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Nutritional evaluation of some seaweeds from the Bay of Bengal in contrast to inland fishes of Bangladesh

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Abstract: *Seaweeds have become a very versatile product widely used for food or food supplement in many countries. However, the seaweed industry in Bangladesh is at its initial stage, people in Bangladesh are still not aware of the potentials of seaweed. However, recently seaweeds received increased attention as a potential source of essential nutrients. In contrast, fisheries and aquaculture are the traditional heritage of livelihood of Bangladesh. This present study was initiated to create a nutritional valuation of edible seaweeds of Bangladesh coast in order to popularize its consumption and utilization. Comparisons to corresponding and comparative nutrient values of commonly consumed inland small indigenous fish species were also made. Eight edible seaweeds and seven small fishes were analyzed to determine its proximate and mineral compositions. The proximate composition and micro-nutrient properties of selected seaweeds (Caulerpa racemosa, Enteromorpha intestinalis, Padina tetrastromatica, Sargassum oligocystum, Hypnea musciformis, Hypnea sp. and Jania rubens) were investigated. The protein content was the most abundant components (5.7 to 22.31 g/100 g) and varied among seaweeds with highest in edible red sea weed Hypnea sp. Total dietary fiber (4.1 to 6.8 g/100 g) and ash (3.96 to 27.95 g/100 g) were the other abundant components in seaweeds studied while their lipid content values were low (0.3 to 2.65 g/100 g). The mineral composition (Ca, K, Na, Fe and Zn) showed higher Ca (2,288.9 mg/100 g), K (98 mg/100 g) and Na (161 mg/100 g) values in red seaweed J. rubens, and was followed by S. oligocystum with Ca (228 mg/100 g), K (61 mg/100 g), Na (144 mg/100 g) and Fe (21 mg/100 g) values. The concentration of Zn (0.1 to 0.8 mg/100g) was at low level, indicating no sign of bioaccumulation of heavy metals. Inclusion of sea weed in food salad proved enrichment of food item with micro-nutrients. When comparing to small indigenous fish species (Amblypharongodon mola, Puntius sophore, Heteropneustes fossilis, Mystus bleekeri, Gudusia chapra, Corica soborna and Glossogobius giuris), the proximate composition was higher in seaweeds. Among minerals, Ca ranged from 476 to 1,093 mg/100 g, K from 134 to 300, Na from 38 to 57, Fe from 2.2 to 7.6 and Zn from 2.1 to 3.2 mg/100 g. This illustrates the diversity of micro-nutrient content of small fish species and in particular the rich nutrient composition of seaweed species in comparison to market price, which should guide policy makers and programmes to improve food and nutrition security in Bangladesh.*
Keywords: *Seaweeds, Small fish, Proximate composition, Minerals, St. Martin's Island.*

I. Introduction

The fisheries sector is important for Bangladesh's overall food security and economic growth. Recently coastal aqua farming strikingly emerged in the country as a potential sector that can contribute immensely to coastal prosperity and earning of foreign exchange (GoB, 2011). On the other hand, seaweed has become a very versatile product widely used for food in direct human consumption. Seaweeds are traditionally consumed in the orient as part of the daily diet. Human consumption of green algae (5%), brown algae (66.5%) and red algae (33%) is high in Asia, mainly in Japan, China and Korea (Dawes, 1998). Seaweed has plenty of essential nutrients, especially trace elements and several other bioactive substances and are major coastal resources which are valuable to human consumption and environment in many countries (Rudolph, 2000). In particular, certain edible seaweeds contain significant quantities of protein, lipids, vitamins and minerals (Wong and Cheung, 2000; Norziah and Ching, 2002), although nutrient contents vary with species, geographical location, season and temperature (Dawes *et al*., 1993; Kaehler and Kennish, 1996). In Bangladesh, the natural abundance of seaweeds is reported from the south-eastern part of the mainland and offshore island, the St. Martin Island having rocky substratum and are suitable for natural growth of seaweeds. Although the seaweed flora of St. Martin's Island in Bangladesh are extensive, yet they are relatively underutilized. In the St. Martin Island, the fishermen, women and their children are engaged in collecting seaweeds. The collected weeds are sun-dried in spreading on the open beach. *Hypnea* was reported to be the most abundant species (Sarker, 1992). Whereas the general mass of Bangladesh do not know that the seaweeds can be used as human food. To grow interest on seaweeds, information on chemical composition and its nutritive value is essential.

