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Chemical Composition and Nutritional Value of Dried Fish in Bangladesh

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ABSTRACT

Nowadays, people are very conscious about health and nutritional issues and they concern about the nutritional value of the dried fish when they buy these foods for their household consumption. The review article mainly focused on the chemical composition of dried fishes of Bangladesh including protein and amino acid, fats and fatty acid profile, and minerals along with their health benefits. Dried fish is a specially processed fishery product along with high nutritional value and health benefits due to important nutritional components. The principal components of dried fish are high-quality protein and amino acids. It also contains lipids, polyunsaturated fatty acids, especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA); richer mainly in marine dried fish. Small dried fishes contain more mineral contents such, as calcium, iron, potassium, sodium, phosphorus, zinc, etc. compared to the larger ones. Therefore, the consumption of dried seafood has beneficial effects on human health. It helps in forming body tissues, antibodies, and enzymes, repairing worn-out tissues, with the decreased risk of coronary heart and cardiovascular diseases. In addition, it cures inflammatory diseases such as arthritis and prevents cancer, reduces lower insulin resistance, triglyceride, and obesity, and improves hyperglycemia, etc. While undernutrition is still negatively affecting the health and well-being of many people. Based on proximate composition, amino acids, fatty acids profile, and minerals, it can be concluded that dried fish can be a good source of health beneficial nutrients for humans.

INTRODUCTION

Fish is one of the most perishable food items and several preservation methods are implemented worldwide for preserving fish. Like other tropical countries, in Bangladesh fish drying is a prime and an inexpensive preservation method **(Balachandran, 2001; Jain & Pathare, 2007; Majumdar *et al.*, 2018)**. Drying implies the removal of water from the fish body through evaporation with the effect of the sun and wind which gives characteristic color texture and flavor of the fish products **(Nowsad, 2005)**. The consumer preference of the dried fish product is not only because of their traditionally desirable

taste and flavor, but also their high content of (n-3) polyunsaturated fatty acids especially in fish lipids. These fatty acids seem to have various health benefits, such as decreasing the risk of stroke, reducing serum triacylglycerol levels, reducing blood pressure, and insulin resistance and modulating the glucose metabolism **(Li, *et al.*, 2003)**.

Bangladesh earns a significant amount of foreign currency by exporting dried fish and fishery products and has a good position in the export item of fish and fishery products. Exporting of dried fish has also increased at a huge rate since the beginning of the 21st century. In 2001-02, about 517 MT dried fish was exported and the value was 832 million BDT. While, Bangladesh earned about 4259 million BDT as foreign currency by exporting about 3143.93 MT of dried fish and fishery products in 2017-2018 **(DoF, 2018)**.

Human body requires a good protein source and other essential nutrients for the maintenance of a balanced health **(Arannilewa *et al.*, 2006)**. In Bangladesh, fish is one of the major sources of animal protein, specifically dried fishes that provide humans with important elements necessary for keeping sound health **(Ravichandran *et al.*, 2012)**. Dried fishery products contain valuable nutritional components for human beings and essential nutrients for balanced and healthy body **(Koffi-Nevry *et al.*, 2011; Sutharshiny & Sivashanthini, 2011)**. Dried fishes are low cost dietary protein source and used most frequently as a substitute of fish at the scarcity of fresh fish **(Khan & Khan, 2001; Rahman *et al.*, 2017)**. Some people do like to consume dried fish products of some freshwater and marine fish species rather than consuming fresh fish. Additionally, dried fish is the most accessible type of processed fish for consumers matching with all income levels. In Bengladish, because of the high demand of the dried products, a sizeable quantity of fish from freshwater and marine fish is sun dried. About 20% of the total marine catch from the coastal region of Bangladesh is sun dried and sold in the domestic market **(Alam, 2010; Begum *et al.*, 2012; Hasan *et al.*, 2016)**.

In Bangladesh, more than 20 million people, particularly women and young children, suffer from chronic deficiencies of protein and micronutrients **(Ahmed *et al.*, 2012)**. The protein requirement for the rural people is 0.8 gm/kg of body weight. This requirement of protein and micronutrients can be covered by dried fish products. A good quality dried fish can provide 52-73% of protein **(Sultana *et al.*, 2011)**, thus if one eats 100 grams of dried fish in a day, he would have the required protein for the body. The dried products processed from small fishes contain very light amount of cholesterol, and interestingly, they are rich in vitamins and minerals like-iron, calcium and phosphorous **(Salaudeen, 2014)**. The dried fishes have the better nutrient profile and act as an alternative source of protein for people in Bangladesh. In this review article, the chemical composition of different freshwater and marine dried fishes are studied to assess their nutritional value along with their health benefits.

