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Seasonal variation of nutritional constituents in fish of South Asian Countries: A review

Md Golam Rasul [1], Israt Jahan [1], Chunhong Yuan [2], Md Shirajul Islam Sarkar [1], Mohammad Abu Jafor Bapary [3], Md Abdul Baten [4], A K M Azad Shah [1*]

[1]Department of Fisheries Technology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh
[2]Department of Food Production and Environmental Management, Faculty of Agriculture, Iwate University, Iwate 020-8550, Japan
[3]Department of Fisheries Technology and Quality Control, Sylhet Agricultural University, Sylhet, Bangladesh
[4]Department of Fishing and Post Harvest Technology, Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh

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hasin96@yahoo.com

**Corresponding Author*
A K M Azad Shah
azad@bsmrau.edu.bd

Abstract

Knowledge of the changes of essential nutritional constituents (i.e. moisture, protein, lipid, minerals, amino acid and fatty acid profile) of fish with seasons is indispensable to estimate their energy value and to plan the most appropriate industrial and commercial processing. This article reviewed the nutritional constituents of 28 different fish species of Bangladesh and other South Asian countries like India, Pakistan in three different seasons *viz.* pre-monsoon (April-June), monsoon (August-October) and post-monsoon (December-February). Available findings have shown that proximate composition, amino acid and fatty acid profile varied in accordance to changes of the seasons. As the environmental factors including water temperature, pH, salinity and food availability changes with the seasons, which in turn influence the amino acid and fatty acid profile of fish in different season. Moisture content known to vary in some fishes for maintaining osmoregulation during migration. This phenomenon also largely affects the seasonal variation of proximate composition of fish. In addition, age, size, sex, habitat, breeding season and starvation during migration are also known to diverge the nutritional composition of fish in different seasons. It is generally view that fish utilizes lipid as energy source in different seasonal circumstances as gonadal development, maturation, spawning or migration and there is an inverse relationship between lipid and moisture content. Protein, lipid, amino acids and saturated fatty acid concentration were comparatively higher in pre-monsoon and lower in post-monsoon, whereas monounsaturated fatty acids and polyunsaturated fatty acids were higher in post-monsoon season in many of the fishes; attributed to gonadal development of fish, when it migrates a long way. Finally, this review might help to understand the changes in nutritional values of some commercial fishes in various seasons and will assist in identifying the proper fish harvesting period.

Keywords: Proximate composition, seasonal variation, freshwater and marine fish, South Asian countries

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1 Introduction

South Asian countries (Bangladesh, India, Maldives, Sri Lanka, Nepal, Bhutan and Pakistan) have many rivers e.g. the Indus River, the Ganges River, the Brahmaputra River etc., and marine waters e.g. the Indian Ocean, the Arabian Sea. Since time immemorial, fish are thus very important food item in communities living in this region (Saylor Academy, 2012). In Bangladesh, about 60% animal protein of diet is acquired from fish (DoF, 2017). Now a day, the demand for protein rich food is increasing, especially in developing countries (Ghosh et al., 2012). In recent years among animal protein-based food price hike in chicken, beef and mutton is seen. Fish proteins are rich in essential amino acids (EAA) (Abdullahi et al., 2001; Sankar and Ramachandran, 2001; Ferdose and Hossain, 1970; Samyal et al., 2011; Peng et al., 2013; Mohanty et al., 2014) and has high biological value i.e. easily digestible (Tilami and Sampels, 2017; Andrew, 2001; Nowsad, 2007).

The main beneficial health effects of eating fish are linked to the long-chain polyunsaturated omega-3 fatty acids: eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) which are very rare in plants and land animals (Stansby, 1985). DHA is important for the development of brain, nerves and eyes. Fish PUFA significantly reduce cardiovascular diseases and in many cases effective for cancer, inflammatory diseases and mental and cognitive disorders (Nichols et al., 2014). Fatty fish species are generally rich in fat soluble vitamins such as vitamin D and vitamin A. Among water soluble vitamins, the content of vitamin B12 is particularly high. Fish also contribute to meet up the requirement for essential minerals and trace elements e.g. iodine, calcium, phosphorus, potassium, iron, zinc, magnesium and copper (Geiger and Borgstrom, 1962). The percentage of water in the composition of fish is a good indicator of the relative energy, protein and lipid content (Quazi et al., 1995; Aberoumad and Pourshafi, 2010).

Over the last 20 years fish production in Bangladesh has been increasing consistently. In 2019 Bangladesh produced 4.38 million metric ton fish, which contributed 3.50% of total GDP, 25.71% of agricultural GDP and earned USD 5.07 billion foreign currency. Fisheries is the second largest export sector of Bangladesh (DoF, 2020). Bangladesh is the top Hilsa (*Tenualosa ilisha*) producer in the world (DoF, 2020). In 2018, Bangladesh achieved 3rd place among countries of inland capture, wherein India placed 2nd (FAO, 2020). In respect of global marine capture fisheries, India was the 6th largest producer in 2018 (FAO, 2020). So, undoubtedly fish and fisheries are integral part of nutrition, livelihood, life and culture in South Asian countries.

Nutritional constituent i.e. proximate biochemical composition of fish basically refers to crude protein, lipid, moisture, ash content (%) of the fish. Principal composition of fish is 16-21% protein, 0.2-25% fat, 1.2-1.5% mineral, 66-81% water and 0-0.5% carbohydrate (Paul et al., 2015a,b, 2017, 2018). The composition, however, varies greatly from species to species and also from individual to individual depending on fishing ground, season, age, sex, reproductive status and environment (Huss, 1988, 1995; Boran and Karacam, 2011; Binoy et al., 2012). The spawning cycle and food supply are the main factors responsible for this variation (Patton, 1975; Huss, 1988, 1995; Osako et al., 2003). During periods of heavy feeding, the protein content of muscle tissue increases slightly at first and then the fat content might show a marked and rapid increase. On the other hand, fish may have starvation periods for natural or physiological reasons (spawning or migration) or because of external factors such as shortage of food. In that case, fat content gradually decreases and then a decline in protein may also be seen (Huss, 1988, 1995). Therefore, to understand the status of nutrient constituents in fish, it is important to consider the change in proximate composition due to change of season.

Our diet influences our health throughout our entire life especially important in fetal, infant, child and youth years. Because of health consciousness, the modern-day man is interested in taking sea food more in view of its nutritional superiority than all other sources of food accessible. Proximate biochemical composition of a species helps to assess its nutritional and edible value in terms of energy units compared to other species (Aberoumad and Pourshafi, 2010).

At this moment 'Blue Economy' is the most pronounced term in fisheries science. Fish processing and different value added product development from fish is most important, easy way to go forward to blue economy. In this case, it is important to know about the effects of seasonal variation on the nutritional constituents of fish for its maximum utilization through various preservation and processing technology (Silva and Chamul, 2000). In addition, information of nutritional constituents that varies in different seasons will also help the consumer, processor and other related stakeholders to promote fish as healthy food in human nutrition (Nargis, 1970). The objective of this review is to comprehensively present seasonal variation in nutrient constituent of some fresh and marine water fishes of South Asian countries.

2 Seasonal variation of proximate composition in fish

2.1 Freshwater fish

Proximate composition is quantitative analysis of a mixture (as food) representing the percentage of components. Fish is a widely accepted food commodity because of its high palatability, low cholesterol, tender