The Small Indigenous Fish Species (SIS) provides food and nutrition, subsistence and supplemental income to the great majority of the people of Bangladesh. The fish consumption survey confirmed that SIS is an important part of the diet of most rural people in Bangladesh (Roos, 2001). Small indigenous fish species have high nutritional value in terms of protein, mineral and vitamins, and these mineral and vitamins are not commonly available in other foods. Since these species are normally cooked and eaten whole, their effects in the diet is further enhanced since the bones also provide a source of calcium (Roos *et al.*, 2007). Knowledge of the nutrient composition of important foods is an invaluable tool in understanding the links between food production, access and nutrient intakes, and in devising policies and programmes such as development of improved production technologies (Thilsted and Wahab, 2014), to ensure that food supply optimally ensures population nutrient requirement security. The main aim of the present study was to document nutrient composition profiles of seaweeds of Bangladesh coast with a comparison of nutrient composition of inland SIS of fishes.

II. Materials and methods

Seaweed sampling

The St. Martin's Island is situated in the extreme south-eastern corner of Bangladesh which has naturally protected coral reefs. Geographically, it is located on the southern-most tip of the country, roughly between 20°34′ - 20°39′ N and 92°18′ - 92°21′ E and separated by a channel of about 13 km from the mainland. The average turbidity (Secchi disc) of in-shore waters of St. Martin Island ranges from 1.5 m to 8.0 m. Water temperature and salinity fluctuates from 22-29°C (Tomascik, 1997) and 21.0-33.5 PSU (Zafar, 2005) respectively, throughout the year. For the collection of natural growing seaweeds, three sampling area were selected at intertidal zone in the eastern part of the Island as shown in Fig. 1.