Chemical composition of dried fish

The chemical composition analysis is the method of determining the values of the moisture, protein, lipid, ash, carbohydrate, vitamin and extractive present in the food samples expressed as the percentage value. Dried fish is an important source of crude protein, amino acids, water, lipids, fatty acids and ash or minerals. The proximate compositions (i.e. moisture, protein, lipid, ash) are important parameters of fishery product quality assessment, which influence the nutritive value, quality, functional properties and sensory properties of fishery product **(Kar *et al*., 2020)**. The composition of a particular species often appears to vary from one habitat to another, and season to season, but changes in this composition are usually caused due to the variation in the amount and the quality of food eaten by fish and in the amount of their movement **(Abdullahi 2001; Effiong & Fakunle, 2011; Rasul *et al.*, 2021)**. In fresh fish, the flesh generally contains up to 65-90% moisture, 10-22% protein, 1-20% fat and 0.5-5% minerals **(Sankar *et al*., 2010; Radhika, 2018)**. Different processing methods cause a considerable change in this composition. In comparison of fresh fish, the drying process results in a significant decrease in moisture content and an increase in other nutritional components, such as protein, lipid, and ash percentages **(Nowsad, 2005)**. In this context, it was noted that, the nutritional value of a kilogram of dried fish is the same as approximately five kilograms of fresh fish **(Salaudeen, 2014)**.

Moisture content in dried fish

The moisture of all living systems contributes as much to the essential properties of life. Thus, it is an important body constituent of fish. While, the water content of fresh fish remains high, drying removes the water from the flesh and reduces the water activity, making the water inaccessible to microorganisms, extending the shelf life of dried products **(Nowsad, 2005)**. In this essence, **Sultana *et al.* (2011)** found that, the moisture content ranges in some dried small indigenous species (SIS) like *Mystus tengra*, *Amblypharyngodon mola*, *Pseudeutropius atherinoides*, *Corica soborna*, *Chanda baculis*, *Chanda ranga* and *Oxygaster bacaila* of Bangladesh from 10.2% to 13.9%. **Hoq (2004)** reported that normally the sun-dried fishes contain an average of 10% to 20% moisture. This also makes the dried product edible for longer period and simultaneously increases other nutrients in the product that are beneficial for human health. The moisture percentage in some freshwater SIS ranged from 12.7%-27.52% in dried *Mystus vitatus* **(Nurullah *et al*., 2006; Hasan *et al*., 2006; Sultana *et al*., 2011; Flowra *et al*., 2012; Rana *et al*., 2019)**. While the moisture was 12.9%-29.25% in dried *Amblypharyngodon mola* **(Nurullah *et al*., 2006; Hasan *et al*., 2006; Sultana *et al*., 2011; Islam *et al*., 2013; Rana *et al*., 2019)**, and 25.13%-31.35% in *Puntius sophore* **(Islam *et al*., 2013; Rana *et al*., 2019)**. In addition, it was 10.9%-26.26% in *Pseudeutropius atherinoides* **(Nurullah *et al*., 2006; Sultana *et al*., 2011)**, and 12.0%-28.2% in *Corica soborna* **(Hasan *et al*., 2006; Sultana *et al*., 2011; Flowra *et al*., 2012; Rana *et al*., 2019)**. Additionally, the rate

of fish moisture was 26.24%-27.32% in *Gudusia chapra* **(Nurullah *et al*., 2006; Rana *et al*., 2019)**, 21.8% in *Chanda nama* and 18.18% in *Palaemon sp.* **(Flowra & Tumpa, 2012)**. Moreover, 23.26% of moisture content was detected in *Osteobrama cotio* **(Nurullah *et al*., 2006)**. To illustrate, the moisture content in dried *Channa punctatus* was recorded to be 14.83%-35.50% **(Flowra *et al*., 2012; Islam *et al*., 2013; Rana *et al*., 2019; Jahan & Akhtar, 2019)**; 16.03%-19.17% in *Channa striatus* and 14.7%-23.12% in *Wallago attu* **(Flowra & Tumpa, 2012; Mansur *et al*., 2013; Majumdar *et al*., 2017)** (Table 1). Notably, the moisture content in freshwater dried fishes in different locations of Bangladesh varied from 10.2%-35.50%. While, the moisture content in marine dried fishes ranged from 11.27%-39.59% (Table 2). The moisture percentage in marine dried Lalchoukya *(Lutjanus johnii)*, Lalpoa *(Johinus argentatus*), Buna chingri *(Penaeus monodon)*, and Riksha *(Riksha sp)* are 22.25%, 21.92%, 18.3% and 23.25%, respectively **(Paul *et al*., 2018)**. Furthermore, **Azam *et al*. (2003)** reported that the moisture content of fourteen selected dried fishes ranged from 18.23% to 23.61%. Similarly, the moisture content of Loitta (*Harpodon nehereus*), Poa (*Johnius dussumieri*) and Churi (*Lepturacanthus savala*) were 22.22%, 20.76% and 13.81%, respectively **(Siddiqui *et al*., 2011)**. Remarkably, the moisture content varies with season and fish species. The high moisture content leads to bacterial and fungal attack and also insect infestation causing the reduction of product quality and safety. It is worth mentioning that, the high moisture content in dried product is due to improper drying, and the absorbance of atmospheric water from the surrounding environment during inappropriate packaging and storage **(Rasul *et al*., 2018; Rasul *et al*., 2020)**.