Table 1. Seasonal variation in proximate composition (%) of some freshwater fish

Particular	Summer		Autumn		Winter	
	Small (<100g)	Big (>100g)	Small (<100g)	Big (>100g)	Small (<100g)	Big (>100g)
Species: *Labeo bata* (Paul et al., 2019)						
Moisture	70.95±1.29	71.73±0.29	74.01±0.6	75.05±0.38	74.09±0.4	73.19±0.86
Protein	18.27±1.01	16.28±0.89	14.84±0.2	16.76±0.33	14.32±0.2	16.27±0.56
Lipid	4.94±0.13	4.86±0.21	3.29±0.27	2.93±0.14	3.35±0.27	3.29±0.34
Ash	2.67±0.34	2.67±0.25	2.56±0.08	2.61±0.15	2.26±0.08	2.68±0.20
Species: *Labeo calbasu* (Paul et al., 2019)						
Moisture	74.51±0.36	74.64±0.29	76.36±0.5	73.70±0.55	76.08±0.23	74.54±0.25
Protein	15.33±0.29	14.19±0.14	13.34±0.5	15.22±0.45	14.02±0.39	14.04±0.12
Lipid	2.69±0.21	2.62±0.17	2.32±0.28	3.41±0.26	3.38±0.28	3.02±0.12
Ash	2.30±0.05	2.19±0.04	1.80±0.12	2.12±0.10	2.29±0.07	2.40±0.05
Species: *Cirrhinus reba* (Paul et al., 2019)						
Moisture	71.99±0.53	69.52±0.29	73.29±0.4	73.95±0.17	74.43±0.4	74.72±0.18
Protein	17.07±0.55	18.61±0.31	15.05±0.3	15.44±0.68	14.08±0.2	13.31±0.19
Lipid	3.07±0.15	3.14±0.44	3.95±0.34	4.42±0.83	5.15±0.48	6.79±0.34
Ash	2.56±0.07	3.19±0.07	2.24±0.05	2.46±0.10	2.24±0.06	2.22±0.06
Species: *Puntius javanicus* (Paul et al., 2019)						
Moisture	73.80±1.06	72.78±0.65	77.28±0.2	73.73±0.53	75.27±0.4	65.75±1.10
Protein	14.72±0.60	15.33±0.34	13.09±0.2	15.21±0.33	13.90±0.2	17.14±0.87
Lipid	3.03±0.22	4.46±1.10	3.28±0.18	4.32±0.16	5.54±0.56	9.40±0.76
Ash	2.14±0.07	2.06±0.09	2.41±0.05	2.43±0.06	2.50±0.07	3.05±0.27
Species: *Ompok bimaculatus* (Paul et al., 2019)						
Moisture	74.86±0.99	70.28±1.70	76.25±0.1	75.73±0.40	77.34±0.16	72.39±0.70
Protein	15.97±0.79	15.87±0.75	13.79±0.9	13.45±0.24	12.71±0.05	14.34±0.45
Lipid	3.02±0.36	6.64±0.38	4.44±0.26	3.63±0.21	3.02±0.18	4.20±0.23
Ash	1.82±0.07	2.45±0.12	1.78±0.07	2.09±0.08	2.50±0.20	2.32±0.08
Species: *Mystus vittatus* (Paul et al., 2019)						
Moisture	70.00±0.76	70.03±0.32	74.18±0.9	71.60±0.53	73.70±0.45	72.71±0.92
Protein	19.19±0.45	18.36±0.27	13.89±0.4	14.50±0.28	14.29±0.22	14.95±0.35
Lipid	5.63±0.36	5.76±0.25	7.24±0.52	8.47±0.38	6.33±0.25	7.07±0.20
Ash	2.99±0.09	2.87±0.09	2.57±0.13	2.94±0.19	2.50±0.08	2.08±0.09
Species: *Channa striata* (Paul et al., 2019)						
Moisture	75.68±0.58	74.66±0.34	76.76±0.3	75.06±0.38	76.67±0.22	77.19±0.35
Protein	15.61±0.58	14.95±0.27	14.11±0.5	16.95±0.72	13.43±0.19	12.85±0.2
Lipid	1.77±0.31	2.68±0.18	1.37±0.12	2.31±0.20	1.89±0.13	2.50±0.32
Ash	2.39±0.10	2.48±0.05	2.55±0.09	2.37±0.11	2.08±0.07	1.98±0.07
Species: *Wallago attu* (Paul et al., 2019)						
Moisture	76.78±0.57	74.50±0.82	76.27±0.6	71.86±1.22	73.19±1.44	73.16±0.58
Protein	12.52±0.21	14.40±0.59	12.96±0.4	15.23±0.30	14.57±0.67	14.72±0.28
Lipid	3.49±0.09	4.13±0.41	3.58±0.23	3.61±0.35	4.11±0.78	2.91±0.09
Ash	2.13±0.06	1.81±0.09	1.94±0.04	1.91±0.12	1.82±0.21	2.09±0.14
Species: *Pangasianodon hypophthalmus* (Paul et al., 2019)						
Moisture	64.53±0.68	72.59±0.66	67.47±1.35	74.07±0.44	74.88±0.66	68.77±0.9
Protein	17.42±0.22	14.39±0.42	17.83±0.77	14.25±0.19	13.03±0.38	16.16±0.5
Lipid	7.32±1.13	5.12±0.36	8.44±1.07	6.27±0.62	6.37±0.68	13.15±0.5
Ash	2.70±0.19	2.43±0.11	1.52±0.08	1.73±0.12	1.55±0.14	1.33±0.05
Species: *Channa striata* (Varghese and Mathew, 2016)						
Moisture	77.74±0.63	73.43±0.85	72.82±0.97	73.04±0.59	72.83±0.95	75.98±.5
Protein	16.09±0.39	18.57±0.27	19.02±0.28	19.45±0.33	16.79±0.18	17.74±.6
Lipid	3.49±0.45	4.78±0.47	4.94±0.62	5.03±0.20	3.69±0.51	4.79±.33
Ash	1.40±0.17	1.37±0.01	1.38±0.02	1.76±0.69	1.83±0.10	1.84±.02
Species: *Heteropneustes fossilis* (Varghese and Mathew, 2016)						
Moisture	75.06±0.97	75.00±0.59	79.36±0.74	80.55±0.63	77.64±0.96	77.06±.5
Protein	17.97±0.25	18.22±0.53	13.01±0.39	14.48±0.25	16.27±0.32	17.46±.4
Lipid	2.89±0.16	3.11±0.12	2.07±0.54	2.21±0.04	2.80±0.10	2.86±.12
Ash	1.16±0.27	2.10±0.06	1.62±0.04	1.89±0.18	2.90±0.10	1.88±.27

Table 1 Continued

Particular	Summer	Autumn	Winter
Species: *Neolissocheilus hexagonolepis* (Aberoumad and Pourshafi, 2010)			
Moisture	77.255±0.845	74.585 ±0.301	75.441±0.428
Protein	18.734±0.401	16.579 ±0.338	19.418±0.410
Lipid	1.434±0.346	4.409 ± 0.203	2.473± 0.425
Ash	1.209±0.278	1.547 ± 0.284	1.356± 0.281
Species: *Schizothorax richardsonii* (Aberoumad and Pourshafi, 2010)			
Moisture	76.051 ±0.560	74.574±0.313	75.381 ±0.307
Protein	16.126 ±0.288	15.746 ±0.489	15.829 ±0.362
Lipid	1.637 ±0.276	3.596±0.310	2.638 ±0.299
Ash	1.483 ±0.325	1.878± 0.371	2.544 ±0.287
Species: *Tor putitora* (Aberoumad and Pourshafi, 2010)			
Moisture	74.265±0.348	72.851±0.213	75.412±0.438
Protein	20.244±0.382	17.659±0.346	18.532±0.441
Lipid	3.192±0.412	4.553±0.463	2.350±0.211
Ash	1.285±0.210	0.575±0.452	1.323±0.453
Species: *Sillaginopsis panijus* (Azim et al., 2012)			
Protein	73.93±0.17	64.55±0.12	57.79±0.21
Lipid	11.87±0.05	13.09±0.16	14.73±0.05
Ash	11.50±0.09	14.13±0.06	15.64±0.03
Moisture	77.60±0.15	76.26±0.03	78.72±0.18
Species: *Cyprinus carpio* (Manon et al., 2015)			
Moisture	72.54±0.55	73.70±0.63	74.53±1.07
Protein	20.07±0.19	18.71±1.07	18.25±1.18
Lipid	4.19±0.23	3.80±0.36	3.36±0.40
Ash	3.02±0.637	3.13±0.42	3.44±0.53
Particular	Pre-spawning	Spawning	Post-spawning
Species: *Glossogobius giuris* (Islam and Joadder, 2005)			
Moisture	78.66	79.5	79.27
Protein	15.36	15.18	16.03
Lipid	1.52	1.06	0.95
Ash	2.18	2.66	2.33
Particular	Pre-monsoon	Monsoon	Post-monsoon
Species: *Labeo boga* (Gandotra et al., 2017)			
Moisture	83.11	78.62	81.4
Protein	16.41	16.46	17.21
Lipid	2.33	1.95	2.96
Ash	1.06	1.03	1.17
Species: *Labeo gonius* (Begum et al., 2013)			
Moisture	72.67	72.84	72.42
Protein	17.21	17.23	15.54
Lipid	4.73	3.92	4.02
Ash	5.21	5.87	7.19
Species: *Labeo calbasu* (Munny et al., 2020)			
Moisture	77.27	–	74.82
Protein	14.6	–	16.13
Lipid	2.84	–	3.65
Ash	1.99	–	2.54

Summer= pre-monsoon (pre-spawning), Autumn= monsoon (spawning), Winter= post-monsoon (post-spawning) flesh, cheap and its aroma in cooking (Gao et al., 2014). The major components of fish muscle include water, protein, ash and lipid is termed as proximate composition. The biochemical composition of the fish muscle generally indicates the nutritional quality of the fish. Feeding habit, sex, species diversity, seasonal variation, climate change and other environmental features greatly affect the nutrient composition of individual fish species (Adelakun et al., 2017). Evaluation of the major components of fish such as protein, lipid, moisture and ash percentages are necessary to ensure whether they meet the requirements of food regulations and commercial guidelines (Waterman, 2000). In this review, we represent some data of 28 freshwater fishes of Bangladesh and other South Asian countries and discuss the reasons behind their variability in proximate composition in different seasons as summer (April-June), autumn (August-October) and winter (December-February).

