World Journal of Dairy & Food Sciences 6 (1): 27-34, 2011
ISSN 1817-308X

Nutrient Content in Fresh Water Red Algae (Lemaneaceae, Rhodophyta) from Rivers of Manipur, North-East India

M. Romeo Singh and Asha Gupta

Department of Life Sciences, Manipur University, Canchipur-795003, Imphal, India

Abstract: Lemanea is a filamentous fresh water red algae belonging to family Rhodydophyta. Traditionally it is consumed and extensively harvested by the local people of Manipur (Latitude 23.80° N to 25.68° N and Longitude 93.03° E to 94.78° E) a state in the north-east corner of India bordering Myanmar. People used it in the form of dried, fried, roasted and as local delicacy because of the fishy smell, taste and flavor it possesses, since times immemorial. The alga is found to grow during cold winter months (December to February) in some of the rivers of Manipur with disjunct distribution in cold, aerated, running water on rocks, boulders, cobbles, bricks, sandstones etc. The proximate composition, ash, protein, lipid, carbohydrate, total free amino acid, crude fibre, carotenoid and mineral profile of five species of Lemanea from four rivers of Manipur northeast India were studied. The species studied were *Lemanea australis, Lemanea torulosa, Lemanea fluviatilis, Lemanea mamillosa* and *Lemanea catenata*. It was found that the ash content lies within the range (7.90-30.45% DW), Crude fibre (0.79-3.03%DW), Total protein content was found highest in *L. fluviatilis* (31.07% DW) and lowest in *L. mamillosa* (17.48% DW) on dry weight (DW) basis. Maximum carbohydrate content was found to exhibit the highest value in *L. australis* from site-II (38.20% DW) and lowest in *L. mamillosa* from site-IV (9.60% DW). Free amino acid was highest in *L. fluviatilis* of site-IV (17.20% DW) and lowest in *L. mamillosa* (9.60% DW) of site-V. Carotenoid content was reported to be maximum by *L. australis* from site-I (0.65 mg/g^{1}FW) and minimum by *L. catenata* from site-VI (0.56 mg/g FW) on fresh weight (FW) basis. Statistical analysis revealed the mean concentration of nutrients differed significantly within species from the six studied sites. Reports of edible seaweed from some regions of the world had been well documented but no reports are available on the nutritive value of freshwater Lemanea so far. In conclusion, the present paper was an attempt to work out the nutritive value of Lemanea species found in rivers of Manipur, Northeast India and to compare the same reported in other algae.

Key words: Nutrient composition · Lemanea · Minerals · Rhodophyta · Freshwater · Manipur

INTRODUCTION

The food demand in the coming years may not be covered by conventional agriculture. Therefore, intensive efforts are being made to find alternate new and unconventional protein sources. Macroalgae are ecologically and biologically important which provide medicinal constituents, nutrition, reproduction and an accommodating environment for other living organisms [1]. A study of the chemistry and biochemistry of algae yields information on organic materials and nutritive elements present in them. This information is also helpful in the evaluation of nutritional value of these minute plants. Macroalgal polysaccharides are used in the food, cosmetics, paints, crop, textile, paper, rubber and building industries. In addition, they are used in medicine and in pharmacology for their antimicrobial, antiviral, antitumor and anticoagulant properties [2]. Utilisation of algae in food supplementation was also studied by Ahmed and Hamza [3]. The principal compounds of the edible algae are carbohydrates (sugar or vegetable gums), small quantities of protein and fat, ash, which is largely compound of sodium and potassium [4] and 80-90% of water. The main emphasis of this part of study was to determine the level of different macronutrients and inorganic elements present in the Lemanea species found in fresh-water environment in rivers of Manipur. A fresh-water alga, as a potential source of food for animals and human consumption, is receiving increasing attention during the last decades [5-9]. Widespread research on

Corresponding Author: Maibam Romeo Singh, Department of Life Sciences, Manipur University, Canchipur-795003, Imphal, India, E-mail: millow_singh@yahoo.com.

utilization of algae as food or fodder is mainly a matter of concern because of the ever increasing gap of world food supplies and population. Besides, the significance of dietary proteins during infancy for resistance towards infection and for physical growth and mental development has now widely been recognized [10]. The extensive investigations indicate the concern of national and international bodies over the scarcity of high quality proteins in certain areas and its availability of protein in future [7]. Despite the fact that chemical composition of algae varies in relation to climatic and geographical conditions and evaluation of its nutritional and manurial value is of great practical applicability, the work was initiated; to explore into the evaluation of its nutritional and manurial value. No phycochemical studies have been reported on the aspects of biochemical composition of freshwater red algae Lemanea found in rivers of Manipur so far. Hence an attempt has been made to investigate the nutrient composition of five Lemanea species (*Lemanea australis, Lemanea torulosa, Lemanea fluviatilis, Lemanea mamillosa* and *Lemanea catenata*) distributed disjunctively in four rivers of Manipur, India. This information is essential in the search for additional healthy food sources from the rivers for use in human nutrition.