Table 1. Proximate composition of freshwater dried fish from different regions of Bangladesh

Fish Species (Local Name and Scientific Name)	Location	Moisture (%)	Protein (%)	Lipid (%)	Mineral (%)	Reference
Baim (*Mastacembelus pancalus)*	Sylhet	19.84	56.34	5.60	16.08	**Hasan *et al*. (2018)**
		23.52	42.08	7.86	23.25	**Hasan *et al*. (2016)**
	Mymensingh	26.42	51.23	10.58	12.20	**Nurullah *et al*. (2006)**
	Mymensingh	26.42	44.72	16.63	12.21	**Hasan *et al*. (2006)**
	Rajshahi	12.70	60.01	12.90	-	**Sultana *et al*. (2011)**
Tengra (*Mystus vitatus*)	Nilphamari	18.20	44.08	17.76	20.08	**Flowra *et al*. (2012)**
	Sylhet	21.43	54.65	6.01	15.76	**Hasan *et al*. (2016)**
	Gazipur	12.44	61.32	11.65	14.54	**Majumdar *et al*. (2018)**
	Dhaka	27.52	43.20	12.84	15.22	**Rana *et al*. (2019)**
Mola	Dhaka	24.85	48.94	10.06	16.12	**Rana *et al*. (2019)**

(*Amblypharyngodon mola*)	Singra, Natore	29.25	32.02	14.03	24.4	**Islam *et al*. (2013)**
	Rajshahi	12.90	51.90	18.20	-	**Sultana *et al*. (2011)**
	Mymensingh	26.02	49.20	10.76	19.32	**Nurullah *et al*. (2006)**
	Mymensingh	26.03	49.63	13.13	11.18	**Hasan *et al*. (2006)**
	Dhaka	25.13	48.82	9.84	16.11	**Rana *et al*. (2019)**
	Savar, Dhaka	40.93	32.61	12.28	10.81	**Huque *et al*. (2013)**
Jat Puti (*Puntius sophore*)	Sylhet	18.32	42.40	5.15	24.17	**Hasan *et al*. (2016)**
	Singra, Natore	31.35	37.12	11.22	20.14	**Islam *et al*. (2013)**
Puti (*Barbides sarana*)	Mymensingh	24.14	50.38	11.52	14.00	**Nurullah *et al*. (2006)**
Batashi (*Pseudeutropius atherinoides*)	Mymensingh	26.26	48.60	8.40	17.80	**Nurullah *et al*. (2006)**
	Rajshahi	10.90	61.70	15.10	-	**Sultana *et al*. (2011)**
	Dhaka	27.05	45.80	11.80	15.00	**Rana *et al*. (2019)**
Chapila (*Gudusia chapra*)	Dhaka	27.32	49.60	08.76	14.31	**Rana *et al*. (2019)**
	Mymensingh	26.24	51.48	9.21	13.45	**Nurullah *et al*. (2006)**
Katchki (*Corica soborna*)	Dhaka	28.20	49.84	09.15	12.63	**Rana *et al*. (2019)**
	Rajshahi	12.0	61.60	22.70	-	**Sultana *et al*. (2011)**
	Mymensingh	27.33	52.75	8.91	11.00	**Hasan *et al*. (2006)**
	Nilphamari	24.58	49.95	8.20	21.8	**Flowra *et al*. (2012)**
Taki (*Channa punctatus*)	Dhaka	35.50	42.06	4.20	18.24	**Rana *et al*. (2019)**
	Chalan beel, Natore	14.83	57.50	3.10	21.00	**Jahan and Akhtar (2019)**
	Singra, Natore	34.43	41.38	3.21	20.74	**Islam *et al*. (2013)**
	Sylhet	21.43	54.65	6.01	15.76	**Hasan *et al*. (2016)**
	Nilphamari	17.80	60.50	2.50	22.73	**Flowra *et al*. (2012)**
Shol (*Channa striatus*)	Mymensingh	19.17	62.85	4.92	4.92	**Mansur *et al*. (2013)**
	Dhaka	18.75	66.44	6.81	6.49	**Majumdar *et al*. (2017)**
	Singra, Natore	16.03	33.23	8.96	13.72	**Flowra and Tumpa (2012)**
Boal (*Wallago attu*)	Mymensingh	23.12	49.23	11.00	18.89	**Mansur *et al*. (2013)**
	Dhaka	22.70	61.85	6.21	6.79	**Majumdar *et al*. (2017)**
	Singra, Natore	14.70	28.20	15.86	13.33	**Flowra and Tumpa (2012)**
Rui (*Labeo rohita*)	Mymensingh	20.27	59.32	9.32	12.89	**Mansur *et al*. (2013)**
Bele (*Glossogobius giuris*)	Dhaka	21.93	62.83	5.98	7.83	**Majumdar *et al*. (2017)**
	Singra, Natore	33.84	38.96	4.88	21.68	**Islam *et al*. (2013)**