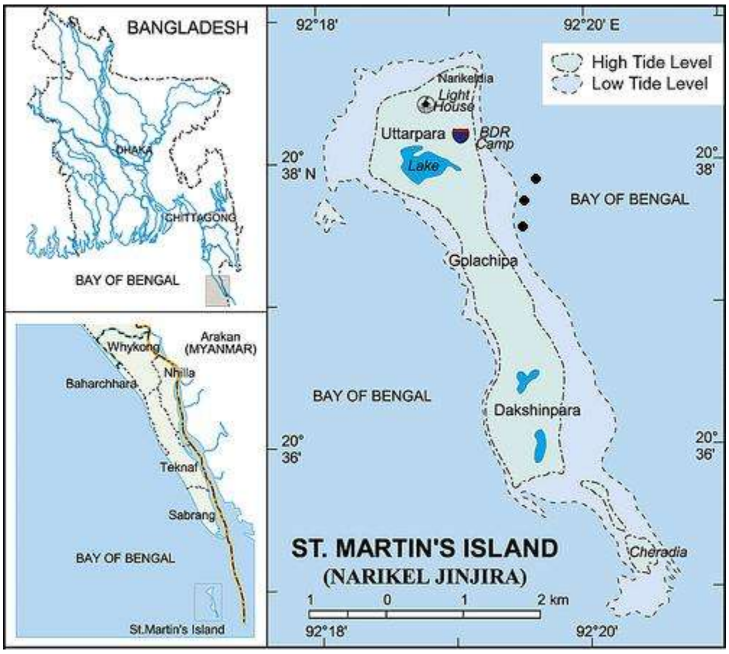

Fig. 1. The seaweed sampling area of St. Martin's Island, Bangladesh

Available seaweeds such as, *Caulerpa racemosa*, *Enteromorpha intestinalis*, *Padina tetrastromatica*, *Sargassum oligocystum*, *Hypnea musciformis*, *Hypnea* sp. and *Jania rubens* were collected from sampling locations. The collection was made during low tide from upper littoral zone of the above mentioned locations during January-April 2015. The seaweeds were handpicked and collected with the help of scalpel then immediately cleaned with seawater to remove sand and epiphytes. Then the seaweeds were immediately transported to the laboratory and cleaned thoroughly using tap freshwater to remove the salt on the surface of the sample. Then it was spread on blotting paper to remove excess amount of water and shade-dried at room temperature until constant weight was obtained.

Fish sampling

Single pooled samples of seven small indigenous fish species (SIS) (Felt *et al.*, 1998) commonly available during monsoon in the open waters of Bangladesh, were collected from local markets and fish landing sites in Cox's Bazar, Chittagong and Chandpur districts. Fish samples were packed in polyethylene bags at the collection site and transported in an insulated ice box lined with ice chips. Samples were cleaned by local fisher-folk to obtain raw, edible parts according to traditional practice. Depending on the fish species, edible parts may or may not include the head, viscera, scales, bones and other parts. Fish samples were washed with deionized water after cleaning and before being packed in polyethylene bags and stored in a deep freezer at -18^{0}C.

Water analysis

The water sample of seaweeds bed was collected at a depth of 50 cm below the surface. The water samples were filtered using membrane filter of 47 mm diameter and 0.45 µm pore size, and the filtered water samples were kept frozen at -18^{0}C for later analysis. Physico-chemical parameters were measured according to the standard methods for examination of water (APHA, 1992) including temperature, pH, salinity, dissolved oxygen (DO), nitrite (NO_2), nitrate (NO_3), sulphate (SO_4) and Ca.

Proximate/biochemical analysis

The proximate compositions of seaweeds were analyzed according to the standard methods described in AOAC (2000). The moisture content was determined by drying the seaweed samples in an oven at 105°C until a constant weight was obtained. The ash content was obtained by calcinations in a muffle furnace at 550°C for 4 h. Protein content was analyzed by the Kjeldahl method with a conversion factor of 6.25 to convert total nitrogen into crude protein. Crude lipid was extracted from the seaweed in a Soxhlet extractor with petroleum ether. After ensuring complete extraction, petroleum ether was evaporated and the residue was dried to a constant weight at 105°C. Fiber was quantified on 2 g samples previously boiled with diluted H_2SO_4 (0.3 N). The mixture was filtered and washed with 200 ml of boiling water and NaOH (0.5 N). The residue was re-extracted, after washing with boiled distilled water and acetone and finally dried at 105°C to constant a weight. The material was heated at 550°C for 3 h and the weight recorded. Carbohydrate content was determined as the weight difference using protein, lipid, fibre, moisture and ash content data.

For the determination of mineral elements (calcium, potassium, sodium, iron and zinc), samples were digested by dry ashing and dissolved in 1 M HCl (AOAC 2000). The concentrations of the elements in seaweed and fish samples were determined with atomic absorption spectrophotometer (Perkin Elmer, model 3110). Triplicate determinations for each element were carried out. The concentrations of the elements were determined from calibration curves of the standard elements.

Statistical procedure

For all analyses, the mean and standard deviation for each of the nutrients analyzed were calculated and reported.

III. Results

Water parameters in seaweed bed

The surface water temperature was 27°C and the average of water salinity was 31.5 ‰ at the seaweed collection area (Table 1). The pH value was 8.5 and the dissolved oxygen content was 7.0 mg/l at the study area. The presence of nutrients for phytoplankton growth has been considered as one of the main factors controlling production in aquatic systems. The results in Table 1 clarified that the values of nitrite, nitrate and sulphate were 0, 0.731 and 10,775.256 mg/l, respectively. Ca element in the surface water was recorded as 439.3 ppm (Table 1).