MATERIAL AND METHODS

Manipur (Latitude 23.80° N to 25.68° N and Longitude 93.03° E to 94.78° E) located in the North-east corner of India bordering one of the Indo-Myanmar hotspot regions. Five species of Lemanea species collected during their growing period (December 2008-February 2009) from the four rivers of Manipur, India were: *Lemanea australis* from site-I: Sanjenthong (Latitude 24.80090°N and Longitude 93.94706°E) in Imphal river and site-II: Serou Lai Maning (Latitude 24.274749°N and Longitude 93.876995°E) from Manipur river; *Lemanea torulosa* from site-III: Ningthem Hidane (Latitude 24.263555°N and Longitude 93.868032°E) from Manipur river; *Lemanea fluviatilis* from site-IV: Thoubal Bridge (Latitude 24.642535°N and Longitude 94.000692°E) from Thoubal river; *Lemanea mamillosa* from site-V: Sawombung Bridge (Latitude 24.86843°N and Longitude 94.02124°E) from Iril river and *Lemanea catenata* from site-VI: Chingaren (Latitude 24.856518°N and Longitude 94.001747°E) from Iril river. Fresh Lemanea species were thoroughly washed with distilled water and their holdfasts and epiphytes removed and then placed in a freezer (-20°C) immediately after collection. Dried ground samples were used for most of the analyses except for carotenoid content fresh samples were used. The ground samples were stored in air-tight plastic containers covered with aluminium foil and stored at (-20°C) for further analyses. Analyses were carried out in triplicate. Significance of difference at $p<0.05$, was analyzed by one-way analyses of variance (ANOVA) followed by Duncan multiple range tests using SPSS system version 12.0 for windows.

The moisture content was determined by oven method at 105°C; AOAC 934.04; ash at 550°C overnight; AOAC 930.05. The total protein content was determined with Folin reagent with bovine albumin serving as standard [11]. The total carbohydrate content was assayed by the phenol-sulphuric acid method [12] after extraction with 2.5 N HCl. The results were calculated from glucose standard curve. Total lipid was determined by Soxhlet method as described by Folch *et al.* [13]. Free amino acid by Yemm and Cocking [14] using glycine as a standard. Crude fibre (successive hydrolysis at 100°C, 0.05N H_2SO_4 and 0.05N NaOH for 30 minute each) were determined as per AOAC [15] and carotenoid content as mentioned by Arnon [16]. Major elements (Na, K, Ca and Mg) and trace elements (Fe, Mn, Zn, Cu and Co) were determined using a Perkin Elmer Instrument (Shelton, USA) model AAnalyst 200 flame atomic absorption spectrometer equipped with deuterium arc background correction. Absorbance measurements were performed by using a Lumina copper hollow cathode lamp against mineral element standards (Merck, Germany). An air-acetylene burner was also used against mineral element standards (Merck, Germany). Nitrogen was determined using microKjeldahl method [17] with some modification incorporated by Lang [18] and calculated by comparing with standard of $(NH_4)_2.SO_4$ after measurement in a spectrophotometer at 440 nm and Phosphorus by calorimetric estimation method whereby concentration of P was calculated with the help of standard curve prepared from an analytical grade of KH_2PO_4 after measuring in a spectrophotometer at 420 nm. All results were expressed as mean ± SD (n=3).

RESULTS AND DISCUSSION

Measurable differences in nutritional composition were apparent among the five species of Lemanea studied. The values of moisture, ash, organic matter, crude fibre, protein, lipid, carbohydrate and total free amino acid of five species of Lemanea belonging to the family rhodophyta and the significant individual differences in the metabolic content of the algae are shown in table 1