Tit puti (*Puntius ticto*)	Singra	12.13	47.32	9.47	11.27	**Flowra and Tumpa (2012)**
Kholisa (*Trichogaster fasciata*)	Gazipur	15.06	53.98	11.02	19.68	**Rasul *et al*. (2019)**
Bata (*Labeo bata*)	Singra, Natore	12.35	45.72	5.38	10.78	**Flowra and Tumpa (2012)**
Icha (*Palaemon sp.*)	Singra, Natore	18.18	51.19	11.53	15.67	**Flowra and Tumpa (2012)**
Silver carp (*Hypophthalmichthys molitrix*)	Gazipur	25.43	61.51	6.21	6.79	**Rasul *et al*. (2018)**
Chanda (*Chanda baculis*)	Rajshahi	10.20	52.20	13.10	-	**Sultana *et al*. (2011)**
Lal Chanda (*Chanda ranga*)	Rajshahi	13.80	51.50	12.20	-	**Sultana *et al*. (2011)**
Nama Chanda (*Chanda nama*)	Nilphamari	21.80	48.10	15.01	18.90	**Flowra *et al*. (2012)**
Chela (*Oxygaster bacaila*)	Rajshahi	12.10	53.10	15.70	-	**Sultana *et al*. (2011)**
Dhela (*Osteobrama cotio*)	Mymensingh	23.26	52.20	9.50	16.00	**Nurullah *et al*. (2006)**

Protein and amino acids in dried fish and their health benefits

Fish is a good source of animal protein which has greater satisfying effect than other animal protein sources like beef and chicken **(Uhe *et al*., 1992; Mohanty *et al*., 2019)**. Dried fish provides an excellent source of protein. **Glover- Amengor *et al*. (2012)** indicated that the dried fish powders could serve as good sources of protein and iron for the low income group. According to **Glover-Amengor *et al.* (2012)**, the protein levels varied from 44.83% to 72.29% in some dried underutilized fish species. Normally, the sun-dried fishes contain 60% to 80% protein **(Haque, 2004)**.

Sultana *et al*. (2011) stated that the protein content ranged from 51.5%-61.6% in seven SIS dried fish (Table 1). The protein varied between 44.08% to 65.65% in dried *Mystus vittatus*, *Channa punctatus*, *Chanda nama*, *Corica soborna* and *Trichuirus haumela* **(Flowra *et al*., 2012)**. Besides, **Rana *et al.* (2019)** found that the protein content in ten indigenous dried fish varied from 42.06% to 65.78%. The protein content was found in the range of 32.02% to 41.38% in dried *Puntius* sp. (puti), *Amblypharyngodon mola* (mola), *Channa punctatus* (taki) and *Glossogobius giuris* (bele) **(Islam *et al*., 2013)**. The crude protein content of some freshwater dried fish ranged from 32.02%-66.44% (Table 1). According to **Ullah *et al.* (2016)**, protein varied from 27.46% to 56.84% in ten different freshwater dried fish in North East India. Therefore, the dried fish of Bangladesh contain higher protein content than those of India. The comparatively protein rich dried fishes are *Channa striatus*, *Channa punctatus*, *Corica soborna*, *Pseudeutropius*

atherinoides, *Mastacembelus armatus*, *Glossogobius giuris*, *Labeo rohita*, and *Hypophthalmichthys molitrix* etc. They contain more than 55% protein. In case of marine dried fish, **Azam *et al.* (2003)** reported the biochemical assessment of fourteen selected dried fish and found the protein content varied between 40.69% and 66.52%. The crude protein content of marine dried fish ranged from 32.25% to 68.09% (Table 2). The crude protein content of dried *Stromateus chinensis*, *S. cinereus*, *Riksha* sp., *Johinus argentatus*, *Trichiurus haumela*, *Harpodon neherus*, *Lutianus johnii* and *Penaeus* sp. ranged from 33.56% to 58.22% with the highest content in shrimp and the lowest in the red snapper **(Paul *et al*., 2018)**. **Pravakar *et al*. (2013)** reported that the mean value of protein content of Chinese pomfret (*Stromateus chinensis*) and Ribbon fishes (*Trichiurus haumela*) collected from Cox's Bazar were 60.03% and 54.36%, respectively. **Siddique *et al*. (2011)** noted that the protein level of three marine dried fishes (*Harpodon nehereus*, *Johnius dussumieri* and *Lepturacanthus savala*) varied from 58.33%-51.98%, 64.39%-56.46% and 71.90%-67.22%, respectively. It was found that the protein content in fish might vary with respect to species due to certain factors, such as the season of the year, effect of spawning and migration, food availability etc. **(Effiong and Tafa, 2005)**.