Paul et al. (2019) reported the proximate composition of nine freshwater fishes included *Mystus vittatus*, *Ompok bimaculatus*, *Channa striata*, *Wallago attu*, *Pangasianodon hypophthalmus*, *Labeo bata*, *Labeo calbasu*, *Cirrhinus reba* and *Puntius javanicus* and found variation in relation to season and body weight. The moisture content of *Labeo bata* was higher in fish (>100 g) during autumn (Table 1). Within the same season of the year, moisture content did not vary between small and large fish (Pal and Ghosh, 2013). Another study showed wide variation (71% to 83%) in moisture content of *Thinlip mullet*, *Liza ramada* occur in different seasons (Kalay et al., 2008). The protein content of *Labeo bata* was found higher in <100 g group during summer season (Paul et al., 2019). The larger fish (>100 g) sampled during autumn showed more protein content than the larger fish sampled during winter (Sankar and Ramachandran, 2001). Moreover, the larger fish (>100 g) sampled during autumn showed more protein content than the larger fish sampled during winter citepSankar2001. The fat content of the *Labeo rohita*, *Catla catla* and *Cirrhinus mrigala* found to be higher during summer irrespective of their body weights in comparison to the fish in other seasons of the year (Shakir et al., 2013). The moisture content higher in autumn and lower in summer and fat content higher in winter and lower in autumn due to the inverse relationship (Ravichandr et al., 2011; Bogard et al., 2015). Similar findings were reported by Paul et al. (2019) in case of *Mystus vittatus*, *Ompok bimaculatus*, *Channa striata*, *Wallago attu*, *Pangasianodon hypophthalmus*, *Labeo calbasu*, *Cirrhinus reba* and *Puntius javanicus*. Fresh flesh of Banded snakehead shows high value for protein 19.45%, and lipid, 6.30% in autumn (Varghese and Mathew, 2016). Hossain et al. (1999) also stated the similar concentration of lipid in small indigenous fish species of Bangladesh. The ash content was similar among the groups according to the size and different seasons of the year. Comparatively higher value for protein content in catfish was found in summer (18.22±0.53) and the lowest in autumn (13.01±0.39). A positive correlation was observed between protein and lipid content during the summer and autumn season (Varghese and Mathew, 2016) (Table 1). Likely, the higher crude protein content found in summer and drastic decrease in crude protein was observed in *C. morulius* when it entered in winter (Ashraf et al., 2011).

It has been found that moisture content in Gangetic Sillago (*Sillaginopsis panijus*) varied slightly remaining within the range of 2% variation (Azim et al., 2012). Lipid percentage decreases in the summer and slightly increases in the monsoon. It has also been found that the main nutrient composition in *Clarias gariepinus* is crude protein (Chakwa and Shaba, 2009). Ash content also decreases from winter to summer and increases in the monsoon. Seasonal differences in the availability of food and changes in the reproduction cycle have considerable effect on the tissue biochemistry of the fish, particularly lipid. The variation of lipid content is related with feed intake (Kabir et al., 2012).

Nutritional composition e.g. protein, lipid, ash, moisture in the edible portion (muscle) of some other fishes in different seasons as post-spawning season, pre-spawning season and spawning season of the year are stated in Table 1. Protein, lipid, ash content was significantly varied in different seasons of the year. It found that *Glossogobius giuris* possessed highest protein content (16.03%) in post-spawning season followed by pre-spawning season (15.36%) and spawning season (15.18%). However, highest lipid content (1.52%) was observed in pre-spawning season followed by spawning season (1.09%) and post-spawning season (0.95%). The highest ash content (total minerals) was found in spawning season (2.66%) followed by post-spawning season (2.33%) and pre-spawning season (2.18%) (Islam and Joadder, 2005). The highest moisture content (79.50%) was found in spawning season followed by post-spawning season (79.50%) and pre-spawning season (78.66%) (Table 1).

Proximate composition as moisture, crude protein, crude lipid and ash content of *Labeo gonius* were found to vary depending on various season mentioned in Table 1. Comparatively higher moisture content was found in May than August. Like other fishes it has the greater percentage of moisture and may vary according to size, sex, season of the year (Azim et al., 2012; Begum and Minar, 2012; Mahfuj et al., 2012; Hossain et al., 2012). The protein percentage show significant variations. The highest value of protein was found in May and the lowest in August. In the case of lipid content, the highest lipid percentage was observed in July, while the lowest was in May. The ash percentage was higher in August and lower in May when subjected to experiment (Begum et al., 2013).

Munny et al. (2020) examined 65 samples of *L. calbasu* over a period of 6 months. They observed that the proximate composition of *L. calbasu* varied seasonally (Table 1). Protein, lipid, ash and moisture contents were 14.6±0.43, 2.84±0.21, 1.99±0.08 and 77.27±1.62, respectively during Monsoon and 16.13±0.49, 3.65±0.16, 2.54±0.21 and 74.82±0.58, respectively during post-monsoon. It was noticed that protein, lipid and ash contents were higher in post-monsoon season, but the water content was higher in Monsoon (Table 1).

Fish myofibrils, scale collagen and gelatin varied with season. The circular dichroism (CD) measurement results showed the melting temperature of s-scale ASC (summer fish collagen) was higher than that of w-scale ASC (winter fish collagen) by 3 °C. It was concluded s-scale ASC was more stable than the equivalent from the winter season. The thermal stability of *Cyprinus carpio* scales collagen caught in summer was 1.8 °C higher than that caught in winter (Duan et al., 2010). The gelatins from summer fish presented higher melting points and gel strengths, as well as better viscosity properties than the winter equivalents (Duan et al., 2011). *Hypophthalmichthys molitrix* myofibrils in autumn and summer surimi were much more stable than those in winter and spring surimi by about 10 °C indicating autumn and summer surimi containing stable myofibrils required higher temperature than winter and spring surimi for the gel formation (Yuan et al., 2005). Besides, the structure thermal stability of myosin rod from silver carp was affected by season change (Zheng et al., 2012).

2.2 Marine-water fish

Generally, composition of live-weight, whole fish is 70 to 80% water, 20 to 30% protein, and 2 to 12% lipid (Love, 1980). Marine fish have long been recognized as a valuable resource of high quality protein with a high biological value, essential minerals, vitamins and good source of essential fatty acids in human diet (Kumaran, 2013; Mohanty et al., 2015). The proximate composition of fish varies greatly from one species or one individual to another based on the starvation and intensive food intake periods (Huss, 1995) and external factors such as salinity and temperature. Moisture has slight role in nutrition whereas it is imperative from technological point of view (Langer et al., 2013). The protein digested and incorporate is mostly integrated in the edible part of the fish (Chakwa and Shaba, 2009). Fat content in the fish increases due to the utilization of plankton rich food. Several authors have reported inverse relationship between the moisture and protein. The protein levels of I*stiophorus platypterus* was increased from March and reached in peak level in the month of September. Decline in protein content was noticed from October (spawning period) to February, coinciding with post-spawning period (Table 2). Such depletion in muscle- protein during spawning period has been reported in many fishes (Love, 1997). Lipids are the prime energy storage substance in fish. Fat content is a good index of prospect survival in some species (Simpkins et al., 2003) and a strong indicator of reproductive prospective in some fish stocks (Pearson, 1999). The concentration of minerals and trace elements that contribute for the total ash contents are known to differ in fish depending on their increasing weight, feeding behavior or length of fish (Langer et al., 2013) season, ecosystem, environment and migration even within the same area. The content of ash varies with the time of storage due to absorbance of moisture and loss of protein (Langer et al., 2013).

Protein content of Harpodon nehereus found high in winter and lowest in autumn as due to spawning (Table 2). Considering the lipid content, minimum and maximum value were observed in the autumn and winter, respectively. Moisture content in muscle tissue shows an inverse relation with that of lipid and protein values and the lowest value is noted in summer and the highest value in autumn. A positive correlation was observed between protein and lipid content of *H. nehereus*.

It has been found that dry matter percentage in *Sardinella gibbosa* varied slightly remaining within the range of 2% variation (Hrubec et al., 2001). Lipid percentage decreases in the summer and slightly increases in the monsoon. It has also been found that the main nutrient composition was crude protein (Chakwa and Shaba, 2009). Crude protein percentage increases in the summer season and decreases in the monsoon. Ash content also decreases from winter to summer and increases in the monsoon. Seasonal differences in the availability of food and changes in the reproduction cycle have considerable effect on the tissue biochemistry of the fish, particularly lipid (Kabir et al., 2012). The variation of lipid content with feed intake and found that intensive feeding. According to FAO moisture and lipid contents in fish fillets are inversely related and their sum is approximately 80% with other components accounting for the remaining 20%. This inverse relationship has also been reported in marine fishes such as, *Pseudosciaena aeneas* and *Johnius carutta* (Rao and Rao, 2002), *Mullus barbatus* (Lloret et al., 2007). Fish protein contains all essential amino acids which are easy to digest. The protein digested and assimilated is mostly incorporated in the muscles of the fish (Dabhade et al., 2009). Ali et al. (2001) has reported that protein content, which is a vital constituent of living cells, tends to vary relatively little in healthy fish unless drawn upon during particular demands of reproduction or during food deprivation periods. Tuna contains high amount of protein (27%) and also rich in essential amino acids (Love, 1997). (Matsumoto et al., 1984) has stated that

Table 2. Seasonal variation in proximate composition (%) of some marine-water fish