Table 1: Nutrient composition of *Lemanea* species from the six study sites

	Imphal river	Manipur river		Thoubal river		Iril river
	I	II	III	IV	V	VI
Nutrients	*L. australis*	*L. australis*	*L. torulosa*	*L. fluviatilis*	*L. mamillosa*	*L. catenata*
Moisture (% DW)	76.24±0.88	79.90±0.12	72.33±0.34	81.82±0.26^{e}	81.99±0.37^{e}	78.47±0.34
Ash (% DW)	26.22±0.76	7.90±0.01	8.75±0.20	31.07±0.75^{e}	26.35±0.25	16.57±0.16^{e}
Crude fiber (% DW)	0.79±0.40^{a}	1.09±0.01^{a}	2.79±0.47^{b}	3.03±0.41^{b}	2.58±0.45^{b}	2.63±0.84^{b}
Protein (% DW)	26.22±0.76^{c}	25.80±0.01^{c}	23.80±0.78^{b}	31.07±0.75^{d}	17.48±0.94^{a}	24.44±0.02^{b}
Lipid (% DW)	1.83±0.02	1.10±0.02	1.17±0.02	1.63±0.01	0.81±0.02	0.93±1.34
Total Carbohydrate (% DW)	26.00±1.36^{b}	38.20±1.37	27.20±1.32^{bc}	20.51±1.40	29.40±1.46^{c}	48.60±0.01
Total Free Amino acid (%)	15.80±0.03	12.80±0.03	15.60±0.02	17.20±0.04^{a}	9.60±0.04	13.60±0.01
Carotenoid (mg /g FW)	0.65±0.03^{c}	0.58±0.01^{ab}	0.61±0.03^{bc}	0.61±0.01^{bc}	0.58±0.02^{ab}	0.56±0.02^{a}
Nitrogen (mg/100g DW)	202.21±0.48^{b}	111.48±0.44^{a}	113.79±0.46^{a}	226.28±0.37^{c}	214.17±0.34^{bc}	134.39±0.46^{a}
Phosphorus (mg/100g DW)	92.37±0.41^{b}	150.70±0.25^{e}	142.88±0.41^{d}	135.17±0.33^{c}	72.42±0.33^{a}	72.92±0.35^{a}
Potassium (mg/100g DW)	363.05±0.55	836.92±0.40	804.3±0.42	1003.2±0.39	815.64±0.22	862.20±0.36
Sodium (mg/100g DW)	474.78±0.28	141.90±0.36	146.80±0.31	423.32±0.25	276.10±0.36	238.09±0.27
Calcium (mg/100g DW)	112.26±0.49^{b}	111.44±0.44^{a}	112.23±0.26^{ab}	113.76±0.50	111.59±0.42^{ab}	111.90±0.38^{ab}
Magnesium (mg/100g DW))	111.30±0.53^{c}	70.87±0.41^{a}	99.85±0.33^{b}	135.51±0.31^{e}	135.65±0.17^{e}	120.20±0.42^{d}
Iron (mg/100g DW)	25.25±0.40^{d}	16.95±0.34^{a}	19.07±0.41^{c}	26.18±0.35^{e}	25.64±0.38^{de}	18.17±0.38^{b}
Manganese (mg/100g DW)	5.80±0.44	5.06±0.48	6.51±0.38	14.34±0.22	8.03±0.22	9.22±0.43
Zinc (mg/100g DW)	5.25±0.41^{c}	3.93±0.41^{b}	5.25±0.37^{c}	3.77±0.26^{b}	1.86±0.22^{a}	1.22±0.44^{a}
Copper (mg/100g DW)	8.23±0.43^{a}	12.98±0.45^{c}	13.08±0.29^{c}	8.91±0.40^{a}	12.13±0.43^{b}	13.09±0.41^{c}
Cobalt (mg/100g DW)	8.79±0.36^{b}	10.40±0.44^{c}	10.74±0.18^{c}	7.98±0.37^{a}	8.96±0.51^{b}	9.02±0.33^{b}
Na/K ratio	1.31±0.50^{f}	0.17±0.90^{a}	0.18±0.73^{a}	0.42±0.64^{d}	0.34±1.64^{c}	0.27±0.75^{b}
Total cations	1409.29±1.70^{a}	1472.63±0.78^{b}	1474.50±0.82^{b}	2098.42±1.65^{e}	1682.19±0.90^{d}	1590.42±1.25^{c}

Values are expressed as mean± standard deviation, n=3

Values in the same row with different superscripts letters (a-e) are significantly different ($p<0.05$) (Duncan's Multiple Range Test).

based on dry weight (DW) except for carotenoid content expressed in fresh weight (FW). In the present study maximum moisture average content was exhibited by *L. mamillosa* from site-V (81.9±0.37%) and minimum by *L. torulosa* from site-III (72.33±0.34%). Our results were found to be very high when compared to the work by Matanjun and Mohamed [19] in tropical edible seaweed like *Eucheuma cottonii* (10.55±1.60%); 10.76±0.80% in *Caulerpa lentillifera* (Chlorophyta) and 9.95±0.55% in *Sargassum polycystum* (Phaeophyta).