Table 1. Physico-chemical parameters and inorganic constituents of the Bay of Bengal, Bangladesh water (Mean ± SE, N=3)

Temp. (°C)	Salinity (ppt)	pH	DO (mg/l)	NO_2 (mg/l)	NO_3 (mg/l)	SO_4 (mg/l)	Ca (ppm)
27±1.0	31.5±1.2	8.5±0.2	7.0±0.2	ND	0.731±0.2	10,775.25±0.3	439.30±0.5

Proximate composition of seaweed and fishes

Proximate composition, total fibre and carbohydrate contents of two green, two brown and three red commercially important seaweeds are presented in Table 2. Ash content (3.96–27.95%) was high in *Padina tetrastromatica*. Protein content ranged from 5.7 to 22.31%, being much higher for *Caulerpa racemosa* and *Hypnea* sp. (22%) and was followed by *P. tetrastromatica* and *H. musciformis* (12.29–13.73%). Minor components were lipids (0.34–0.98%) in all samples except for *C. racemosa* (2.65%). Fiber content ranged between 4.1 and 6.8%. Carbohydrate was high in *Jania rubens* (63.14%), and was followed by *Sargassum oligocystum and Hypnea* sp. (51.4-51.75%).

Table 2. Proximate composition of some selected seaweeds from the St. Martin Island, Bangladesh

Seaweed spp.	Class	Proximate composition (g/100 g)					
		Moisture	Ash	Protein	Lipid	Fiber	Carbohydrate
Caulerpa racemosa	Green	16.36 ±0.4	9.9 ± 1.2	22.25 ± 1.1	2.65 ± 0.7	4.8 ± 0.2	44.04±0.7
Enteromorpha intestinalis	Green	24.6±0.9	15.2±1.5	19.5±0.6	0.3±0.5	4.9±0.30	35.5±1.8
Padina tetrastromatica	Brown	15.68 ± 0.1	27.95±0.8	12.29 ± 0.8	0.98 ± 0.4	6.8 ± 0.5	36.30±0.9
Sargassum oligocystum	Brown	21.09±0.3	12.94±0.5	8.19±0.6	0.83±0.3	5.2±0.6	51.75±0.7
Hypnea musciformis	Red	24.31±0.5	9.76 ± 1.4	13.73±0.8	0.34±0.4	5.6±0.7	46.26±0.6
Hypnea sp.	Red	17.45±0.2	3.96±0.9	22.31±1.0	0.78±0.3	4.1±0.5	51.4±0.5
Jania rubens	Red	8.58±0.4	16.27±1.0	5.7±0.7	0.41±0.1	5.9±0.4	63.14±0.4

In contrast, proximate compositions of 7 species of small indigenous fish species are presented in Table 3. Protein, the most important component, was in the range of 13.34 to 18.03% with the highest value in *Heteropneustes fossilis* and the lowest in *Mystus bleekeri*, while lipid content was in the range of 1.97 to 7.67% with the highest value in *Puntius sophore* and the lowest in *Glossogobius giuris.* Ash content ranged from 1.55 to 3.00%. An inverse relationship was found to exit between the moisture and lipid content of fishes under study, but sum of the two approximates 80% except *H. fossilis* and *P. sophore*. The summation of lipid and water is not necessarily constant and it frequently spans a range of 78 to 85%.

Table 3. Proximate composition of some selected small fishes from inland waters of Bangladesh.

Inland small fishes	Common name	Proximate composition (g/100 g)					
		Moisture	Ash	Protein	Lipid	Fiber	Carbohydrate
Amblypharongodon mola	Mola carplet	77.61±0.4	4.48±0.3	15.71±0.9	2.20±0.2	0	0
Puntius sophore	Pool barb	71.59±0.6	4.87±0.5	15.87±0.6	7.67±0.2	0	0
Heteropneustes fossilis	Stinging catfish	71.37±0.5	3.82±0.6	18.93±0.7	5.87±0.5	0	0
Mystus bleekeri	Day's mystus	79.45±0.8	4.39±0.7	13.34±1.1	2.82±0.8	0	0
Gudusia chapra	Indian river shad	76.46±0.7	4.30±0.3	14.23±0.8	5.02±0.9	0	0
Corica soborna	Ganges river shad	78.31±1.0	1.55±0.4	16.12±0.9	4.02±0.4	0	0
Glossogobius giuris	Tank goby	80.43±0.5	3.00±0.6	14.60±0.7	1.97±1.0	0	0

