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Nutritional profiling of selected fish’s scales: An approach to determine its prospective use as a biomaterial

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Abstract
Fish scale, the chief waste materials generated during fish processing is however a promising and cost efficacious source of different important nutrients but unfortunately it has not received much attention. This consideration stresses to explore the proximate composition and minerals contents of fish scales from 12 different fish species collected from three different fish market in Dhaka city to evaluate their usage as potential bioactive compounds. The average carbohydrate, lipid, protein, moisture and ash contents were recorded within a range of 0.35± 0.24 to 2.18 ±0.68 %, 0.27±0.21 to 1.60± 0.08 %, 40.28 ±1.02 to 71.57± 0.64 %, 7.87± 0.57 to 20.53±0.48 % and 19.06± 0.6 to 39.55± 0.94 % respectively. The research reveals that all the twelve species of fish’s scales contained reasonable amount of micronutrients more notably calcium (3246.93±18.98 to 7930.42±60.02 mg/100g), iron (24.15±1.74 to 1360.60±10.43 mg/100g), magnesium (151.13 ±18.5 to 236.56 ±25.61 mg/100g) and phosphorous (230.40 ±5.11 to 2031. 09 ±25.01 mg/100 g).

Keywords: Fish processing wastes, proximate composition, minerals, bio-plastic, multi-industrial application

1. Introduction

Every year over 100 million tons of fish are being collected globally with 29.5% of a capture is used as fish feed due to its lack of functional properties [13]. Approximately 70-85 % of a capture becomes fishery processing waste and 30 % of these wastes are bones, fins, scales, skin which contain high levels of protein and minerals. Bangladesh is a small and developing country overloaded with almost unbearable pressure of human population. In the past, people of Bangladesh were mostly dependent upon land-based proteins. But, the continuous process of industrialization and urbanization consumes the limited land area. Now there is no other way than to harvest the vast under water protein from the inland water bodies, which can meet the country's demand. It is a country of river with its rich inland waters and river systems, has significant capture fishery and aquaculture expectation. However, the favorable geographic position of Bangladesh adds up a large number of aquatic species and provides abundant of resources to support fisheries potential. In Bangladesh, fish is by far the most commonly consumed animal-source food across all population groups with an average of 19.71 kg/person/year providing a rich source of micronutrients and accounting for 60% of animal protein intake. So, fish has become a popular complement to rice in the national diet, giving rise to the adage Maache-Bhate Bangali ("a Bengali is made of fish and rice") [10]. The fisheries sector plays a very vital role in the national economy, contributing 3.57% to the Gross Domestic Product (GDP) of the country and 25.30% of the agricultural GDP and 1.5% of the foreign exchange earnings by exporting fish and fishery products [5]. Over the last 10 years (2004-2005 to 2013-2014 FY), the fisheries growth was fairly sturdy and at an average of 5.38% per year [8].

The dietary contribution of fish is more significant in terms of animal proteins, as a portion of 150 g of fish provides about 50–60 percent of the daily protein requirements for an adult. It has grown most substantially in East Asia (from 10.8 kg in 1961 to 39.2 kg in 2013), (from 13.1 to 33.6 kg) and North Africa (from 2.8 to 16.4 kg) [6].

Above statement indicate that this huge consumption creates a great amount of fish waste (Viscera, gill, fin, scale) which generally thrown away and not properly utilized in our country.

Worldwide, fish industry wastes are regarded as a harmful pollutant having a serious impact on the environment. During fish processing operations, a large portion of wastes, which typically accounts for 40–70% of the raw material, including skin, bones, scales, and viscera, is generated. Even though these are essential sources of bioactive molecules, they are often dumped for alteration to low-value fertilizers. Fish processing waste generally shows high biological oxygen demand (BOD) and, typically, generates a strong off-smell. Besides, it often acts as a reservoir for several pathogens, including *Salmonella* and *Shigella*, parasite eggs and amoebic cysts, if not sufficiently addressed. There are certain environmentally friendly and commercial options for utilization of fish processing waste, such as converting it into high-value by-products and value-added fishery products. Such products include bioactive proteins and peptides, omega-3 fatty acids, customized health products, natural pigments and industrial enzymes, functional poultry and aquaculture feed, biodiesel and biogas compositions, organic fertilizer, compost etc. Other options for utilization of fish processing waste include isolation of substrates for microbial culture media, production of attractants as well as repellants for economically important insects of agricultural crops etc. [3].