The ash content in algae is probably connected with the concentration of inorganic compounds and salts in water environment where the algae grow. In the selected red and brown algae form north-eastern Mediterranean Sea, the ash contents varied from 17 to 27% on a dry weight basis [20]. In the present study, ash content showed remarkable variation with a highest value of 30.45±0.93% in *L. australis* from site-I followed by *L. catenata* from site-VI (30.37±0.39%), *L. mamillosa* from site-V (26.35±0.25%), *L. fluviatilis* from site-IV (16.57±0.16%), *L. torulosa* from site-III (8.75±0.20%) while the lowest value of 7.9±0.017% was recorded in *L. australis* from site-II (7.90±0.01%). Ash content of *L. australis* (site-I), *L. fluviatilis* (site-IV) *L. mamillosa* (site-V) and *L. catenata* (site-VI) were found to be higher when compared with the *Laminaria* spp. (Brown algae) found in Japan, China, Korea, U.S.A., U.K., France containing 21.1% and *Porphyra tenera* (Red algae) found in China, Korea and Japan containing 10.3%, *Ulva latuca* (Green alga) found in China, S.E. Asia, West Indies, Chile containing 15.6% [21]. Probably one of the reasons is different environmental conditions of the growing habitats. According to a report on species liability of trace elements content within Rhodophyta, Chlorophyta and Phaeophyta the metal accumulation by one and the same species depends not only on genotype characteristics but also on ecological factors [22].

Like vegetables, such as cabbage, wheat bran and sugar beet pulp [23], average, macroalgae may provide up to 12.5% of a person's daily fibre needs in an 8 g serving intake [24]. The consumption of dietary fibers and plant cell walls containing such fibre components protects human organisms against a number of chronic diseases e.g., colon cancer [25]. During the present study maximum crude fibre content was exhibited by *L. fluviatilis* of site-IV (3.03±0.41%) and minimum by *L. australis* of site-I (0.79±0.40%). Our results were found to be low when compared with the crude fibre content given by Misurcova [26] in brown algae i.e. (12.55±0.27%) and *Laminaria japonica* (5.45±0.46%). Our results are found to lie within the range given by Misurcova [26] in blue green algae i.e. *Spirulina pacifica* (0.18±0.30%), *Spirulina platensis* (0.10±0.11%), *Chlorella pyrenoidosa* (1.97±0.38%) a green algae and in red algae *Palmaria palmata* (1.49±0.23%) and *Porphyra tenera* (3.24±0.17%).

Protein is typically the major biochemical component of algae [27, 28] although as already mentioned; growth medium and growth stage will affect biochemical composition [29]. In the present study protein content showed remarkable variation with a highest value of 31.07±0.75% by *L. fluviatilis* from site-IV followed by *L. australis* from site-I (26.22±0.76%), *L. australis* (site-II) 25.80±0.01%, *L. catenata* (24.44±0.84%), *L. torulosa* from site-III (23.80±0.78%) while the lowest value of 17.48±0.94% was recorded by *L. mamillosa* from site-V of Iril river. Protein contents were comparatively similar when compared with the values reported by Manivannan *et al.* [30] from seaweeds of Vedalai coastal waters in *Geldiella accrosa* (31.07±0.33%), 28.94±0.68% in *Halimeda macroloba*; 23.12±0.86% in *H. tuna*. Lower than our values were reported by the same workers in *Enteromorpha compressa* (12.27±0.88%), 13.47±0.60% in *Ulva reticulata* and 13.63±0.43% in *Padina pavonica* and 6.6±0.42% in *Enteromorpha compressa* [31]. Similar to ours findings were obtained by Nirmal Kumar *et al.* [32] in *Soliera robusta* (Rhodophyta) as 35.3%, 32.10% in *Acanthopora delilei Lamour* and *Porphyra spp.* (28.40%) belonging to Rhodophyta. Dere *et al.* [33] observed the maximum protein content in some of the Rhodophyta and some green seaweeds belonging to the genus *Ulva*.

Lipids are rich in-C=0-bonds, producing much more energy in oxidation processes than other biological compounds. They constitute a convenient storage material for the living organism. In macro algae, the lipids are widely distributed, especially in several resistance stages [34]. Lewin [35] stated that the lipids of algae comprise photosynthetic pigments chlorophylls and carotenes and other compounds while carotenoids are powerful antioxidants. Of the *Lemanea* species studied from the four rivers, *L. australis* from site-I of Imphal river exhibited the highest lipid content (1.83±0.02%) while *L. mamillosa* from site-V of Iril river had the lowest lipid content (0.84±0.02%). The lipid content was observed in the sequence of species as *L. australis* (site-I)>*L. fluviatilis* (site-IV)>*L. torulosa* (site-III) >*L. australis* (site-II)>*L. catenata* (site-IV)>*L. mamillosa* (site-V). Lipid content lies within the range given by Chu *et al.* [36] in Rhodophyta (0.45-0.85%), Banerjee *et al.* 2009 in seaweed (*Catenella repens*) where the values lie between 0.17% to 0.24%, Matanjun and Mohamed [19] from tropical edible seaweeds in *Eucheuma cottonii* (Rhodophyta) i.e. 1.10±0.05%; 1.11±0.05% in *Caulerpa* (Chlorophyta) and 0.24±0.01% in *Sargassum* (Phaeophyta).

