.020 ^a	8.013±0.015 ^c	8.245±0.001 ^b	8.473±0.006 ^d
Arachidic acid (C20:0)	0.198±0.001 ^a	ND	0.226±0.003 ^b	ND
Behenic acid (C22:0)	ND	ND	0.072±0.001	ND
Margaric acid (C17:0)	ND	ND	0.128±0.001	ND
Σ SFAs	40.119	39.865	39.748	37.573
Unsaturated Fatty Acids (UFAs)				
Monounsaturated Fatty Acids (MUFAs)				
Palmitoleic acid (C16:1)	4.782±0.001 ^a	2.707±0.009 ^c	4.616±0.007 ^b	1.609±0.052 ^d
Oleic acid (C18:1)	44.067±0.002 ^a	42.351±0.008 ^c	32.764±0.180 ^b	44.994±0.007 ^d
Eicosenoic acid (C20:1)	0.747±0.003 ^a	0.281±0.002 ^c	0.857±0.003 ^b	0.435±0.003 ^d
Σ MUFAs	49.596	45.339	38.237	47.038
Polyunsaturated Fatty Acids (PUFAs)				
Hexadecatrienoic acid (C16:0)	0.133±0.001 ^a	ND	0.744±0.003 ^b	ND
Hexadecadienoic acid (C16:2)	0.103±0.006 ^a	ND	0.503±0.006 ^b	ND
Linoleic acid (C18:2)	4.384±0.005 ^a	11.923±0.004 ^c	10.704±0.011 ^b	10.028±0.003 ^d
Linolenic acid (C18:3)	1.613±0.009 ^a	0.825±0.006 ^c	3.567±0.015 ^b	1.383±0.003 ^d
Eicosadienoic acid (C20:2)	0.321±0.003 ^a	ND	0.466±0.001 ^b	ND
Eicosatrienoic acid (C20:3)	0.322±0.001 ^a	0.396±0.007 ^c	0.527±0.003 ^b	0.583±0.025 ^d
Arachidonic acid (C20:4)	1.238±0.002 ^a	0.646±0.001 ^c	2.173±0.060 ^b	1.195±0.055 ^b
Eicosapentaenoic acid (C20:5)	0.062±0.001 ^a	ND	0.162±0.001 ^b	0.329±0.002 ^c
Docosatrienoic acid (C22:3)	0.444±0.006 ^a	ND	0.621±0.003 ^b	0.257±0.004 ^c
Adrinic acid (C22:4)	0.344±0.003 ^a	ND	0.335±0.011 ^a	0.371±0.000 ^b
Docosapentanoic acid (C22:5)	0.756±0.007 ^a	0.014±0.001 ^c	0.582±0.011 ^b	ND
Docosahexaenoic acid (C22:6)	0.971±0.006 ^a	0.971±0.001 ^b	1.408±0.018 ^b	0.138±0.000 ^c
Σ PUFAs	9.078	14.775	21.792	14.284
n-3/n-6	0.35	0.14	0.48	0.17

both seasons. Docosapentanoic acid (DPA) (C22:5) was not detected in cultured fish in post-monsoon but present in pre-monsoon cultured fish. Eicosadienoic acid (C20:2) was not found in cultured fish but present in wild Koi fishes. In pre-monsoon, ratio of n-3/n-6 were 0.35 and 0.14 for wild and cultured Koi fish, Values in the same row having the different superscript are significantly respectively whereas in post-monsoon these ratios were 0.48 and 0.17, respectively. Different ($p < 0.05$)

Our analysis suggested that wild Koi fish are nutritionally superior to the cultured Koi fish in terms of fatty acid content. In particular, PUFAs were predominant in wild Koi while MUFAs were dominant in cultured Koi fish.

Stansby (1982) documented palmitic acid (C16:0) as the prevalent SFA, which accounted for 20–50% of total fatty acid in some fish lipids. Similarly, we found palmitic was dominant in both the farmed and wild Koi fish, contributing approximately 70% to the total SFA content irrespective of both seasons (pre-monsoon and post-monsoon).

Proportions of saturated fatty acids (C14:0, C16:0, C18:0, C20:0) varied irregularly in lipids of the liver from both wild and cultured *Gibelion catla* fish (Hassan *et al.*, 2010). Oleic acid (C18:1) was contained in large quantities in the liver of wild as well as cultured *G. catla*, while linolenic acid (C18:3) and eicosadienic acid (C20:2) were detected only in the liver of wild *G. catla*. These findings were corroborated with our findings of higher concentration of PUFA in wild Koi than in cultured Koi.

In relation to the relative nutritional values of fish oil of various species, Piggott and Tucker (1990) proposed the n-3/n-6 ratio is a better quality measure. Therefore, it would be better to consume fish that have a high ratio of n-3/n-6. In pre-monsoon, wild and cultured fish amount of n-3/n-6 ratio is 0.35 and 0.14 whereas in post-monsoon the amount was 0.48 and 0.17, respectively.

CONCLUSION

Findings of the study showed seasonal variations in proximate, fatty acid and amino acid profile of wild and cultured *A. testudineus*. Generally, cultured fish are supplemented with nutrient-rich foods and the supplemented food is mainly rich in animal protein. As a result cultured fish contain more protein than wild. This amount is also varying based on season may be due to the change in water quality and other parameters of the environment. But more research is needed to draw a conclusion regarding these findings.

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