Particular	Summer	Autumn	Winter
Species: *Istiophorus platypterusin* (Pearson, 1999)			
Moisture	77.53±0.12	76.61±0.10	77.80±0.18
Protein	18.16±0.05	18.59±0.07	16.37±0.02
Lipid	2.45±0.09	2.43±0.08	2.67±0.08
Ash	1.54±0.10	1.55±0.08	2.79±0.11
Species: *Harpodon nehereus* (Shingadia, 2013)			
Moisture	82.21±2.07	88.15±0.96	85.54±0.17
Protein	27.6±0.17	21.0±0.12	31.7±0.05
Lipid	0.26±2.09	0.25±0.11	0.19±0.41
Ash	0.72±3.07	0.60±0.05	1.31±0.64
Species: *Sardinella gibbosa* (Bagthasingh et al., 2016)			
Moisture	76.47±0.28	76.5±0.28	75.16±0.10
Protein	17.5±0.14	15.5±0.20	15.43±0.23
Lipid	2.34±0.02	3.89±0.01	6.33±0.03
Ash	1.92±0.01	2.11±0.04	2.19±0.005
Species: *Schizothorax niger* (Ahmed and Sheikh, 2016)			
Moisture	71.92±2.09	72.12±1.89	76.87±1.31
Protein	17.53±0.61	16.26±0.99	12.92±0.57
Lipid	5.56±0.52	5.14±0.69	3.18±0.26
Ash	2.42±0.32	3.02±0.18	3.20±0.33
Species: *Rastrelliger kanagurta* (Nisa and Asadullah, 2011)			
Moisture	74.21±2.17	73.07±2.36	70.11±3.05
Protein	20.0±.85	19.4±.29	16.65±.91
Lipid	3.00±0.09	4.50±2.27	12.00±.96
Ash	1.2±0.04	1.34±.01	.89±.01
Species: *Auxis thazard* (Rani et al., 2016)			
Moisture	79.71±0.36	74.87±0.18	76.55±0.34
Protein	18.86±0.30	23.34±0.21	21.34±0.35
Lipid	0.69±0.19	1.25±0.07	1.17±0.05
Ash	0.86±0.20	0.77±0.19	1.01±0.27
Species: *Euthynnus affinis* (Rani et al., 2016)			
Moisture	77.01±0.16	73.5 3±0.21	75.61±0.52
Protein	20.54±0.31	25.16±0.10	22.50±0.22
Lipid	1.37±0.16	0.75±0.11	0.68±0.01
Ash	1.13±0.14	1.00±0.02	0.96±0.13
Species: *Lethrinus lentjan* (Mathana et al., 2012)			
Carbohydrate	1.42±0.05	1.489±0.03	1.457±0.04
Protein	19.15±0.01	22.82±0.13	18.10±0.11
Lipid	9.79±0.02	8.71±0.04	7.64±0.07
Species: *Holothuria leucospilota* (Sree et al., 1994)			
Moisture	64.09	73.63	61.57
Protein	3.26	1.84	2.99
Lipid	14.37	6.98	9.64
Ash	14.03	14.51	11.56

Summer= pre-monsoon (pre-spawning), Autumn= monsoon (spawning), Winter= post-monsoon (post-spawning) protein content of skipjack was 21.45%, and that of *Thunnus tonggol* 21.8% (Manzano et al., 2000). Decline in protein content was noticed from October (spawning period) to February, coinciding with post-spawning period. Such depletion in muscle-protein during spawning period has been reported in many fishes (Love, 1997). Selvaraj (1984) has reported depletion in muscle protein in I*lisha melastoma*, and noted that it might be due to the fact that the build-up of gonad is often accomplished at the expense of body proteins. According to Dabhade et al. (2009) muscle protein started declining gradually during spawning and post-spawning phases in *Channa gachua*. This decline of muscle protein is attributed to its transfer into ovaries to meet energy requirement of fish during spawning and post spawning phases. Fats are the primary energy storage material in fish (Selvaraj, 1984; Love, 1997; Adams, 1999). Lipid content is a good index of future survival in some species and a strong indicator of reproductive potential in some fish stocks (Simpkins et al., 2003). The higher lipid content in some species of fish is of nutritional value as that support protective effect against coronary heart disease due to the presence of marine omega-3 fatty acids (Alonso et al., 2003). In another study, the lipid content is relatively lower than blue fin tuna *Thunnus orientalis* (2.06 ± 0.57) (Peng et al., 2013). Ash is a measure of the mineral content of any food including fish (Omotosho et al., 2010). The concentration of minerals and trace elements that contribute for the total ash contents are known to vary in fish depending on their feeding behavior, increasing weight or length of fish season (Hassan, 1996) environment, ecosystem and migration even within the same area (Andres et al., 2000; Canli and Atli, 2003; Abdallah, 2007). The ash content changes with the time of storage due to absorbance of moisture and loss of protein (Hassan, 1996). Smaller sized fish species show higher ash content due to the higher bone to flesh ratio (Daramola et al., 2007). Rani et al. (2016) observed that the accumulation of ash was more in pre-monsoon season followed by monsoon season and post-monsoon season in *E. affinis* whereas ash percentage was found to be more in post-monsoon season followed by pre-monsoon season and monsoon season of *A. thazard*.

During all the season, the moisture content was ranged from 71.92-76.87% (Table 2) with the highest (76.87%) values was recorded during winter season. However, no significant difference was observed in moisture content of *S. niger* among three seasons except winter season. Contrary to this, the present study, showed a wide variation in the body moisture contents of *S. niger* during the month wise study, where in between the season some months showed significant difference in their body moisture content, though at the same time some insignificant differences in the moisture content in between the months of the same season were also seen (Ahmed and Sheikh, 2016). Moisture content shows an inverse relationship with that of fat content as one increases, the other decreases (Hrubec et al., 2001; Pradhan et al., 2011). The present finding is in agreement with the findings of the above researchers. Clark and Almy (1918) also found inverse relationship between moisture and fat content, while protein content was varied little with the season. The changes in moisture can be attributed to changes in fat level directly and to spawning and feeding intensity indirectly.

In general, the body composition of *Rastrelliger kanagurta* showed considerable monthly variation among their major biochemical constituents, which showed a well-defined seasonal cyclic pattern. Overall, the substantial difference in various biochemical constituents of *R. kanagurta* between the seasons were presented in Table 3. The body moisture content of *R. kanagurta* was found to be higher (74.21±2.17%) in summer season, whereas the lowest body moisture content (70.11±3.05%) was recorded in winter season. The maximum body protein content (20.0±.85%) was recorded during summer season. After summer season the next higher protein content (19.4±.29%) was registered during autumn season, while lowest (16.65±.91%) body protein content was observed in *R. kanagurta* during winter season. The maximum fat content (12.00±.96%) was observed during winter season. After winter season, the next higher value of body fat content (4.50±2.27%) was reported in the autumn season which was not much different with the fat value recorded during summer season. The body ash content was found to be higher (1.34±.01%) during autumn season, while the remaining two seasons had not mark any influence on the body ash content of *R. kanagurta*.

The proximate composition of *Auxis thazard* and *Euthynnus affinis* has been given in Table 2. The moisture content was higher during pre-moonson and lowest during moonson for *A. thazard* and *E. affinis*, respectively (Table 2). Protein content was higher during the first and second season of the year in both cases. *A. thazard* and *E. affinis* showed higher fat content during post-moonson and pre-moonson of the year, respectively. In comparison of two species, *A. thazard* accumulated more fat content in monsoon and post-monsoon and less content was observed in pre-monsoon season than *E. affinis*. Similar results was found in case of ash content for both cases. The total mean concentration of ash content was accumulated more in *E. affinis* when compared to *A. thazard*. Season wise data of the two species indicated more ash percentage in monsoon and pre-monsoon season and less percentage was found in postmonsoon season in *E. affinis*, respectively (Rani et al., 2016). Seasonal data showed that even though fat content is somewhat high in the study but the variation trend was to some extent in agreement with the values of Nisa and Asadullah (2011) for the Indian horse mackerel.

According to Borges and Gordo (1991), the spawning season of this species takes place during the first semester of the year, which would be the probable reason of low fat content in this time of year. Protein percent reached its maximum in summer and minimum in winter. Low protein in this month may suggest that protein may utilize for metabolic energy.

Proximate composition of *Lethrinus lentjan* in different seasons was observed by Mathana et al. (2012) is also shown in Table 2. Carbohydrate, protein, and lipid contents were 1.42±0.05, 19.15±0.01 and 9.79±0.02, respectively during pre-spawning season and during spawning season the proximate compositions were 1.489±0.03, 22.82±0.13 and 8.71±0.04 respectively, and in post-spawning season the proximate composition were 1.457±0.04, 18.10±0.11 and 7.64±0.07, respectively (Table 2). It was noticed that protein and carbohydrate contents were higher in spawning season, but the lipid content was higher in pre-spawning season and then gradually decrease. Among the biochemical components analyzed, the lipid content in the tissues showed more seasonal variations during the progress of gonad maturation (Castell et al., 1972).

The substantial differences in biochemical composition of *Holothuria leucospilota* between the seasons were mentioned in Table 2 studied by (Sree et al., 1994). Significantly higher moisture content (73.63%) was found in spawning season while maximum protein (3.26%) and fat (14.37%) and ash (14.03%) contents were recorded during pre-spawning season. Lowest lipid and protein content was reported during spawning season.

3 Seasonal variation in amino and fatty acid profiles

The variation of different essential and non-essential amino acids at different season has presented in Table 3. Analysis of the amino acid profile showed that lysine was predominant followed by glutamic acid. High concentration of arginine, glycine and aspartic acid were found during amino acid analysis and they also showed seasonal dependency (Rana et al., 2019). Among 6 essential and 8 non-essential amino acids higher concentration were observed during premonsoon season than any other season and lower amount of amino acids were found in post-monsoon season. In pre-monsoon, monsoon and post-monsoon season ratio of EAA/NEAA was 0.68, 0.68 and 0.69 respectively. Ratio of EAA/NEAA were more or less similar during seasonal variation (Table 3).