Carbohydrate is one of the important components for metabolism and it supplies the energy needed for respiration and other most important processes [38]. Out of the five species studied, *L. fluviatilis* from site-IV observed the lowest carbohydrate content (20.51±1.40%) while *L. catenata* from site-VI recorded the highest carbohydrate content (48.60±1.34%) followed by *L. australis* (38.20±1.37%) from site-II, *L. mamillosa* (29.40±1.46%) from site-V, *L. torulosa* of site-III (27.2±1.32%); and *L. australis* from site-I (26.00±1.36%). Carbohydrate contents were also found to be very high when compared with the edible seaweeds from Vedalai Coastal waters (Gulf of Mannar) in the work reported by Manivannan *et al.* [39] in *Turbinaria ornata* (17.49±1.18%); 17.20±0.71% in *Halimeda macroloba*) 17.12±0.44% in *Halimeda tuna,* 17.07±0.75%, *in Gracilaria crassa*; 17.0±0.65% in *Enteromorpha compressa* (Chlorophyta). Abdallah [31] reported 16.62±0.75% in red seaweed *Gracilaria acerosa*, 14.73±0.07% in *Padina pavonica*; 14.83±0.61% in *Cladophora glomerata* and 8.16±0.27% in *Entemorpha compressa* of carbohydrates.

The free amino acid content is of great value from nutritional and biochemical points of view. The amino acids of algae have a wide application in human and animal feed, as such in nutrition industries [40]. In the present study average maximum total free amino acid was contributed by the species *L. fluviatilis* from site-IV (17.20±0.04%) and minimum by *L. mamillosa* from site-V (9.60±0.04%). According to report by Nirmal Kumar *et al.* [32] high amount of amino acid was found in Rhodophyta in the range of (13-20%) in the species *Porphyra necnamessis*, *Porphyra spp.*, *Scinaia farcellata* and *Soliera robusta* as compared to species belonging to Phaeophyta (11-19%) and Chlorophyta (9-18%). Amino acid values were low compared to previous reports made by Norziah and Ching [34], where the amino acid concentration in *Gracilaria changgi* was reported to be comparable to that of hen's egg.

Carotenoids are the pigments involved in the initial absorption of water, which ruled as an environmental factor of growth and development. *Lemanea australis* from site-I exhibited its highest carotenoid content (0.65±0.03 mg/g FW) followed by *L. torulosa* from site-III (0.61±0.03 mg/g FW), *L. fluviatilis* from site-IV (0.61±0.01 mg/g FW), *L. catenata* from site-VI (0.56±0.02 mg/g FW), *L. mamillosa* from site-V (0.58±0.02 mg/g FW) and lowest by *L. australis* from site-II (0.58±0.01 mg/g FW).

Freshwater algae could be an interesting source of nitrogen compounds [41]. In the present study, nitrogen content showed remarkable variation with a highest value of 226.28±0.37 mg/100g in *L. fluviatilis* from site-IV, followed by *L. australis* (site-II) containing 202.21±0.48 mg/100g, *L. mamillosa* (site-V) containing 134.79±0.46 mg/100g and *L. torulosa* (site-III) containing 113.79±0.46 mg/100g while the lowest value of 111.48±0.44 mg /100g was recorded in *L. australis* from site-II.

The phosphorus level within algal cells may fluctuate widely depending on whether the algae are growing under phosphorus limited conditions or not. Even at very low levels in the environment the algae can accumulate and store phosphorus [42]. Phosphorus showed remarkable variation with highest value obtained by *L. australis* from site-III (150.71±0.25 mg/100g) followed by *L. torulosa* from site-III (142.88±0.41 mg/100g), *L. australis* from site-I (92.37±0.42 mg/100g), *L. catenata* from site-VI (72.92±0.35 mg/100g) while the lowest value was recorded by *L. mamillosa* from site-V (72.42±0.33 mg/100g).