Bio-plastic can also be formed from fish scales with heat and pressure [14] this is because the scales are primarily composed of protein collagen, a biopolymer [11]. Fish glue is a natural product which is acquired from fish scale or skin through cooking it, followed by evaporation. It is a highly viscous liquid at room temperature. Fish scales also have the enormous biomedical application like wound healing, Cornea substitution, Fixation of bone fracture, skin rejuvenation and tissue engineering etc. The transparent fish scales of tilapia (*Oreochromis mossambicus*) were analyzed as a potential alternative for corneal reconstruction.

Fish scale is a great source of collagen Type I. Collagens are the major structural element of connective tissues in vertebrate, comprising 30% or so of total protein. They also exist in the interstitial tissues of virtually all parenchymal organs, wherein they stabilize organs and keep them in good shapes [21].

Collagen has been widely processed as products in food, cosmetic, biomedical, and pharmaceutical industries. For examples, oral consumption of collagen peptides as a food supplement may improve low bone mineral density in people in malnutrition and people suffering from degenerative joint diseases [20].

Fish scale is another good source of gelatin which has a rheological property of thermo-reversible transformation between sols and gel thus widely utilized in food, pharmaceutical, and photographic industries especially in the culinary area. In recent years, there is an emerging use for fish scales in food therapy, where it is used as a healing jelly and as a dessert soup [7]**.** Fish scale is rich in protein and calcium, therefore it is an ideal resource to produce calcium supplement as alternatives of CPP (Casein phosphor peptides) [24]. Fish scale or skin derived collagen extensively used in beverage industry around the world**.**

Above statement clarifies that fish scale has a multi-industrial application but only a few studies have been undertaken on the nutritional quality assessment of fish scales during the last couple of years. However, in the present study an attempt was made to evaluate the nutritive value of fish scales of twelve different fish species using standard methods and to popularize their consumption and utilization in Bangladesh thus bridging the information gap.

2. Materials and methods

2.1. Source of samples

Carp fish species is the far most important species among the fish species available in the fish market of Bangladesh and an integral part of every dish as a source of daily protein requirements. So, in the present study twelve (12) different fish species including carp fish (Table 1) were chosen and purchased fresh from 3 different fish market-Kawran bazar, Mohammadpur Krishi Market, and Hatirpool Bazar of capital city Dhaka. These fish species are among the commonly consumed in many households in Bangladesh and have potential for nutrition. Samples of each species collected were immediately kept in an ice box containing ice with a fish/ice ratio of 1:2 (w/w) to sustain freshness and convoyed to the laboratory/Fisheries Technology Research Section, Institute of Food and Science Technology, Bangladesh Council of Scientific and Industrial Research (BCSIR) for analysis.

Table 1: List of fish samples collected for our study.

Local name	English name	Scientific name	References
Ilish	Hilsa shad	*Tenualosa ilisha*	Hamilton, 1822
Rui	Rohu	*Labeo rohita*	Hamilton, 1822
Catla	Giant barb	*Gibelion catla*	Heckel, 1843
koi	Climbing perch	*Anabas testudineus*	Bloch, 1792
Tatkini	Reba	*Cirrhinus reba*	Hamilton, 1822
Chital	Humped featherback	*Chitala chitala*	Hamilton, 1822
Mrigel	Caurvery white carp	*Cirrhinus cirrhosis*	Bloch,1795
Kalibaus	Orange fin labeo	*Labeo calbasu*	Hamilton, 1822
Tilapia	Mozambique tilapia	*Oreochromis mossambicus*	Trewavas, 1983
Japani rui	Common carp	*Cyprinus carpio*	Linnaeus, 1758
Sarpunti	Olive barb	*Puntius sarana*	Hamilton, 1822
Shol	Snakehead murrel	*Channa striata*	Bloch, 1793

2.2 Sample preparation

Fish scales were washed with deionized water to remove other debris followed by air dried for two days to achieve the constant weight. Sampling of fish scale was done 3 times in each market for each species.