Dried fish is a cheaper and exceptional source of protein and necessary amino acids with fewer calories than other foods such as beef **(Jonsson *et al*., 2007; Hassan *et al*., 2014)**. One hundred grams of dried fish contain around 80% protein with 300 calories against animal meat, which contains double the calorie and far less protein **(Legacy Food Storage, 2016)**. Those proteins are a key source of antibodies and enzymes for all living beings, that make up an essential part of muscles, hair and other body components. Dried fish contain all the essential amino acids including sulphur containing amino acids as cysteine and methionine which are absent in plant protein **(Bindu, 2005; Atowa *et al*., 2014)** and methionine and lysine that are absent in terrestrial meat proteins **(Tacon and Metian, 2013)**. Fish and dried fish protein are of high quality and contains sufficient amounts of all the essential amino acids required for body growth, maintenance of lean muscle tissues and active metabolism, repairing worn out tissues, and they contribute to the prevention of some diseases **(Talabi 1995; Pal *et al*., 2018; Dale *et al*., 2019)**. In addition, proteins, peptides and amino acids from fish and fish products have recently become well known for their positive health effects **(Rudkowska *et al*., 2010; Pilon *et al*., 2011)** though some amino acids reduction occurred in dried fish during drying and storage **(Atowa *et al*., 2014)**. Nevertheless, **Wu and Mao (2008)** reported that there was no effect of the drying method on the amino acid composition of grass carp (*Ctenopharyngodon idella*) fillets. In addition, aquatic protein is highly digestible and rich in several peptides and essential amino acids such as methionine and lysine that are limited in terrestrial meat proteins **(Tacon & Metian, 2013)**. It is noteworthy to mention that, during drying, the digestibility of protein reduces slightly as IVPD (%) remains lower **(Atowa *et al*., 2014)**. On the other hand, it has been investigated that when fish

proteins are warmed at a temperature below 100°C, protein digestibility is not affected **(Opstvedt, 1998)**. **Madani *et al.* (2012)** suggested that the dietary sardine protein acts as a possible prophylaxis against insulin resistance. Thus, the dried sardine could lower insulin resistance, improve hyperglycemia and decrease adipose tissue oxidative stress. It has been shown in human macrophages that fish protein hydrolysates decreased tumor necrosis factor a (TNFα) **(Rudkowska *et al.*, 2010)**. Additionally, the sardine protein has potentials of lowering the effects on cardiovascular risk **(Balfego *et al.*, 2016)**. In addition, angiotensin-I converting enzyme (ACE) inhibition substances were determined in the tuna muscle protein **(Kohama *et al.*, 1988)** and in the krill muscle protein **(Kawamura *et al.*, 1992)** which have positive effect in reducing blood pressure of human. Hence, it is clear that small portions of dried fish can meet the need of proteins in the body aligned with positive health effects.

Table 2. Proximate composition of marine dried fish from different regions of Bangladesh

Fish Species (Local Name and Scientific Name)	Location	Moisture (%)	Protein (%)	Lipid (%)	Mineral (%)	Reference
Churi (*Trichuirus haumela*)	Nilphamari	14.10	65.65	11.8	9.63	**Flowra *et al.* (2012)**
	Cox's Bazar	23.20	54.36	11.45	11.05	**Pravakar *et al.* (2013)**
Loitta *(Harpodon nehereus)*	Chittagong	22.22	58.33	7.78	7.56	**Siddique *et al.* (2011)**
Poa *(Johnius Dussumieri)*	Chittagong	20.76	64.39	5.54	6.37	**Siddique *et al.* (2011)**
Churi *(Lepturacanthus Savala)*	Chittagong	13.81	71.90	7.79	4.86	**Siddique *et al.* (2011)**
Rupchanda *(Stromateus chinensis)*	Cox's Bazar	14.20	59.14	11.60	7.02	**Pravakar *et al.* (2013)**
Lalchoukya *(Lutjanus johnii)*	Cox's Bazar	22.25	30.15	11.8	32.25	**Paul *et al.* (2018)**
Lalpoa *(Johinus argentatus*)	Cox's Bazar	21.92	38.75	2.85	23.8	**Paul *et al.* (2018)**
Buna chingri *(Penaeus monodon)*	Cox's Bazar	18.30	62.15	7.80	14.83	**Paul *et al.* (2018)**
Riksha *(Riksha sp)*	Cox's Bazar	23.25	45.75	5.77	27.25	**Paul *et al.* (2018)**
Phasa (*Setipinna phasa*)	Cox's Bazar	22.14	52.82	10.40	15.17	**Siddiky *et al.* (2017)**
	Dhaka	23.34	47.84	23.91	3.78	**Bhuiyan *et al.* (2009)**
	Kuakata	24.46	62.36	3.67	9.51	**Azam *et al.* (2003)**
Banded Needle Fish *(Strongylura leiura*)	Cox's Bazar	22.10	50.16	9.18	17.57	**Siddiky *et al.* (2017)**
Coral *(Lates calcarifer)*	Cox's Bazar	26.74	40.31	5.03	11.50	**Hossain *et al.* (2017)**
Parshe (*Mugil cephalus)*	Kuakata	19.93	68.09	4.87	7.45	**Azam *et al.* (2003)**

	Dhaka	21.19	68.09	8.22	10.35	**Hossain *et al.* (2015)**
Kamot *(Scoliodon sorrakowah)*	Kuakata	23.49	58.35	7.84	11.32	**Azam *et al*. (2003)**
Taposhi (*Polynemus paradiseus*)	Kuakata	21.65	57.25	8.95	12.14	**Azam *et al*. (2003)**
Shamudrik baim (*Muraenesox bagio)*	Kuakata	20.98	56.77	11.19	9.98	**Azam *et al*. (2003)**
Potka (*Chelonodon patoca)*	Kuakata	23.31	57.51	9.69	7.22	**Azam *et al*. (2003)**
Kukurjib (*Cynoglossus bengalensis)*	Kuakata	21.7	54.86	11.44	11.85	**Azam *et al*. (2003)**
Shaplapata (*Himantura walga)*	Kuakata	21.08	54.19	25.3	11.01	**Azam *et al*. (2003)**
Folichanda *(Stromateus cinereus)*	Cox's Bazar	39.59	32.25	6.75	15.73	**Hossain *et al.* (2017)**