Micronutrients contents

The mineral compositions of the green, brown and red seaweeds are demonstrated in Table 4. It can be noted that the higher values of calcium (2,289−228 mg/100 g) and potassium (98−60.8 mg/100 g) were recorded with *Hypnea* sp., *J. rubena* and *S. oligocystum.* The major constituent of the investigated seaweeds was calcium and sodium which formed the bulk of total minerals. The present result clarified that calcium (2,289 mg/100 g), potassium (71 mg/100 g) and sodium (161 mg/100 g) values of *J. rubena* was actually high. Fe content ranged from 12.5 to 28.7 ppm among the studied seaweeds except for *J. rubens* (4.6 mg/100 g). Presence of low concentration of Zn (0.1−0.8 mg/100 g) was recorded from the investigated seaweeds.

Table 4. Micronutrients in selected seaweeds from Bangladesh coast

Seaweed species	Class	Minerals (mg/100 g)				
		Ca	K	Na	Fe	Zn
Caulerpa racemosa	Green	202.0±0.1	25.8±0.4	106.6±0.5	13.3±1.0	0.8±0.2
Enteromorpha intestinalis	Green	103.8±0.3	35.0±0.1	51.6±0.1	21.7±0.3	0.7±0.3
Padina tetrastromatica	Brown	279.4±1.1	41.4±0.3	4.7±0.3	28.7±0.2	0.1±0.5
Sargassum oligocystum	Brown	228.0±0.4	60.8±1.0	144.4±1.2	21.0±0.3	0.2±0.4
Hypnea musciformis	Red	140.7±0.2	30.8±0.2	110.3±0.5	14.2±0.5	0.5±0.1
Hypnea sp.	Red	102.1±1.0	98.0±0.8	150.0±0.1	12.5±0.6	0.4±0.2
Jania rubens	Red	2,288.9±0.6	71.0±0.5	161.0±0.4	4.6±1.1	-

Table 5 highlights the mineral composition of some inland small fishes that are commonly consumed by the rural people. All the fish species were found to contain higher values of calcium and potassium compared to seaweeds under study. *Puntius sophore*, *Mystus bleekeri* and *Gudusia chapra* represented with higher Ca (1,042−1,093 mg/100 g) and highest K (281−203 mg/100g) values. Iron was highest in *G. chapra* and *Amblypharongodon mola,* while zinc was within 2.1-3.2 mg/ 100 g level. Fishes contained less Fe than seaweeds.

Table 5. Minerals in some inland fish species of Bangladesh

Fish species	Minerals (mg/100 g)				
	Ca	K	Na	Fe	Zn
Amblypharongodon mola	853	152	39	5.7	3.2
Puntius sophore	1,042	203	53	2.2	2.9
Heteropneustes fossilis	60	300	54	2.2	1.1
Mystus bleekeri	1,093	203	57	4.0	3.1
Gudusia chapra	1,063	281	57	7.6	2.1
Corica soborna	476	134	38	2.8	3.1
Glossogobius giuris	790	210	56	2.3	2.1

Source: Bogard *et al.* (2015)

The contribution of seaweeds in our diet was evaluated through enrichment of fresh salad. In a common vegetable salad, red sea weed (*H. musciformis*) was added @ 10% volume and served as normal dish. Both the salads were then dried and tested for mineral composition (Table 6). It was observed that salad enriched with seaweed resulted with higher values of Ca, Na, Fe and Zn.