2.3 Proximate analysis

The collected samples were subjected to major biochemical constituent's analysis following standard protocols. For each of the fish species, triplicate analyses were averaged for each of the scale samples for total protein, total lipid, carbohydrate, moisture and ash content. The crude protein of the fish scale was determined by Micro- Kjeldhal method [26] while the moisture was estimated after drying an accurately weighed amount (7-8 g) fish scale in a hot air oven (Gallenkamp, HOTBOX, Model OVB-305) at 105 °C for 24 h. The percentage of the ash content was determined by igniting sample about 4-5 g in a Muffle Furnace (Philip Harris Ltd, England), for 6 hours at a temperature of 550° -800° C, while the lipid content of the experimental fish scale had been extracted using hexane in a soxhlet extractor as described by [2]. Finally, carbohydrate content was calculated by subtracting fat, protein, moisture and ash content from 100. While lipid content in pulp was extracted using hexane in a soxhlet extractor as described by AOAC method [2].

2.4 Mineral element analysis

The preparation of samples for mineral elements analysis followed a method described by AOAC. Approximately 5 g of sample was weighed into acid-washed crucible and dried in oven 105 ^{0}C for one day. Dried samples were then digested in furnace oven at 550^{0}C overnight. The ash was digested in 5ml of 65% nitric acid (HNO_3) by boiling for about two minutes and cooling to room temperature. The cooled solution was filtered through Whatman filter paper (No. 41) and made up to 25 ml with 65% nitric acid. A 10 ml were transferred into 15 ml polypropylene test tube for injection into inductively-coupled plasma-optical emission spectrometer (ICP-OES) (Perkin Elmer, USA). Samples were then analyzed for its micro minerals content iron (Fe), calcium (Ca), phosphorus (P) and Magnesium (Mg. Sample blank (65% nitric acid) were analyzed together with each batch of samples.

However, calcium determination was followed by titration method [30]. Precipitate it as calcium oxalate and titration the solution of oxalate in dilute sulphuric acid against standard $KMnO_4$ solution and Magnesium is estimated from calcium free filtrate as its pyrophosphate content. Iron (Fe) content was determined spectrophotometrically at 540 nm by thio-cyanate method as described in practical physiological chemistry [30]. Determination of phosphorus was carried out by measuring colorimetrical the blue formed when the solution was treated with ammonium molybdate and the phosphomolybdate thus formed was reduced. The developed blue color was then measured at 660 nm against a standard solution.

2.5 Statistical Analysis

The statistical analysis of the important data was used to test correlation significance of differences, based on ANOVA test, at $p < 0.05$. All the analyses involved were performed in triplicates and the results were expressed as mean (n=3) ± standard deviation (SD).

3. Results and discussion

Fish scales of twelve different fish species were collected from three different markets of Dhaka city and evaluated their nutritive properties viz. moisture, ash, lipids, proteins and carbohydrates. Findings have shown that differences in nutritional composition were prominent among the twelve species studied (Table 1).

3.1 Proximate composition

The biochemical composition of the sample scales is presented in Table 2. Proximate composition analysis of fish scales has reported protein as the most abundant component.

Table 2: Proximate composition of fish's scales of different fish species collected from three markets (mean percentage ± SD).