Lipids and fatty acids in dried fish and their health benefits

Lipids are water-insoluble macro-biomolecules that are soluble in organic solvents and have a variety of biological roles ranging from fuel molecules, energy stores to components of membranes **(Mohanty *et al*., 2019)**. Fish and dried fish are comprised of lipids and fatty acids **(Shah *et al*., 2009; Balange *et al*., 2017)**. There was no significant effect of drying on the fatty acids profile and composition of the dried cod heads **(Salaudeen, 2014)**. Dried fish may become a good source of EPA and DHA **(Rasul *et al*., 2021a)**. The previous authors found that the major fatty acids of solar dried *Megalaspis cordyla* are palmitic acid (16:0), stearic acid (18:0), oleic acid (18:1n-9), cetoleic acids (22:1n-11), EPA (20:5n-3) and DHA (22:6n-3), which are beneficial for human health (Table 3). **Sultana *et al*. (2011)** observed that the lipid content ranged from 12.2%-22.7% in seven SIS dried fish (**Table 1**). Whereas, lipid content varied from 4.20% to 13.03% in ten indigenous dried fish **(Rana *et al*., 2019)**. Also, **Flowra *et al.* (2013)** found that the lipid content of dried *Mystus vittatus*, *Channa punctatus*, *Chanda nama*, *Corica soborna* and *Trichuirus haumela* varied between 1.91% and 17.76%. In another study, **Majumdar *et al*. (2017)** found that the lipid contents of dried *W. attu*, *C. striatus* and *G. giuris* were 6.21%, 6.81% and 5.98%, respectively. The fat content in freshwater dried fishes varied between 3.10% and 22.7% (Table 1). The highest lipid content was found in dried *Corica soborna* and the lowest was found in *Channa punctatus.*

The lipid content varied from 2.74% to 15.44% in dried *Stromateus chinensis*, *S. cinereus*, *Riksha* sp., *Johinus argentatus*, *Trichiurus haumela*, *Harpodon neherus*, *Lutianus johnii* and *Penaeus* sp. from Cox'x Bazar **(Paul *et al*., 2018)**. On the oter hand, **Azam *et al*. (2003)** found that the lipid content in some selected marine dried fishes ranged from 3.67% to 25.3%. The lipid content in marine dried fishes collected from

different regions in Bangladesh varied from 4.87% (*Mugil cephalus*) to 23.91% *Setipinna phasa* (Table 2). Moreover, dried cod (*Gadus morhua*) head contained 27.7% MUFA, 37.8% PUFA, 10.4% EPA and 19.8% DHA **(Salaudeen, 2014)**. Comparatively, marine dried fishes contain more lipid percentage than freshwater dried fishes. This is possibly related to the variation in initial lipid content of raw materials used for processing **(Stansby, 1962)** as fat content in fish may vary according to seasons, species, and age and maturity of the respective species **(Piggot, 1990)**. Oxidation of lipids is another reason of variation in lipid content as the degree of lipid oxidation was reported to be high in traditional dried fish products available in Bangladesh **(Majumdar *et al*., 2018; Rana *et al*., 2019; Rasul *et al*., 2020)**.

Fish lipids are known to provide high contents of important components for the human diet, such as essential fatty acids, n-3 polyunsaturated fatty acids (PUFA) that have shown a positive role in preventing certain human diseases, including cardiovascular ones **(Simopoulos, 1999; Abeywardena & Patten, 2011; Pal *et al*., 2018)**. Usually marine fish lipids, however, differ from the other lipids in that they contain longer-chain fatty acids, and a larger proportion of highly unsaturated fatty acids **(Tilami & Samples, 2017; Pal *et al*., 2018)**. Remarkably, the most beneficial omega-3s are EPA and DHA that are found in seafood and seafood products, and have several beneficial impacts on human health **(Tir *et al*., 2017)**. These benefits include decreasing the risk of myocardial infarction **(Bucher *et al*., 2002)** and keeping the body's circulation functioning well **(Weitz *et al*., 2010; Bowen *et al*., 2016)**. They , in addition, lower both blood pressure and triglyceride concentration in blood **(Harris *et al*., 1997)**. Additionally, they enhance the immune system **(Damsgaard *et al*., 2007)**, sustain proper brain function in human body **(Pal *et al*., 2018)** and fight with diabetes and obesity **(Legacy Food Storage, 2016)**. They also protect against various psychological disorders, , particularly, depression and the attention deficit hyperactivity disorder in addition to their efficacy to protect the body against cancer **(Sinn, 2007)**. The DHA together with the EPA are preventive to several diseases like atherosclerosis, dementia, rheumatoid arthritis, alzheimer disease (AD), and age-related macular degeneration (AMD) **(Connor, 2000; Calder, 2012; Hashimoto *et al*., 2015)**. It was found that free fatty acids, especially DHA content increased significantly during the drying period of the herring fillet, indicating partial hydrolysis of phospholipids **(Shah *et al*., 2009)**. The consumption of long chain n-3 PUFA in pregnancy is also known to be linked with improved cognitive development scores **(Swanson, *et al*., 2012; Kwasek *et al*., 2020)**. Dietary guidelines from the World Health Organization and the Dietary Reference Intakes recommend a total fat intake between 20% and 35% of total calories **(FAO, 2010)**. In this case, dried fish is considered a good diet for human.