Fatty acids have specific importance in nutritional values concept. Concentration of fatty acids in *Monopterus cuchia* is shown in Table 4. Total 25 fatty acids were found in this fish. In tested samples of fish, total 55.8% of saturated fatty acid (SFA) content were found in pre-monsoon season, 42.8% were found in monsoon period and 33.9% were found in post-monsoon season. Among all the fatty acids saturated fatty acids were found at higher concentration compared to mono and poly unsaturated fatty acids all over the year. The palmitic acid was primary fatty acid in the analysis of all the saturated fatty acids. 19.81±0.002%, 22.10±0.067%, 15.98±0.002% were found in pre-monsoon, monsoon and post-monsoon season respectively in *Monopterus cuchia* (Rana et al., 2019). Similarly, the total saturated fatty acid (SFA) varied from 31.6% to 46.85% ($p<0.05$) in Indian mackerel (*Rastrelliger kanagurta*), the highest in July and the lowest in February (Nisa and Asadullah, 2011). More or less similar result reported by other researchers (Bandarra et al., 2001; Celik, 2008; Nisa and Asadullah, 2008; Zlatanos and Laskaridis, 2007),

In case of MUFAs higher content was found in post-monsoon season than any other season and lower content was found in pre-monsoon season. PUFAs also showed the same thing in case of total content. Among all the MUFAs oleic and palmitoleic acids were predominant fatty acids (Table 5). Among the PUFAs linoleic acid was the most abundant fatty acid 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. EPA was not found in *Monopterus cuchia* in pre-monsoon period, on the other hand DHA were found in all the season though the content of DHA showed seasonal dependency. But the summation of EPA and DHA values showed higher content in monsoon period. 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. The seasonal changes of total PUFA had a considerable effect on the variation of unsaturated fatty acid content, from season to season which may suggest that PUFA may be responsible for the seasonal variation of total unsaturated fatty acids (Nisa and Asadullah, 2011).

The amount of total lipid obtained from the muscle of W. attu during generation period (February to May, being a pre-monsoon breeder), shows a tendency to decrease. The value reaches its minimum in May and again starts increasing from June to October. During breeding season the amount of total fatty acid also shows the same tendency to decrease till May when it reaches its minimum. From June onwards the total fatty acid increases significantly. Thus one can conclude that both the total lipid content and total fatty acid content of W. attu varies throughout the year (Table 6). This is quite natural as the storage of lipids, fatty acids in different organs and tissues in a fish are the results of irregular seasonal variations and water temperature, which affect the fish diet (Agren et al., 1987; Dutta et al., 1985; Kinsella, 1987).

Reproduction and nutritional physiology are two major biological event in the whole life span of a fish

Table 3. Amino acids profile (%) of *Monopterus cuchia* captured in different seasons (Rana et al., 2019)

Amino acids	Pre-monsoon	Monsoon	Post-monsoon
Threonine	1.25±0.02	0.63±0.02	0.54±0.02
Valine	1.68±0.03	0.72±0.02	0.65±0.02
Methionine	2.15±0.02	0.97±0.02	0.93±0.02
Isoleucine	1.85±0.02	0.88±0.02	0.82±0.03
Leucine	2.19±0.02	0.87±0.03	0.84±0.02
Lysine	3.88±0.02	1.76±0.02	0.68±0.02
∑EAA	12.99	5.42	5.86
Aspartic acid	2.24±0.02	0.95±0.02	0.95±0.02
Serine	1.62±0,02	0.74±0.02	0.74±0.03
Glutamic acid	3.60±0.03	1.56±0.02	1.26±0.03
Glycine	3.11±0.02	1.46±0.02	1.31±0.02
Alanine	1.68±0.02	0.76±0.02	0.65±0.02
Histidine	1.89±0.03	0.85±0.04	0.88±0.03
Tyrosine	1.64±0.03	0.78±0.02	0.67±0.03
Arginine	3.36±0.02	1.53±0.02	1.47±0.02
∑NEAA	19.13	8.62	7.91
EAA/NEAA	0.68	0.68	0.69

Table 4. Saturated fatty acid (%) of *Monopterus cuchia* captured in different seasons (Rana et al., 2019)

Saturated fatty acids	Pre-monsoon	Monsoon	Post-monsoon
Caproic acid (C6:0)	4.67±0.002	1.87±0.002	0.30±0.001
Caprylic acid (C8:0)	8.56±0.004	0.99±0.002	0.84±0.001
Lauric acid (C12:0)	8.27±0.002	3.09±0.012	3.77±0.002
Tridecanoic acid (C13:0)	ND	0.35±0.001	0.49±0.004
Myristic acid (C14:0)	6.15±0.003	4.02±0.019	2.13±0.002
Pentadecyclic acid (C15:0)	0.88±0.001	1.43±0.0004	1.12±0.002
Palmitic acid (C16:0)	19.81±0.002	22.10±0.067	15.98±0.002
Stearic acid (C18:0)	3.98±0.005	5.18±0.001	6.15±0.001
Arachidic acid (C20:0)	1.05±0.005	1.52±0.003	1.76±0.001
Behenic acid (C22:0)	0.66±0.002	–	0.44±0.002
Lignoceric acid (C24:0)	1.75±0.002	2.21±0.003	0.94±0.005
∑SFAs (Total)	55.79	42.77	33.94

Table 5. Mono and poly unsaturated fatty acids (%) of *Monopterus cuchia* captured in different seasons (Rana et al., 2019)

MUFA composition	Pre-monsoon	Monsoon	Post-monsoon
Myristoleic acid (C14:1)	0.37±0.001	1.35±0.001	1.79±0.001
Pentadecenoic acid (C15:1)	9.89±0.001	0.42±0.002	0.83±0.002
Palmitoleic acid (C16:1)	–	9.62±0.003	8.29±0.001
Oleic acid (C18:1)	18.96±0.003	20.79±0.002	25.99±0.001
Eicosenoic acid (C20:1)	–	0.31±0.002	0.50±0.002
∑MUFAs	29.23	32.48	37.42
PUFA composition	Pre monsoon	Monsoon	Post monsoon
Hexadecadienoic acid (C16:2); n-3	0.64±0.001	1.38±0.001	0.68±0.001
Hexadecatrienoic acid (C16:3); n-3	–	2.91±0.001	2.16±0.001
Linoleic acid (C18:2); n-6	6.38±0.001	5.41±0.002	17.79±0.001
α-Linolenic acid (C18:3); n-3	3.98±0.0001	1.98±0.001	1.68±0.001
Eicosadienoic acid (C20:2); n-6	–	0.64±0.002	0.65±0.001
Arachidonic acid (C20:4); n-6	2.07±0.001	3.07±0.001	2.04±0.003
Eicosapentaenoic acid (C20:5, EPA); n-3	–	0.60±0.001	0.28±0.002
Docosapentanoic acid (C22:5); n-3	–	4.02±0.001	2.21±0.002
Docosahexaenoic acid (C22:6, DHA); n-3	1.91±0.0001	4.74±0.001	1.16±0.001
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

Table 6. Seasonal variation of total lipid and fatty acid of muscle of *Wallago attu* (Agren et al., 1987)

Season	Total lipid % (TL)	Total fatty acid % (TFA)	Approx. TFA with respect to TL
Winter	5.89±0.03	3.70±0.04	62.82±0.41
Summer	3.14±0.01	2.39±0.03	76.12±0.30
Autumn	6.98±0.03	5.04±0.05	72.21±15

are closely related with the seasonal changes (Farkas and Csenger, 1976). The amount of total lipid storage in different organs and its utilization is generally varied in accordance to the seasonal changes to meet the requirement of their physiological function. During breeding seasons, lipids are mobilized to the gonads for the development of the gonads (Castell et al., 1972). So, the lipid/fatty acid content in the organs/muscle tissues should decrease. During the summer season, the total lipid percentage and total fatty acid percentage in the muscle tissues of *W. attu* is the minimum (Table 6). At the end of breeding season, fish start the process of storing energy in the form of lipid for future use during reproduction and scarcity of food. That is why during monsoon the fat content reaches to the maximum level in the muscle tissue of *W. attu* and starts to decrease in winter as the reproduction approaches and becomes minimum in summer season.

4 Factors affecting seasonal variation in proximate composition

Seasonal variation of proximate composition in fish influences by various factors like nutrition, age, gender, reproduction (Kalay et al., 2008), and adaptation with environment change. Silver carp produced two types of myosin isoforms, thermostable myosin in summer and unstable one in winter, for the adaptation of the environmental changes (Abe et al., 2019). During May–July, a reduction in muscle protein and lipid were observed and this season was noticed as spawning period. It might be due to utilization of stored energy source to fulfill the high energy demands, during the ovulation and spawning period (Nargis, 1970).