Fish species	Moisture (%)	Protein (%)	Lipid (%)	Ash (%)	Carbohydrate (%)
Hilsa	11.81±1.39	63.08±0.59	0.32± 0.06	22.63 ±0.67	1.52± 1.27
Rui	10.72±0.61	67.08± 0.74	0.55± 0.16	19.18± 0.23	2.18 ±0.68
Catla	13.87±1.19	65.91± 0.92	0.43± 0.04	19.37 ±1.78	0.40± 0.13
Koi	20.53±0.48	40.28 ±1.02	1.24± 0.09	36.89 ±0.59	1.02± 0.69
Tatkini	15.91±0.67	62.51± 0.70	0.35± 0.04	19.07± 0.16	2.12±.45
Chital	11.63±1.03	51.79± 1.69	1.60± 0.08	33.21± 0.76	1.75± 0.43
Mrigel	11.28±0.48	61.67± 0.73	0.87± 0.21	25.86± 0.88	0.51± 0.08
Kalibaus	10.75±1.15	63.74±1.19	0.56± 0.1	24.33±1.66	0.63 ±0.16
Japani rui	7.87± 0.57	71.57± 0.64	0.73± 0.19	19.06± 0.6	0.77 ±0.13
Tilapia	10.66±0.92	50.29±0.81	0.27±0.21	38.15 ±1.15	0.64 ±0.35
Sarpunti	9.77± 0.15	65.59± 0.93	0.68±0.29	22.99± 0.48	0.96 ±0.08
Shol	12.75±0.04	46.61± 1.21	0.72± 0.13	39.55± 0.94	0.35± 0.24

*Values are ± Mean Standard deviation of triplicate determinations.

In the present study, protein content showed remarkable variation, with highest value of 71.57± 0.64% in the scales of japani rui (*Cyprinus carpio*) followed by 67.08± 0.74% in rui (*Labeo rohita*) and lowest 40.28 ±1.02% in the scales of koi (*Anabas testudineus*) (Table 2). This is in agreement with the finding of Masood *et al.* [17] in *Labeo rohita* fish scale was found to be 82.29% on dry weight basis and Zhang *et al.* [31] in *Hypophthalmas molitrix* fish scale was found to be 43.43%. Masood *et al.* [18] determined crude protein content in dry matter of the scales of four mullet species were found to be in order of 78.07% in *Liza melinoptera,* 76.45% in *Mugil cephalus*, 70.66% in *Liza macrolepis*, 62.28 % in *Valamugil speigleri* which is more or less similar with our present findings. This investigation showed that crude proteins had remarkably high values in all the twelve fish scales which may indicate the potential use of scales as proteins source. However, Saraswat [28] stated that variation in the protein content in the scales obtained from the different fish species might be due to their different feeding habit, season, age, size, stages of growth as well as habitat.

Lipid content varied from 0.27±0.21% to 1.60± 0.08% (Table 1). The maximum value found in the scales of chital (*Chitala chitala*) and the minimum value found in the scales of tilapia (*Oreochromis mossambicus*). This result is in-line with the findings of Naqvi *et al.* [22] in wild and farmed *Ctenopharyngodon idella* scales. The maximum lipid content were found to be 0.74% in farmed fish of 901-1200 gm. Akter *et al.* [1] found 0.44% and 0.55% lipid content in Tilapia and Carp fish scales which also more or less similar with our present findings. Our present findings also indicating that fish scales were low amount of lipid and varied from species to species (Fig. 1).

Carbohydrate content is found to be at a very low amount in the present analysis ranging from roughly 0.35± 0.24% to 2.18 ±0.68% in tatkini (*Cirrhinus reba*) and shol (*Channa striata*) respectively (Table 2), which is similar with the other research. Naqvi *et al.* [22] found 0.11% carbohydrate in farmed *Ctenopharyngodon idella and* also coincide with the finding of Mahboob *et al.* [16].