Table 6. Micronutrients enrichment case study

Food items	Minerals (mg/100 g)				
	Ca	K	Na	Fe	Zn
Vegetable salad	833.05±0.2	6,507.82±0.4	15,636.07±0.5	16.29±0.6	4.93±0.9
Vegetable salad with seaweed	1,565.14±0.7	6,031.64±0.3	17,663.24±0.8	154.17±0.4	8.85±0.5

IV. Discussion

As there is no industrial set up for seaweed processing and utilization in Bangladesh, the dried seaweeds are sold to the marketing agents and straddled from Bangladesh to Myanmar. The St. Martin Island with rocky substratum and about 30 km of the coastline of the Bay of Bengal at Cox's Bazar are suitable for natural growth of seaweeds. Major groups of naturally growing seaweeds in these areas represent 20–22 species (Islam and Aziz, 1982). The direct seaweed consumption in Bangladesh is almost negligible except in the preparation of fresh salad by some tribal people along the coastal districts. The total seaweed harvest is about 143,000 metric tons from the St. Martin Island (Aziz, 2015). *H. musciformis* occurring in harvestable quantities represent a potential raw material for carrageenan in the food industry as an additive and for pharmacological applications (Rafiquzzaman *et al.,* 2015). A pilot-scale motivational culture trial of *Hypnea*, *Caulerpa* and *Enteromorpha* spp. by the local NGO- Coast Trust to local fisher folks and woman proved encouraging result (Coast Trust, 2013).

Comparative proximate composition

The green and red seaweeds, *Caulerpa racemosa*, *Enteromorpha intestinalis* and *Hypnea* sp. were found to contained higher protein (20-22%). These values were compared to corresponding data for small indigenous species (SIS) under study (Table 3). Some seaweeds, such as *Porphyra* spp. (Nori) are relatively high in proteins and the protein content can be as high as 47% of the dry weight (Fleurence, 1999), but these levels vary according to the season and the species. For most seaweed species, aspartic and glutamic acids constitute a large part of the amino acid make-up of these proteins. The bioavailability of seaweed proteins can sometimes be inhibited by the entrapped nature of the proteins in the cellular matrix. Increasing the bioavailability by using physical processes or fermentation to break down the fibers and liberate more protein has been studied, particularly for *P. palmata* (Marrion, 2003). Red seaweeds contain a group of proteins called biliproteins, some of which are extracted for their valuable use as fluorescent markers. Overall, seaweeds have been reviewed favorably as sources of proteins for nutritional purposes (Wong and Cheung, 2000). In the present study, ash content (13-28%) in brown algae was higher than in green and red algae (4-10%) except for *E. intestinalis* and *J. rubens*. Edible brown and red seaweeds could be used as a food supplement to help meet the recommended daily intake of some essential minerals and trace elements (Rupérez, 2002).

The protein content of fish ranged from 14 to 18 g/100 g raw edible parts (Darnton-Hill *et al.*, 1988). From the last national survey in rural Bangladesh, the mean total protein intake was 48 g/person/d, of which fish contributed 3 g (Ahmad and Hassan, 1983). The value of fish in the Bangladeshi diet focused on the contribution made to protein, because protein recommendations in the typical diet are met provided that the energy recommendations are met (Roos, 2001). Now-a-days the SIS are not low-cost protein source to poor people, rather, they are main constituent of urban populations health. So, from nutritional point of view focus should be placed on the seaweeds in comparison to fish and the contribution of micronutrients, especially minerals, from the different types of seaweeds.

Total fiber and carbohydrate content in seaweed studied varied from 4.1-6.8 g/100 g and 36.30 to 63.14 g/100 g, respectively. Maximum fiber was recorded in *P. tetrastromatica* and minimum was recurded in

Hypnea sp. Carbohydrates comprised 50-60% of the dry weight of seaweeds (Manivannan, 2009). Seaweeds have salted flavor, somewhat mildly spicy and they can be eaten and used in the preparation of food. Seaweeds typically contain high amounts of fiber, trace metals and contrary to land based plant foods, they contain complete proteins (Jaspars and Folmer, 2013).