Table 3. Fatty acid composition (mg/g dry matter) of total lipids in *Megalaspis cordyla* **(Rasul *et al*., 2021a)**

Fatty acids	Solar dried *M. cordyla*
14:0	3.09 ± 0.02
16:0	10.32 ± 0.04
18:0	7.04 ± 0.02
20:0	0.27 ± 0.01
Σ saturated	20.72 ± 0.02
14:1n-9	0.16 ± 0.01
16:1n-9	4.23 ± 0.03
18:1n-9	7.04 ± 0.03
20:1n-9	3.32 ± 0.03
22:1n-11	32.58 ± 0.33
Σ monounsaturated	47.33 ± 0.34
14:2	0.50 ± 0.01
16:2	2.92 ± 0.03
16:3	0.45 ± 0.02
18:2n-6	1.00 ± 0.01
18:3n-6	0.61 ± 0.10
18:4n-3	0.66 ± 0.06
20:3n-6	0.73 ± 0.02
20:4n-6	1.31 ± 0.02
20:5n-3	2.26 ± 0.06
22:2	3.29 ± 0.02
22:3	0.95 ± 0.02
22:4n-6	3.31 ± 0.12
22:6n-3	12.46 ± 0.15
Σ polyunsaturated	30.45 ± 0.36
Others	1.50 ± 0.03

Mineral composition in dried fish and their health benefits

Mineral ratios are often more important in determining nutritional deficiencies and excess; it is predictive of future or hidden metabolic disfunctions **(Begum *et al*., 2017)**. Most fishes available in dried forms have less amounts of cholesterol and salt and great amounts of minerals that are necessary for the development of one's body and make fish unavoidable as healthy diet **(Eyo, 2001)**. The mineral content of dried *W. attu*, *C. striatus* and *G. giuris* were 6.79%, 6.49% and 7.83%, respectively **(Majumdar *et al*., 2017)**. While, the mineral content ranged from 9.63% to 22.73% in five selected dried fish **(Flowra *et al*., 2012)**, 10.78% (*Labeo bata*) to 15.67% (*Palaemon* sp.) in five traditionally dried fish (*Puntius ticto, Labeo bata, Wallago attu, Channa striatus* and *Palaemon* sp.) **(Flowra & Tumpa, 2012)**, 11.11 to 18.89% in *Channa striatus, Wallago attu* and *Labeo rohota* **(Mansur *et al*., 2013)**. The mineral content ranged from 4.92%-24.4% in freshwater dried fishes (Table 1). This content in fourteen marine dried fishes ranged between 5.08% and 12.14% **(Azam *et al*., 2003)**. The amount of minerals in dried marine fish ranged between 4.86% and 7.56% **(Siddique *et al*., 2011)**, 11.50% in dried *Lates calcarifer*, and 15.75% in *Stromateus cinensis* **(Hossain *et al*., 2017)**. It ranged from 3.78%-32.25% in marine dried fishes (Table 2). The variation in mineral contents is

related to different locations, species, pre-treatments of raw materials with salt and herbal substance during drying **(Paul *et al*., 2018)**.

It has been reported that the calcium percentages are high in Tengra (*Mystus vittatus*) 1.33% and low in Katchki (*Corica soborna*) 0.90%. Phosphorus content is high in Lal chanda (*Chanda ranga*) 2.90% and low in Katchki (*Corica soborna*) 1.72% (Table 4). The higher amount of iron was found in Mola (*Amblypharyngodon Mola*)with a value of 44.90 mg/100gm, whereas the lower amount was observed in Chela (*Oxygaster bacaila*), recording a value of 16.85 mg/100g **(Sultana *et al*., 2011)**. Comparatively, the small fish and their dried products are known to be a good source of minerals **(Fawole *et al*., 2007; Roos *et al*., 2007)**. The calcium, iron and phosphorus content of the fish powder from the selected species varied from 2.49 g/kg (*L. rohita*) to 2.55 g/kg (small prawns), 0.043 g/kg (*H. molitrix and P. sophore*) to 0.184 g/kg (*C. mrigala*) and 0.94 g/kg (*L. rohita*) to 1.91 g/kg (*P. sophore*), respectively **(Jahan *et al*., 2017)**. The highest calcium content was found in small prawns (2.54 g/kg) and the lowest in *L. rohita* (2.48 g/kg) (Fig. 1). Another study reported that *Cirrhina reba* contained 822 mg calcium/100g of fish **(Islam *et al*., 2003)** and dried tuna contained 844 mg calcium/100gm of fish **(Thilsted *et al*., 2014)**. The highest iron content was found in *C. mrigala* (0.184 g/kg) and the lowest in *H. molitrix* and *P. sophore* (0.043 g/kg). This difference could be attributed to the factors affecting the iron content such as species, individuals, and sampling periods **(Yilmaz *et al*., 2010)**. The highest phosphorus content was found in *P. sophore* (1.91g/kg) and the lowest in *L. rohita* (0.94 g/kg). Markedly, the burrito fish (*Brachydeuterus auritus*) contains 93.71 mg/100 g phosphorus **(Abbey *et al*., 2017)**. The lowest value of phosphorus might be due to the removal of head, bones and scales from the fish body. Limited data have been found on other minerals in dried fish in Bangladesh. In addition, the presence of Fe, Ca, K, C, S, P, Si, Al, Mg, Na, and O were detected in ten dried fish samples in north east India **(Ullah *et al*., 2016)**. Similarly, **Akinneye *et al.* (2010)** found K (250 mg), Na (218 mg), Mg (183 mg) and Ca (150 mg) in *Sardinella* sp. (oven dried) and *H. niloticus* (sun-dried).