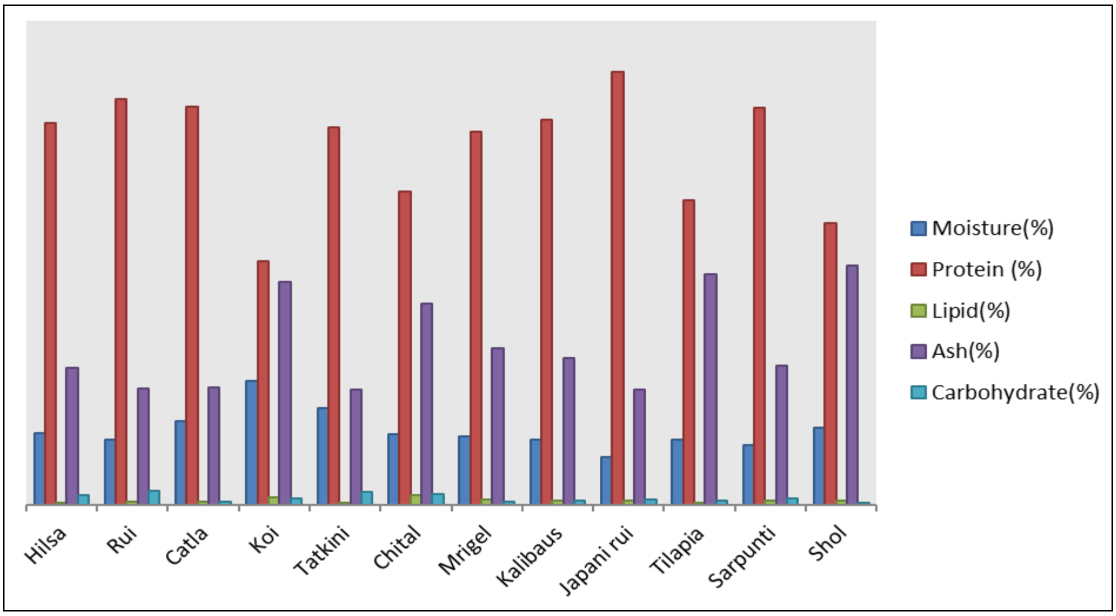

Fig 1: Variation in proximate composition of fish's scales.

Moisture content in fish scale was reported to be between 7.87± 0.57% and 20.53±0.48% (Table 2) with highest value observed in koi (*Anabas testudineus*) and lowest in japani rui (*Cyprinus carpio*). Other research shows high moisture content in fish scale which because of wet weight basis. Masood *et al.* [18] evaluated moisture content in wet matter of the scales of four mullet species were found to be in order of 44.4% in in *Liza melinoptera*, 58.3% in *Mugil cephalus*, 42.85% in *Liza macrolepis*, and 55.5% in *Valamugil speigleri*. Prommajak and Raviyan [27] found 60.86 % moisture in Thai pangus. Naqvi *et al.* [22] found maximum moisture in wild *Ctenopharyngodon idella* which was 52.07%.

This present research show limited moisture percentage than other findings which because of scales were air dried before analysis.

Ash content in fish scales is moderately high and varied from 19.06± 0.6 % in japani rui (*Cyprinus carpio*) to 39.55± 0.94% in shol (*Channa striata*) (Table 2). The present finding coincide with Naqvi *et al.* (2014) found 23.68%, 24.17%, 24.13% ash in weight category W1 (601-900gm), W2 (901-1200gm) and W3 (1201-1500) respectively in wild *Ctenopharyngodon idella*. Akter *et al.* [1] found 17.56% ash in Carp scale and 18.72% in Tilapia scale. Mahboob *et al.* [16] found 7.96% ash in Common carp scale.

3.1.1 *Mineral content*

Mineral analyses reveal that fish scales are a good source of relatively high levels of macrominerals and reasonable levels of micronutrients except sodium and potassium which were found below detectable levels (Table 3).

Table 3: Mineral contents in the scales of twelve different fish species (mean percentage ± SD).