Mineral composition

Seaweeds are high in minerals due to their marine habitat, and the diversity of the minerals they absorb is wide and this mineral content in seaweeds is much higher when compared to the edible terrestrial vegetables (Indegaard and Minsaas, 1991; USDA, 2001). Mineral content has been shown to vary according to species, geographical place of harvest, seasonal, environmental and physiological factors, type of processing and method of mineralization (Honya *et al.,* 1993; Mabeau and Fleurence, 1993; Yoshie *et al.,* 1994). Calcium, accumulates in seaweeds at much higher levels than in terrestrial foodstuffs. This is illustrated as in an 8 g portion of *Ulva lactuca* (sea lettuce), which provides 260 mg of calcium, equaling approximately 37% of the RNI of calcium for an adult male (Committee on Medical Aspects of Food and Nutrition Policy, 1991). Calcium content ranged from 476 to 1,093 mg/100 g in fishes from inland waters of Bangladesh. As would be expected, calcium content was much higher in species in which bones are commonly consumed and included in the edible parts. In developed countries, dairy products tend to be the primary source of dietary calcium; however, this is not the case in Bangladesh where frequency of dairy consumption is very low (Belton *et al.,* 2014). The content of calcium in seaweed is not only up to 10 times higher than that in cow's milk but is also much easier for the body to assimilate (Leyman, 2002). In the present study *S. oligocystum* showed maximum content of mineral composition and the lower level of mineral content was present in *H. musciformis*.

Sodium and potassium also presented at relatively high levels in seaweeds under study, although Na:K ratios are usually below 1:5 (Ruperez, 2002). Minerals such as iron and copper are present in seaweeds at higher levels than in many well-known terrestrial sources of minerals, such as meats and spinach (Institut de Phytonutrition, 2004). As for the heavy metals, zinc content was found within the range of 0.1–0.8 mg/100 g and also below the maximum level allowed in seaweeds for human consumption in Japan (Indegaard and Minsaas, 1991). The use of seaweeds in the diet, probably, can reduce the impact of contamination, as seaweeds have the property to bind with the metals and toxic substances (Aderhold and Edyvean, 1996). The present study indicates the possibility of seaweed species being used as food supplements to improve the nutritive value for the human diet.

Iron content varied from 12.5 to 28.7 mg/100 g in seaweeds under study and 2.2 to 7.6 mg/100 g in fish species. Overall, the data presented here indicate that seaweeds may contribute higher than fish species to dietary iron intakes in Bangladesh which is of high bioavailability as an animal-source food (FAO and WHO, 2004). This may have important policy implications given the public health significance of iron deficiency in Bangladesh, with prevalence recently estimated at 10.7% in pre-school aged children and 7.1% in adult women (ICDDRB, 2013).

V. Conclusions

The edible seaweeds found in the Bay of Bengal, Bangladesh coast were analyzed for their proximate and mineral composition, and were then compared to that with local inland small fishes. Seaweeds were found to contain a higher concentration of protein, fiber and good concentration of minerals. The data presented here show that from a nutritional perspective, sea weeds hold the potential to provide a much greater contribution to micronutrient intakes of vulnerable groups in the population compared to common small indigenous fish species. Thus results of the present study conclude that seaweeds are potential healthy food in our diets and may be of use to the food industry as a source of ingredients with high nutritional value. Sea weeds can provide a dietary alternative for its nutritional value and its commercial value can be enhanced by improving the quality and expanding the range of seaweed-based value added products. With respect to the high protein level and balanced micro-nutrient profile of the seaweeds studied here appeared to be an interesting potential source of plant food. The nutritional values of the seaweeds obtained here were based on chemical analyses only. Biological evaluation using human and animal feeding studies would be required to establish the nutritional value of these seaweeds. More studies are necessary (e.g. fatty acids, vitamins, toxic elements and other bioactive compounds) to further enrich our knowledge and promote the exploitation of these marine algae.

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