Of the *Lemanea* sp. studied from the 4 rivers *L. fluviatilis* from site-IV exhibited the highest amount of K content (1003.20±0.39 mg/100g) while *L. australis* from site-I obtained the lowest K content (363.05±0.50 mg/100g). Amounts of potassium obtained were found to be low when compared with the values by workers like Matanjun *et al.* [19] in *Eucheuma cottonii* (Rhodophyta) containing 1315.19±1.14 mg/100g *Caulerpa lentillifera* (Chlorophyta) containing 1142.68±0.00 mg/100g and *Sargassum polycystum* (Phaeophyta) containing 6213.00±0.00 mg/100g and in *Entemorpha compressa* (785.±5.8 to 2115±8.3 mg/100g) by Abdallah [31]. Lower than our values were reported by Manivannan *et al.* [30] in Phaeophyta *Padina gymnospora* (26.00±0.05 mg/100g) and in Rhodophyta *Gracilaria folifera* (0.08±0.05 mg /100g) from Mandapam coastal regions, Southeast coast of India.

In the present study sodium content showed remarkable variation with a highest value of 479.78±0.28 mg/100g in *L. australis* from site-I followed by *L. fluviatilis* from site-II (423.31±0.25 mg/100g), *L. mamillosa* (276.10±0.36 mg/100g) from site-V, *L. catenata* (238.09±0.27 mg/100g) from site-IV and *L. torulosa* (146.80±0.31 mg/100g) from site-III, while the lowest value of 141.90±0.36 mg/100g was recorded in *L. australis* from site-II. Sodium content in our study was found to be low when compared with the values obtained by work of Matanjun *et al.* [19] in *Eucheuma cottonii* (1771.84±0.01 mg/100g) a Rhodophyta, *Caulerpa lentillifera* (Chlorophyta) containing 8917.46±0.00, *Sargassum polycystum* (6213±0.00%) a Phaeophyta. Sodium content was found to be high when compared with *Enteromorpha compressa* (74.2±0.55 mg /100g to 74.62±0.91 mg/100g) by Abdallah [31]. Lower than our values were reported in work of Manivannan *et al.* [30], *Hypnae valentiae* (Rhodophyta) recorded a value of 29.33 mg /100g and *Padina gymnospora* (Phaeophyta) observed a value of 65.66 mg/100g.

Calcium contents showed a remarkable variation with highest values obtained by *L. fluviatilis* from site-IV (13.76±0.50 mg/100g) followed by *L. australis* from site-I (12.26±0.42 mg/100g); *L. torulosa* from site-III (12.23±0.26 mg/100g); *L. catenata* from site-V (11.90±0.38 mg/100g) and *L. mamillosa* from site-V (11.59±0.42 mg/100g) while the lowest value was recorded in *L. australis* from site-II (11.44±0.44 mg/100g). Higher calcium content than our results were reported by Manivannan *et al.* [30] from a Phaeophyta *Padina gymnospora* (414.00±13.10 mg/100g) a marine macroalgae collected from Mandapam coastal region, Southeast coast of India.

Magnesium content showed a remarkable variation with a highest value of 135.65±0.17 mg/100g in *L. mamillosa* from site-V followed by *L. fluviatilis* from site-IV (135.51±0.31 mg/100g), *L. catenata* from site-VI (120.20±0.42 mg/100g), *L. australis* (site-I) containing 111.30±0.53 mg/ 100g and *L. torulosa* from site-III (99.85±0.33 mg/100g) while the lowest value of 70.87±0.41 mg/100g was obtained by *L. australis* from site-II. Amount of Magnesium content were found to be low when compared with the values obtained by some of the workers like Matanjun *et al.* [19] in *Eucheuma cottonii* (Rhodophyta) containing 271.33±0.20 mg/100g, *Caulerpa lentillifera* (Chlorophyta) containing 1028.62±0.58 mg/100g, *Sargassum polycystum* (Phaeophyta) containing 487.84±0.24 mg /100g and *Enteromorpha compressa* (380±2.0 to 320±1.9 mg/100g) by Adallah [31]. Lower than our results were reported by Manivannan *et al.* [30] in Chlorophyta *Ulva lactuca* (17.45±13.15 mg/100g) and from red algae *Hypnae valentiae* (3.98±4.56 mg/100g) from marine algae collected from Mandapam coastal regions, Southeast coast of India.

In the present investigation, iron content showed remarkable variation with a highest value of 26.18±0.35 mg/100g in *L. fluviatilis* from site-IV, followed by *L. mamillosa* from site-V (25.64±0.38 mg/100g), *L. australis* from site-I (25.25±0.40 mg/100g), *L. torulosa* from site-III (19.07±0.41 mg/100g) and *L. catenata* from site-VI (18.17±0.38 mg/100g) while the lowest value of 16.95±0.34 mg/100g was recorded in *L. australis* from site-II. Values of Fe contents were found to be very high when compared with the results obtained in work of Matanjun *et al.* [19] in *Eucheuma cottonii* (Rhodophyta) containing 2.61±0.00 mg/100g, *Caulerpa lentillifera* (Chlorophyta) containing 21.37±0.00 mg/100g and *Sargassum polycystum* (Phaeophyta) containing 8.21±0.03 mg/100g and from brown alga *Padina gymnospora* (3.8±3.67 mg/100g). *Hypnae valentiae* contain (1.08±1.68 mg/100g) collected from Mandapam coastal regions, Southeast coast of India Manivannan *et al.* [30]. Higher than our values were reported by Abdallah [31] in *Enteromorpha compressa* (101.2±3.7 to 177.83±4.0 mg/100g).