Fish species	Calcium (Ca) (mg/100g)	Magnesium(Mg) (mg/100g)	Iron (Fe) (mg/100g)	Phosphorus (P) (mg/100g)
Hilsa	4425.54±10.78	236.56 ±25.61	45.01±2.15	860.88 ±9.80
Rui	4477.35 ±7.50	151.71± 25.36	56.90±1.82	942.28 ±8.49
Catla	6432.28±13.23	151.13 ±18.5	93.31±4.42	726.58± 9.04
Koi	7930.42±60.02	187.51 ±6.32	91.92±2.47	2031. 09 ±25.01
Tatkini	4879.72±29.05	154.78 ±7.54	24.15±1.74	1128.07 ±10.50
Chital	7805.54±10.71	190.16 ±5.94	1360.60±10.43	311.70 ±9.31
Mrigel	5934.21±15.71	183.63 ±2.65	71.38± 2.65	430.83 ±5.44
Kalibaus	5303.39±19.05	178.57± 3.01	77.36 ±2.98	360.79 ±5.19
Japani rui	3785.99±25.52	164.13 ±2.01	66.37 ±1.92	259.86 ±7.46
Tilapia	7325.07±10.82	205.29 ±3.35	87.56 ±4.38	501.42 ±5.99
Sarpunti	3246.93±18.98	159.74 ±3.48	39.15 ±2.19	230.40 ±5.11
Shol	7442.89±18.98	195.03±3.21	135.89 ±3.44	527.88 ±6.23

*Values are ± Mean Standard deviation of triplicate determinations.

Among the macrominerals, calcium (3246.93±18.98 to 7930.42±60.02 mg/100g) was the most abundant element, followed by phosphorus (to 230.40 ±5.11 to 2031. 09 ±25.01 mg/100 g), iron (24.15±1.74 to 1360.60±10.43 mg/100g) and magnesium (151.13 ±18.5 to 236.56 ±25.61 mg/100g) in the scales of twelve fish species studied (Table 3). Calcium is essential mineral for forming bone and skeletal. The present finding shows high calcium content in fish scales which varied from 3246.93±18.98 to 7930.42±60.02 mg/100g (Table 2) with highest value recorded in the scales of koi (*Anabas testudineus*) and lowest in sarpunti (*Puntius sarana*). Several researches found in Ca content of fish waste. A similar trend was reported by Nemati *et al.* [23] where they evaluated Ca 24.42g/100g in tuna fish frame and 38.16 g/100g Ca in tuna bone powder. Toppe *et al.* [29] found 17.0g/100g in Blue whitening fish frame. Above findings of fish waste support our present study about scale. Our present study including that calcium content in fish scale is varied from species to species (Fig. 2) and if properly utilized it can be used as calcium supplement for aquafeed or poultry feed industry.