The peak in the muscle lipid and protein content is observed in autumn for fin fish and low at late summer for shellfish (Nargis, 1970). This could be due to optimum availability of food and active feeding, facilitates a good circumstance for building energy reserve in the form of protein and lipid. During monsoon season, a reduction in muscle protein and lipid are observed and this season is noticed as spawning period (Langer et al., 2008). It might be due to utilization of stored energy source to fulfill the high energy demands, during the ovulation and spawning period (Jyotsna et al., 1995). It has been found that change in endocrine system during spawning season have an influence on protein content in fish muscle and is due to the controlling action of endocrine system in supplying nutrients to gonads from all parts of body and thereafter a noticeable rise in protein content is observed a recovery of normal life (Langer et al., 2013). It is also decline that the fat content might be due to low feeding intensity and low availability of food. Declining of muscles lipid content during the period of development and maturation of gonads (John and Hameed, 1995). Fluctuation in lipid content in fish fluctuate greatly and is associated to migratory swimming, sexual changes in connection with spawning, and depletion of gonad and food consumption (Jonsson and Jonsson, 2005; Nargis, 1970). High lipid and protein content in both pre-breeding and breeding season also noticed in three major carps and is due to probable augmented vitellogenesis in ovary and spermatogenesis in testes that required large amount of lipoproteins (Memon et al., 2010). It has been also reported that protein contents decreased with age and fat contents increased accordingly, while no effect on other elements like Cu, Zn and Fe (Oduor-Odote and Kazungu, 2009; Rodrigues et al., 2013). They also reported a negative relationship between protein and lipid levels with age/size. The lipid kept on decreasing with age/size while protein increased accordingly (Hashimoto et al., 1979). The mean water content in the flesh of both fish species reaches its highest level during June to August, as monsoon season, shows an inverse relationship with fat and protein content. This inverse relation might be due to unavailability of food, low food intake, low atmospheric temperature, and high energy demands to homeostasis the body temperature etc. (Langer et al., 2013; Simat and Bogdanović, 2012). Ash content showed no significant correlation with other constituents in the tissue, proving there is no direct relationship between the ash and feeding or spawning activities.

5 Conclusion

This study has provided the basic information about nutritional values including principal nutrients, fatty acids and amino acids profile of different freshwater and marine fishes of Bangladesh and other South Asian countries like India, Pakistan in respect to seasonal changes. We found a greater variation in lipid content compared to protein, moisture and ash content. Amino acid and fatty acids also showed seasonal dependency in several fish species. These types of seasonal data of various commercial species can help us to understand the changes in nutritional values in different seasons are important for the fish used as food by consumers and it also helps in determining the time of fish harvesting. However, this review suggests advanced research on the nutritional composition of different fishes focusing on amino acid, fatty acid, micronutrients (vitamins and minerals) and nutritional variation in sexes i.e. male and female.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

Abdallah MAM. 2007. Speciation of Trace Metals in Coastal Sediments of El-Mex Bay South Mediterranean Sea–West of Alexandria (Egypt). Environmental Monitoring and Assessment 132:111–123. doi: 10.1007/s10661-006-9507-z.

Abdullahi SA, Abolude DS, Ega RA. 2001. Nutrient quality of four oven dried freshwater catfish species in Northern Nigeria. Journal of Tropical Biosciences 1:70–76.

Abe K, Yuan C, Kumagai Y, Kishimura H. 2019. The potential of freshwater fish viscus from silver carp hypophthalmichthys molitrix for trypsin source. aste and Biomass Valorization 11:3971–3978. doi: 10.1007/s12649-019-00717-7.

Aberoumad A, Pourshafi K. 2010. Chemical and proximate composition properties of different fish species obtained from Iran. World journal of fish and marine science 2:237–239.

Adams SM. 1999. Ecological role of lipids in the health and success of fish populations. In: Lipids in Freshwater Ecosystems. Springer New York. p. 132–160. doi: 10.1007/978-1-4612-0547-0_8.

Adelakun KM, Mustapha MK, Amali RP, Mohammed N. 2017. Seasonal variation in nutritional quality of Catfish (*Clarias gariepinus*) from Upper Jebba Basin, Nigeria. Journal of Nutrition & Food Science 7:5–9.

Agren J, Muje P, Hanninen O, Herranen J, Penttila I. 1987. Seasonal variations of lipid fatty acids of boreal freshwater fish species. Comparative Biochemistry and Physiology Part B: Comparative Biochemistry 88:905–909. doi: 10.1016/0305-0491(87)90262-8.

Ahmed I, Sheikh ZA. 2016. Study on the Seasonal Variation in the Chemical Composition, Hematological Profile, Gonado-somatic Index and Hepato-somatic Index of Snow Trout, Schizothorax niger from the Freshwater Dal Lake, Kashmir. American Journal of Food Technology 12:1–13. doi: 10.3923/ajft.2017.1.13.

Ali M, Salam A, Iqbal F. 2001. Effect of environmental variables on body composition parameters of *Channa punctata*. Journal of Research Science 12:200–206.

Alonso A, Martinez MAG, Serrano MM. 2003. Fish omega-3 fatty acids and risk of coronary heart disease. Medicina Clínica 121:28–35. doi: 10.1016/s0025-7753(03)74116-5.

Andres S, Ribeyre F, Tourencq JN, Boudou A. 2000. Interspecific comparison of cadmium and zinc contamination in the organs of four fish species along a polymetallic pollution gradient (Lot River, France). Science of the Total Environment 248:11–25. doi: 10.1016/s0048-9697(99)00477-5.

Andrew AE. 2001. Fish Processing Technology. University of IIorin press, Nigeria.

Ashraf M, Zafar A, Naeem M. 2011. Comparative studies on the seasonal variations in the nutritional values of three carnivorous fish species. International Journal of Agriculture & Biology 13:701–706.

Azim MA, Islam MR, Hossain MB, Minar MH. 2012. Seasonal variations in the proximate composition of Gangetic Sillago, *Sillaginopsis panijus* (Perciformes: Sillaginidae). Middle-East Journal of Scientific Research 11:559–562.

Bagthasingh C, Aran SS, Vetri V, Innocen A, Kannaiyan SK. 2016. Seasonal variation in the proximate composition of sardine (*Sardinella gibbosa*) from Thoothukudi coast. Indian Journal of Geo-Marine Science 45:800–806.

Bandarra NM, Batista I, Nunes ML, Empis JM. 2001. Seasonal variation in the chemical composition of horse-mackerel (*Trachurus trachurus*). European Food Research and Technology 212:535–539. doi: 10.1007/s002170100299.

Begum A, Minar MH, Mahfuj MSE, Begum M. 2013. Monthly variation of biochemical composition of gonia (*Labeo gonius*) collected from Bangladeshi water. International Journal of Life Sciences Biotechnology and Pharma Research 2:227–232.

Begum M, Minar MH. 2012. Comparative study about body composition of different SIS, shell fish and ilish; commonly available in Bangladesh. Trends in Fisheries research 1:38–42.

Binoy KD, Mahanta R, Goswami UC. 2012. Seasonal variation of protein and essential amino acid contents in *Labeo gonius* from lotic and lentic water bodies. World Journal of Life Sciences and Medical Research 2:71.

Bogard JR, Thilsted SH, Marks GC, Wahab MA, Hossain MA, Jakobsen J, Stangoulis J. 2015. Nutrient composition of important fish species in bangladesh and potential contribution to recommended nutrient intakes. Journal of Food Composition and Analysis 42:120–133. doi: 10.1016/j.jfca.2015.03.002.

Boran G, Karacam H. 2011. Seasonal changes in proximate composition of some fish species from Black sea. urkish Journal of Fisheries and Aquatic Science 11. doi: 10.4194/trjfas.2011.0101.

Borges MF, Gordo LS. 1991. Spatial distribution by season and some biological parameters of horse mackerel (*Trachurus trachurus* L.) in the Portuguese continental waters (Division IXa). ICES CM 54:17–21.

Canli M, Atli G. 2003. The relationships between heavy metal (Cd, Cr, Cu, Fe, Pb, Zn) levels and the size of six Mediterranean fish species. Environmental Pollution 121:129–136. doi: 10.1016/s0269-7491(02)00194-x.

Castell JD, Sinnhuber RO, Wales JH, Lee DJ. 1972. Essential fatty acids in the diet of rainbow trout (*Salmo gairdneri*): Growth, feed conversion and some gross deficiency symptoms. The Journal of Nutrition 102:77–85. doi: 10.1093/jn/102.1.77.

Celik M. 2008. Seasonal changes in the proximate chemical compositions and fatty acids of chub mackerel (*Scomber japonicus*) and horse mackerel (*Trachurus trachurus*) from the north eastern mediterranean sea. International Journal of Food Science and Technology 43:933–938. doi: 10.1111/j.1365-2621.2007.01549.x.

Chakwa O, Shaba IM. 2009. Effect of drying method on proximate composition of cat fish (*Clarias gariepinus*). ICES CM 5:114–116.

Clark ED, Almy LH. 1918. A chemical study of food fishes the analysis of twenty common food fishes with especial reference to a seasonal variation in composition. Journal of Biological Chemistry 33:483–498. doi: 10.1016/s0021-9258(18)86566-8.

Dabhade VF, Pathan TS, Shinde SE, Bhandare RY, Sonawane DL. 2009. Seasonal variations of protein in the ovary of fish *Channa gachua*. Recent Research in Science and Technology 1:78–80.

Daramola J, , Fasakin EA, and EOA. 2007. Changes in physicochemical and sensory characteristics of smoke-dried fish species stored at ambient temperature. African Journal of Food and Agriculture, Nutrition and Development 7:169–178. doi: 10.18697/ajfand.17.1980.

DoF. 2017. National Fish Week 2017 Compendium (In Bengali). Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh.

DoF. 2020. National Fish Week 2020 Compendium (In Bengali). Department of Fisheries, Ministry of Fisheries and Livestock, Bangladesh.

Duan R, Konno K, Zhang J, Wang S, Yuan C. 2010. Different thermostability of collagens from scale of carp (*Cyprinus Carpio*) in winter and summer. Journal of Food Biochemistry 34:1275–1287. doi: 10.1111/j.1745-4514.2010.00376.x.