Manganese content registered a maximum of 20.34±0.22 mg/100g by *L. fluviatilis* from site-IV and a minimum of 5.26±0.48 mg/100g by *L. australis* from site-II. Mn content was found to be high when compared with the work reported by Abdahllah [31] in seaweeds of *Enteromorpha compressa* containing 11.43±6.9 mg/100g to 15.51±4.4 mg/100g. However lower than our values were reported by Manivannan *et al.* [30] from Rhodophyta *Hypnae valentiae* (1.12±0.50 mg/100g) and from Phaeophyta *Turbinaria ornata* (0.037±0.04 mg /100g).

Zinc belongs to a group of trace metals, which are essential for the growth of humans, animals and plants but at the same time potentially dangerous for the biosphere when present in high concentrations. Calcareous rocks normally have the higher levels of Zinc, while zinc is readily absorbed by clay minerals, carbonates and the main sources of Zinc pollution are industries and the use of liquid manure composted materials and agrochemicals such as fertilizers and pesticides. Out of the five species of *Lemanea* studied, *L. australis* from site-I obtained the highest Zinc content (5.25±0.41 mg/100g) while *L. catenata* from site-VI exhibited the lowest zinc content (1.22±0.44 mg/100g). Amount of Zn contents were found to be high when compared with the results obtained by workers like Matanjun *et al.* [19] in *Eucheuma cottonii* (Rhodophyta) containing 4.30±0.02 mg/100g, *Caulerpa lentillifera* (Chlorophyta) containing 3.51±0.00 mg/100g and *Sargassum polycystum* (Phaeophyta) containing (2.15±0.00 mg/100g). Similar findings were reported by Abdahlla [31] in *Entemorpha compressa* (3.94±0.58 mg/100g to 4.05±0.77 mg/100g). Lower than our values were reported by Manivannan *et al.* [30] in Rhodophyta member *Hypnae valentiae* (0.18±0.06 mg/ 100g) and in *Gracilaria folifera* (0.08±0.05 mg/100g) a marine macro algae collected from Mandapam coastal regions, Southeast coast of India.

In the present investigation, Cu content showed marked variation with a highest value of 13.09±0.41 mg/100g in *L. catenata* (site-VI), followed by *L. torulosa* from site-III (13.08±0.29 mg/100g), *L. australis* from site-II (12.98±0.45 mg/100g) and *L. fluviatilis* from site-IV (8.91±0.40 mg/100g) while the lowest value of 8.23±0.43 mg/100g was recorded in *L. australis* from site-I. Cu content were found to be high when compared with the values reported by Abdahllah [31] in *Enteromorpha compressa* (1.58±0.76 mg/100g).

Cobalt itself is not a particularly rare metal (ranked 33 of all metals for abundance) and can be found distributed widely not only on land, but also underwater in the Earth's crust, vegetables and meat dishes. Cobalt is an important component in the vitamin B_{12}, which is required for the normal functioning of the brain and nervous system. Cobalt content showed a remarkable variation with a highest value of 10.74±0.19 mg/100g by *L. torulosa* from site-III, followed by *L. australis* (site-II) containing 10.40±0.44 mg/100g, *L. catenata* (site-VI) containing 9.02±0.33 mg/100g and *L. mamillosa* (site-V) containing 8.96±0.51 mg/100g while the lowest value of 7.98±0.37 mg/100g was recorded in *L. fluviatilis* from site-IV. Lower than our results were reported by Manivannan *et al.* [30] in Chlorophyta *Ulva lactuca* (0.0054±0.0001 mg/100g) and Phaeophyta *Gracilaria folifera* (0.0028±0.005 mg/100g) a marine macroalgae collected from Mandapam coastal regions, southeast coast of India.