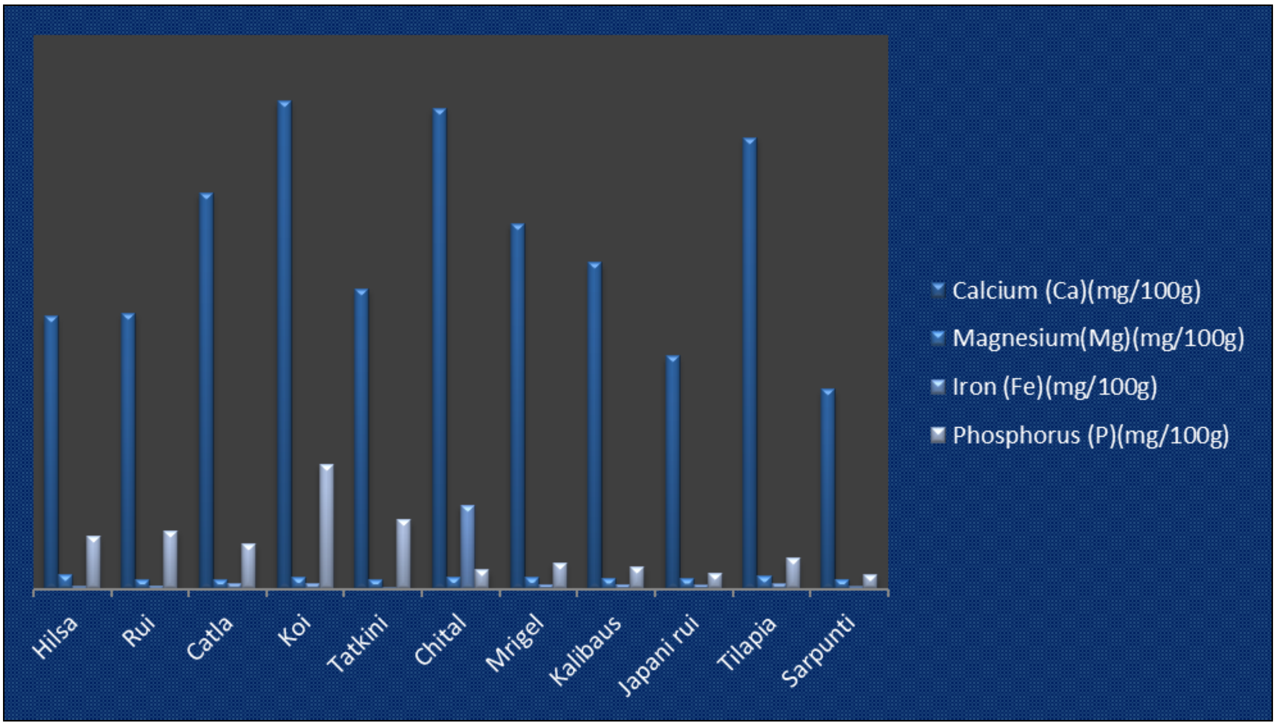

Fig 2: Comparison of mineral contents in twelve different fish's scales.

It was estimated that in this study average value of phosphorus content in fish scales varied from 230.40 ±5.11 to 2031 ±25.01 mg/100g (Table 3). The maximum average value found in koi (*Anabas testudineus*) fish scale which was 2031 ±25.01 mg/100g while minimum in sarpunti (*Puntius sarana*) scale with 230.40 ±5.11 mg/100g (Table 3). Several researches found in phosphorus content of fish waste like bone and skeletal. Logesh *et al.* [15] found 14.2% phosphorus in oil sardine and 11.6% phosphorus in ribbon fish. The present finding indicate that fish scale contain more phosphorus than bone.

The average iron content in fish scales varied from 24.15±1.74 to 1360.60±10.43 mg/100g (Table 3). However, iron content was found at its maximum in the scales of chital (*Chitala chitala*) and minimum in tatkini (*Cirrhinus reba*).Several researches found in iron content of fish waste and fish processing by product. Nemati *et al.* [23] evaluated 4.25 mg/100g and 6.20 mg/100g iron content in tuna frame and tuna bone powder. The present finding indicates that scale is more iron content than bone or other waste.

In the present study, average value of magnesium content in fish scales ranged from 151.13 ±18.5 to 236.56 ±25.61 mg/100g (Table 3). The maximum value found in Hilsa fish (*Tenualosa ilisha*) scale. Several researches found in magnesium content of fish waste like bone. Njinkoue *et al.* [25] found 0.22% Mg in *Pseudotolithus typus* and 0.33% Mg in *Pseudotolithus elongatus* bone. In the present findings implies that magnesium content in fish scale more or less similar with the magnesium content of fish bone.

4. Conclusion and recommendations

From the scale samples analyzed, it is evident that scales are nutritionally enriched potential biomaterial in terms of carbohydrate, protein, lipid and minerals content. So, the present research findings can be used as a guideline for promoting fruitful utilization of fish scales in food, cosmetics and pharmaceutical industries for various purposes thus paving a way for further detailed studies. This investigation, however, demonstrated that the differences in the proximate profiles of fish scale probably can be attributed to feeding habit, season, age, size, habitat as well as reproductive status of the fish species selected. Amino acid determination along with extraction of collagen & gelatin is inevitable for better understanding of the significance of scales. Moreover, fish scale also used as bio-indicator. However, research is required in this sector which keeps our environment green and properly utilizes the fish processing waste. Considerable dilemma exists as to whether the fish scales are safe for health as a nutritious ingredient. So, detection of heavy metals level should be carried out to affirm safety in its usage.

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