Duan R, Zhang J, Xing F, Konno K, Xu B. 2011. Study on the properties of gelatins from skin of carp (*Cyprinus carpio*) caught in winter and summer season. Food Hydrocolloids 25:368–373. doi: 10.1016/j.foodhyd.2010.07.002.

Dutta H, Das A, Das AB, Farkas T. 1985. Role of environmental temperature in seasonal changes of fatty acid composition of hepatic lipid in an air-breathing Indian teleost, *Channa punctatus* (Bloch). Comparative Biochemistry and Physiology Part B: Comparative Biochemistry 81:341–347. doi: 10.1016/0305-0491(85)90323-2.

FAO. 2020. The state of world fisheries and aquaculture 2020: Sustainability in action. Food and Agriculture Organization, Rome, Italy.

Farkas T, Csenger I. 1976. Biosynthesis of fatty acids by the carp, *Cyprinus carpio* L., in relation to environmental temperature. Lipids 11:401–407. doi: 10.1007/bf02532847.

Ferdose A, Hossain MB. 1970. Nutritional value of wild, cultured and frozen prawn *Macrobrachium rosenbergii* (De Man, 1879). Int J Nat Sci 1:52–55. doi: 10.3329/ijns.v1i2.8821.

Gandotra R, Sharma M, Kumari R. 2017. Studies on the seasonal variations in proximate composition of *Labeo boga*. International Journal of Scientific Research and Modern Education 2:2455–5630.

Gao M, Feng L, Jiang T, Zhu J, Fu L, Yuan D, Li J. 2014. The use of rosemary extract in combination with nisin to extend the shelf life of pompano (*Trachinotus ovatus*) fillet during chilled storage. Food Control 37:1–86. doi: 10.1016/j.foodcont.2013.06.055.

Geiger E, Borgstrom G. 1962. Fish Protein—Nutritive Aspects. In: Fish As Food. Elsevier. doi: 10.1016/b978-0-12-395570-8.50010-6.

Ghosh S, Suri D, Uauy R. 2012. Assessment of protein adequacy in developing countries: quality matters. British Journal of Nutrition 108:S77–S87. doi: 10.1017/s0007114512002577.

Hashimoto K, Watanabe S, Kono M, Shiro K. 1979. Muscle protein composition of sardine and mackerel. Bulletin of the Japanese Society of Scientific Fisheries 45:1435–1441. doi: 10.2331/suisan.45.1435.

Hassan M. 1996. Influence of pond fertilization with broiler dropping on the growth performance and quality of major carps. PhD Thesis, University of Agriculture, Faisalabad, Pakistan.

Hossain M, Adhi RK, Mah KR, Begum M, I MRU. 2012. Effect of 10% concentrations of salt, garlic and coriander on the quality of smoked hilsa fish (*Tenualosa ilisha*). American Journal of Food Technology 7:501–505. doi: 10.3923/ajft.2012.501.505.

Hossain MA, Afsana K, Azad Shah AKM. 1999. Nutritional value of some small indigenous fish species (SIS) of Bangladesh. Bangladesh Journal of Fisheries Research 3:77–85.

Hrubec TC, Smith SA, Robertson JL. 2001. Age-Related Changes in Hematology and Plasma Chemistry Values of Hybrid Striped Bass (*Morone chrysops* × *Morone saxatilis*). Veterinary Clinical Pathology 30:8–15. doi: 10.1111/j.1939-165x.2001.tb00249.x.

Huss HH. 1988. Fresh fish: quality and quality changes. Food and Agriculture Organization, Rome, Italy.

Huss HH. 1995. Quality and quality changes in fresh fish. Fisheries Technical, Food and Agriculture Organization, Rome, Italy.

Islam MN, Joadder MAR. 2005. Seasonal Variation of the Proximate Composition of Freshwater Gobi, *Glossogobius giuris* (Hamilton) from the River Padma. Pakistan Journal of Biological Sciences 8:532–536. doi: 10.3923/pjbs.2005.532.536.

John TS, Hameed MS. 1995. Biochemical composition of *Nemipterus japonicus* and *Nemipterus mesoprion* in relation to maturity cycle. Fishery Technology (India) 32:102–107.

Jonsson B, Jonsson N. 2005. Lipid energy reserves influence life-history decision of Atlantic salmon (*Salmo salar*) and brown trout (*S. trutta*) in fresh water. Ecology Freshwater Fish 14:296–301. doi: 10.1111/j.1600-0633.2005.00098.x.

Jyotsna K, Nilesh K, Verma PK, Fasihuddin MD. 1995. Distribution of bio constituents in various tissues during pre and post-spawning periods of *Channa striatus* (Bloch). Journal of Inland Fisheries Society of India 27:14–17.

Kabir KMR, Adhikary RK, Hossain MB, Minar MH. 2012. Livelihood status of fishermen of the old Brahmaputra River, Bangladesh. World Applied Sciences Journal 16:869–873.

Kalay M, Sangun MK, Ayas D, Gocer M. 2008. Chemical Composition and Some Trace Element Levels of Thinlip Mullet, *Liza ramada* Caught from Mersin Gulf. Ekoloji 17:11–16. doi: 10.5053/ekoloji.2008.682.

Kinsella JE. 1987. Summary of needs, in Sea foods and fish oils in human health and disease. Marcel Dekker, Inc. New York.

Kumaran R. 2013. Studies on nutritional aspects of trash/ low coast fishes of Thoothukudi, southeast coast of India. PhD Thesis in Annamalai University, Tamil Nadu, India.

Langer S, Manhas P, Bakhtiyar Y, Rayees S, Singh G. 2013. Studies on the Seasonal Fluctuations in the Proximate Body Composition of *Paratelphusa masoniana* (Henderson) (Female), a Local Freshwater Crab of Jammu Region. Advanced Journal of Food Science and Technology 5:986–990. doi: 10.19026/ajfst.5.3336.

Langer S, Samyal A, Bakhtiyar Y. 2008. Studies on ovarian development of *Macrobrachium dayanum* (hend.) in relation to *Gonadosomatic index* and *Hepatosomatic index*. Biosciences Biotechnology Bioresearch Asia 5:289–294.

Lloret J, Demestre M, Sánchez-Pardo J. 2007. Lipid reserves of red mullet (*Mullus barbatus*) during prespawning in the northwestern mediterranean. Scientia Marine 71:269–277. doi: 10.3989/scimar.2007.71n2269.

Love RM. 1980. The Chemical Biology of Fishes. Academic press. New York, USA.

Love RM. 1997. Biochemical dynamics and the quality of fresh and frozen fish. In: Hall GM (Ed), Fish Processing Technology. Springer. doi: 10.1007/978-1-4613-1113-3_1.

Mahfuj MSE, Hossain MB, Minar MH. 2012. Biochemical Composition of an Endangered Fish, *Labeo bata* (Hamilton, 1822) from Bangladesh Waters. American Journal of Food Technology 7:633–641. doi: 10.3923/ajft.2012.633.641.

Manon MR, Hossain MD, Khanom A, Jewel MAS, Khatun MM. 2015. Biochemical composition of *Cyprinus carpio* var. *specularis* on the basis of sex and seasonal variation in Atrai River 34:15–19.

Manzano MG, Navar J, Pando M M, Martínez A, et al. 2000. Overgrazing and desertification in northern Mexico: highlights on north eastern region. Annals of Arid Zone 39:285–304.

Mathana P, Raj ST, Nair CRK, Selvamohan T. 2012. Seasonal changes in the biochemical composition of four different tissues of red spotted emperor *Lethrinus lentjan* (family: Lethrinidae). Annals of Biological Research 3:5078–5082.

Matsumoto WM, Skillman RA, Dizon AE. 1984. Synopsis of biological data on skipjack tuna, *Katsuwonus pelamis*. 136. National Oceanic and Atmospheric Administration, National Marine Fisheries.

Memon NN, Talpur FN, Bhanger MI. 2010. A comparison of proximate composition and fatty acid profile of indus river fish species. International Journal of Food Properties 13:328–337. doi: 10.1080/10942910802398479.

Mohanty B, Mahanty A, Ganguly S, Sankar TV, Chakraborty K, Rangasamy A, Paul B, Sarma D, Mathew S, Asha KK, Behera B, Aftabuddin M, Debnath D, Vijayagopal P, Sridhar N, Akhtar MS, Sahi N, Mitra T, Banerjee S, Paria P, Das D, Das P, Vijayan KK, Laxmanan PT, Sharma AP. 2014. Amino acid compositions of 27 food fishes and their importance in clinical nutrition. Journal of Amino Acids 2014:1–7. doi: 10.1155/2014/269797.

Mohanty SS, Dash BP, Pramanik DS. 2015. Proximate composition of three marine fishes of Chandipur, Bay of Bengal, India. International Journal of Fisheries and Aquatic Studies 2:354–358.

Munny FJ, Uddin MS, Islam MS, Debnath P, Suravi IN, Alam MMM. 2020. Proximate composition of Labeo calbasu at different seasons in Sunamgonj of Bangladesh. Journal of Fisheries and Life-science 5:1–4.

Nargis A. 1970. Seasonal Variation in the Chemical Composition of Body Flesh of Koi Fish *Anabas testudineus* (Bloch) (Anabantidae: Perciformes). Bangladesh J. Sci. Ind. Res. 41:219–226. doi: 10.3329/bjsir.v41i3.292.