Table 4. Mineral composition of freshwater dried SIS in Bangladesh (**Sultana *et al.*, 2011)**

Fish species (local name and scientific name)	Location	Ca (%) g	P (%) g	Fe mg/100 gm
Chanda (*Chanda baculis*)	Rajshahi	1.22	2.70	36.00
Lal chanda (*Chanda ranga*)		1.10	2.90	17.00
Tengra *(Mystus vitatus)*		1.40	2.80	31.20
Mola (*Amblypharyngodon Mola*)		1.18	2.20	44.90
Chela (*Oxygaster bacaila*)		1.16	2.60	16.85
Batashi *(Clupisoma atherinoides*)		0.99	1.80	34.90
Katchki (*Corica soborna*)		0.90	1.72	22.00

Mineral contents in fish depend on its availability in their environment followed by diet absorptive capability and preferential accumulation of same by the fish **(Adewoye & Omotosho 1997; Ibiyo *et al*., 2006)**. Calcium plays an essential role in human body for the formation of bones, muscle tone and nervous impulse **(Molla *et al*., 1998)** and it also helps in blood clotting, muscle contraction, osmoregulation. Moreover, calcium acts as a cofactor for enzymatic procession **(Lovell, 1989)**. Phosphorous helps in many physiological processes, such as activity of adinosine polyphosphates and phospholipids **(Nair & Mathew, 2001)**, regulation of the whole-body acid-base balance and as a major constituent of teeth and bone **(EFSA, 2006)**. Potassium helps in normal functioning of nerves, muscle and heart, sugar metabolism, acid-base balance, oxygen of brain. Numerous aspects of cellular metabolism are zinc dependent. It supports the function of some proteins in the body. Zinc helps to strengthen their defense against free radical attack and assists in the work of the immune system and in growth and development **(Jónsson *et al*., 2007)**. Iron prevents anemia **(Demirezen, 2006)** and dried fish is one of the major sources of iron for adults and children. With iron, copper catalyses oxidation-reduction mechanisms and tissue respiration. Manganese is needed for growth and good health, and its deficiency can cause nervous problem **(Demirezen, 2006)**.

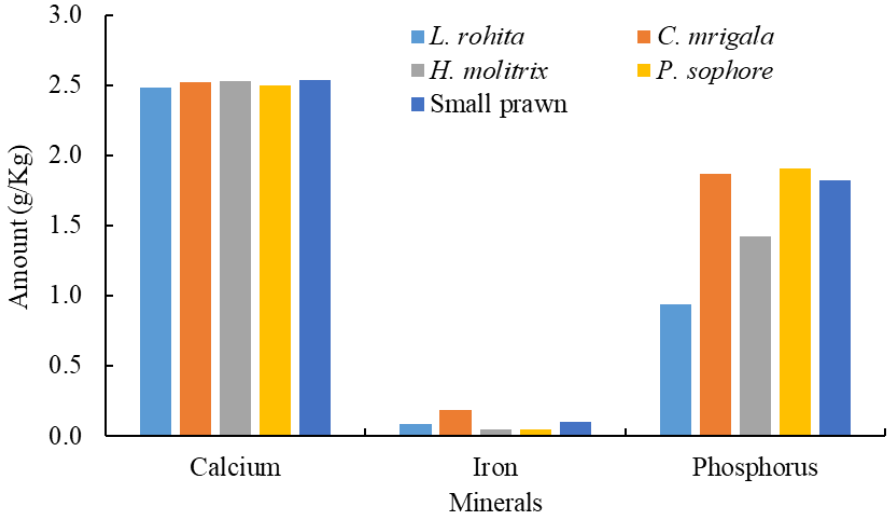

Fig. 1. Mineral content of dried fish powder from different fish species and small prawns **(Jahan *et al*., 2017)**

CONCLUSION

Dried fish is a natural product and important source of protein, lipids and acts as a better nutrient source compared to the fresh fish for many developed and developing countries, and particularly for individuals with low income. It plays an important role in improving food security and nutritional status. This food item is regarded as most eco-friendly and the healthiest one for humans.

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