Nichols P, McManus A, Krail K, Sinclair A, Miller M. 2014. Recent advances in omega-3: Health benefits, sources, products and bioavailability. Nutrients 6:3727–3733. doi: 10.3390/nu6093727.

Nisa K, Asadullah K. 2008. Seasonal variation in lipid composition of sardine (*Sardinella gibbosa*) from Karachi coast. Journal of the Chemical Society of Pakistan 30:436–441.

Nisa K, Asadullah K. 2011. Seasonal variation in chemical composition of the Indian mackerel (*Rastrelliger kanagurta*) from Karachi Coast. Iranian Journal of Fisheries Sciences 10:67–74.

Nowsad AKMA. 2007. Participatory Training of Trainers: A New Approach Applied in Fish Processing. Bangladesh Fisheries Research Forum, Bangladesh.

Oduor-Odote PM, Kazungu JM. 2009. The body composition of low value fish and their preparation into a higher value snack food. Western Indian Ocean Journal of Marine Science 7. doi: 10.4314/wiojms.v7i1.48271.

Omotosho OE, Oboh G, Iweala EEJ. 2010. Comparative effects of local coagulants on the nutritive value, *in vitro* multienzyme protein digestibility and sensory properties of wara cheese. International Journal of Dairy Science 6:58–65. doi: 10.3923/ijds.2011.58.65.

Osako K, Yamaguchi A, Kurokawa T, Kuwahara K, Saito H, Nozaki Y. 2003. Seasonal variation in docosahexaenoic acid content in horse mackerel caught in the east china sea. Fisheries Science 69:589–596. doi: 10.1046/j.1444-2906.2003.00661.x.

Pal M, Ghosh M. 2013. Assay of biochemical compositions of two indian fresh water eel with special emphasis on accumulation of toxic heavy metals. Journal of Aquatic Food Product Technology 22:27–35. doi: 10.1080/10498850.2011.622070.

Patton JS. 1975. The effect of pressure and temperature on phospholipid and triglyceride fatty acids of fish white muscle: A comparison of deepwater and surface marine species. Comparative Biochemistry and Physiology Part B: Comparative Biochemistry 52:105–110. doi: 10.1016/0305-0491(75)90124-8.

Paul BN, Bhowmick S, Chanda S, Sridhar N, Giri SS. 2018. Nutritional values of minor carps. SAARC Journal of Agriculture 16:215–231. doi: 10.3329/sja.v16i1.37436.

Paul BN, Bhowmick S, Singh P, Chanda S, Sridhar N, Giri SS. 2019. Seasonal variations in proximate composition of nine freshwater fish. Indian journal of Animal Nutrition 36:65. doi: 10.5958/2231-6744.2019.00011.2.

Paul BN, Chanda S, Bhowmick S, Sridhar N, Saha GS, Giri SS. 2017. Nutrient profile of indian climbing perch, anabas testudineus. SAARC Journal of Agriculture 15:99–109. doi: 10.3329/sja.v15i1.33156.

Paul BN, Chanda S, Sridhar N, Saha GS, Giri SS. 2015a. Fatty acid profile of indian major carp. Indian journal of Animal Nutrition 32:221–226.

Paul BN, Chanda S, Sridhar N, Saha GS, Giri SS. 2015b. Proximate and mineral composition of magur (*Clarias batrachus*) and singhi (heteropneustes fossilis). Indian journal of Animal Nutrition 32:453–456. doi: 10.5958/2231-6744.2015.00017.1.

Pearson D. 1999. Pearson's Composition and analysis of foods. University of Reading.

Peng S, Chen C, Shi Z, Wang L. 2013. Amino acid and fatty acid composition of the muscle tissue of yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*). Journal of Food and Nutrition Research 1:42–45.

Pradhan SC, Patra AK, Sarkar B, Pal A. 2011. Seasonal changes in hematological parameters of *Catla catla* (Hamilton 1822). Comparative Clinical Pathology 21:1473–1481. doi: 10.1007/s00580-011-1316-2.

Quazi S, Banu CP, Rahman MM, Sayeed S. 1995. Mineral content of fresh water and marine fish species. University Library, University of the Philippines at Los Banos.

Rana S, Faruque MH, Eshik MME, Hasan MR, Rahman MS. 2019. Seasonal variations in nutritional profile of the freshwater mud eel, *Monopterus cuchia* (Hamilton, 1822). Journal of Fisheries 7:671–680. doi: 10.17017/jfish.v7i1.2019.327.

Rani PSCHPD, Kumar VP, Rao RK, Shameem U. 2016. Seasonal variation of proximate composition of tuna fishes from Visakhapatnam fishing harbor, east coast of India. International Journal of Fisheries and Aquatic Studies 4:308–313.

Rao PS, Rao LM. 2002. Variations in bio-chemical composition of *Glossogobius giuris* (Hamilton) from Gosthani with observation on distribution (*Caranx sexfasciatus* host India). Current Science 35:101–102.

Ravichandr S, Joseph FRS, Kanagalaks R, Ramya MS. 2011. Variation in nutritive composition of two commercially important marine fin fishes. International Journal of Zoological Research 8:43–51. doi: 10.3923/ijzr.2012.43.51.

Rodrigues KA, Macchi GJ, Massa A, Militelli MI. 2013. Seasonal analysis of condition, biochemical and bioenergetic indices of females of Brazilian flathead, *Percophis brasiliensis*. Neotropical Ichthyology 11:153–162. doi: 10.1590/s1679-62252013000100018.

Samyal A, Bakhtiyar Y, Verma A, Langer S. 2011. Studies on the seasonal variation in lipid composition of muscles, hepatopancreas and ovary of freshwater prawn, *Macrobrachium dayanum* (henderson) during reproductive cycle. Advanced Journal of Food Science and Technology 3:160–164.

Sankar TV, Ramachandran A. 2001. Changes in biochemical composition in Indian major carps in relation to size. Fisheries Technology 38:22–27.

Saylor Academy. 2012. South Asia (Chapter 9). In: World Regional Geography: People, Places and Globalization. https://saylordotorg.github.io/text_world-regional-geography-people-places-and-globalization/s12-south-asia.html.

Selvaraj G. 1984. Note on the biochemical composition of the Indian Shad *Ilisha melastoma* (Schneider). Indian Journal of Fisheries 31:162–165.

Shakir HA, Qazi JI, Chaudhry AS, Hussain A, Ali A. 2013. Nutritional comparison of three fish species co-cultured in an earthen pond. Biologia (Pakistan) 59:353–358.

Shingadia HU. 2013. Seasonal Variation in Proximate Composition of Bombay duck, Harpodon nehereus (Ham-Buch) from Mumbai Coast. International Journal of Advanced Research 1:52–55.

Silva JJ, Chamul RS. 2000. Composition of marine and fresh water finfish and shellfish species. Marine and fresh water handbook. Technomic Publishing, Lancaster.

Simat V, Bogdanović T. 2012. Seasonal changes in proximate composition of anchovy (*Engraulis encrasicolus*, L.) from the central Adriatic. Acta Adriatica 53:125–132.

Simpkins DG, Hubert WA, Rio CMD, Rule DC. 2003. Physiological responses of juvenile rainbow trout to fasting and swimming activity: Effects on body composition and condition indices. Transactions of the American Fisheries Society 132:576–589. doi: 10.1577/1548-8659(2003)132<0576:projrt>2.0.co;2.

Sree VJ, Parulekar AH, Wahidulla S, Kamat SY. 1994. Seasonal changes in biochemical composition of *Holothuria leucospilota* (echinodermata). Indian Journal of Geo-Marine Sciences 23:60–63.

Stansby ME. 1985. Fish or fish oil in the diet and heart attack. Marine Fishery Review 46:60–63.

Tilami SK, Sampels S. 2017. Nutritional value of fish: Lipids, proteins, vitamins, and minerals. Reviews in Fisheries Science & Aquaculture 26:243–253. doi: 10.1080/23308249.2017.1399104.

Varghese T, Mathew S. 2016. Seasonal variations in the proximate composition of Asian stinging catfish *Heteropneustes fossilis* (bloch, 1794) and banded snakehead (*Channa striata*) (bloch, 1793) collected from paddy field of Kerala. Trends in Fisheries Resserach 5:2319–4758.

Waterman JJ. 2000. Composition and Quality of Fish. Torry Research Station, Edinburgh.

Yuan C, Fukuda Y, Kaneniwa M, Chen S, Cheng Y, Wang X, Konno K. 2005. Comparison of gel-forming properties of silver carp (*Hypophthalmichthys molitrix*) surimi prepared in different seasons. Journal of Food Science 70:326–331. doi: 10.1111/j.1365-2621.2005.tb09961.x.

Zheng L, Yu K, Yuan C, Wang X, Chen S, Kimura I, Konno K. 2012. Characterization of myosin subfragment-1 of summer and winter silver carp (*Hypophthalmichthys molitrix*) muscle. Journal of Food Science 77:C914–C920. doi: 10.1111/j.1750-3841.2012.02835.x.

Zlatanos S, Laskaridis K. 2007. Seasonal variation in the fatty acid composition of three mediterranean fish – sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicholus*) and picarel (*Spicara smaris*). Food Chemistry 103:725–728. doi: 10.1016/j.foodchem.2006.09.013.

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