The Na/K ratios were found to be exhibited highest by *L. australis* from site-I (1.31±0.50) followed by *L. fluviatilis* from site-IV (0.42±0.64), then by *L. mamillosa* from site-V (0.34±1.64), by *L. catenata* from site-VI (0.27±0.75), *L. australis* from site-II (0.17±0.90) and lowest by *L. torulosa* (0.18±0.73). Similar with our findings were reported by Matanjun *et al.* [19] from the tropical edible seaweeds studied where the Na/K ratios of *E. cottonii* and *S. polycystum* lie within the range of (0.14-0.16). Ruperez [43] also reported low Na/K ratios, below 1.5 for red and brown seaweeds studied. Intakes of high Na/K ratios have been related to the higher incidence of hypertension. *Lemanea* can therefore help balance Na/K ratios diets. In contrast, olives and sausages have Na/K ratios of 45.63 and 4.89, respectively [44].

In conclusion, the results of our study suggest that these algae which are scarcely available during their short growing period in this ecosystem also have considerable potential of carbohydrate, protein, free amino acids, carotenoid, iron and measurable quantities of minerals for their use as food and pharmaceutical industry as a source in preparation of nutrient supplements, medicine and fine chemical synthesis. The algae has been used as a potential food source by the poor since times immemorial in the state of Manipur, northeast India and preferred for its fishy smell. The study provides an evidence for the above food practice of people and recommends its consumption; however cautions for over harvesting of it. Conservation measures should be undertaken because of its short growing period, stable environment with disjunct distribution in few localities in these rivers of Manipur.

ACKNOWLEDGEMENTS

The authors thank Moatsetung Ningombam for accompanying in hardship field tour during collection of the algal samples; Head, Department of Life Sciences, Manipur University for providing the AAnalyst 200 flame atomic absorption spectrophotometer for the laboratory and Abdul Hei for assistance in mineral and trace element analysis.

REFERENCES

1. McClanahan, T.R., B.A. Cokos and E. Sala, 2002. Algal growth and species composition under experimental control of herbivory, phosphorus and coral abundance in Glovers reef, Belize Mar. Poll. Bull., 44: 441-451.
2. Fleurence, J., 1999. Seaweed proteins: biochemical, nutritional aspects and potential uses. Trends in Food Sci and Technol, 10: 25-28.
3. Ahmed, N.S. and M.A. Hamza, 1990. Chemical composition and utilization of some marine algae collected from Alexandria Coast. Com. Sci. Dev. Res., 32: 17-36.
4. Ishibashi, M. and T. Yamamoto, 1960. RCC. Oceanog Works Jap., 5: 55.
5. Vincent, W.A., 1980. Algae for food and feed. Process Biochemistry, June, pp: 54-47.
6. Enebo, L., 1969. Chem. Eng., Chem. Eng. Progr. Symp. Ser., 65(93): 80.
7. Kihlberg, R., 1972. The microbe as a source of food. Ann. Rev. Microbiol., 26: 127.
8. Oswald, W.J., J.R. Benemann and B.L. Koopman, 1977. Proceedings of fuels from Biomass Symposium, University of III. Champaign, III., Apr., pp: 18-19 pivovarnickı a sladařskı, a.s., Praha, pp: 61-81.
9. Waslien, C.I. and K.H. Steinkraus, 1980. The potential of Microbial cells as protein for man. Bioscience, 30(6): 397-398.
10. Read, B.E., 1936. Chinese Medicinal Plants from Pen Tsao Kang Mu A.D 1956, 3rd ed. Perking Nat. Hist. Bull., pp: 300.
11. Lowry, O.H., N.J. Rosebrough, A.L. Farr and R.J. Randall, 1951. Protein measurement with Folin phenol reagent. J. Biol. Chem., 193: 265-275.
12. Dubois, M., K.A. Gilles, J.K. Hamilton, P.A. Rebers and F. Smith, 1956. Colorimetric methods for determination of Sugars and related substances. Analit Chem., 28: 350-356.
13. Folch, J., M. Lees and G.H. Solam-Stanley, 1957. A simple method for the isolation and purification of claot lipid from animal tissue, J. Biol. Chem., 226: 497-509.
14. Yemm, E.W. and E.C. Cocking, 1955. The determination of Amino Acids with ninhydrin. Analyst, 80: 209-213.
15. AOAC., 2000. Official methods of analysis AOAC international, 17^{th} edn. AOAC International, Md., USA.
16. Arnon, D.I., 1949. Copper enzymes in isolated chloroplast polyphenoloxidase in *Beta vulgaris*. Plants Physiol., 249: 1-15.
17. Doneen, L.D., 1932. A micro method for N_2 in plant material. Plant Physiol., 7: 717-720.
18. Lang, C.A., 1958. Simple micro-determination of Kjeldahl nitrogen in biological material. Anal Chem., 30: 1962-1969.
19. Matanjun, P., S. Mohamed, N.M. Mustapha and K. Muhammad, 2009. Nutrient content of tropical edible seaweeds, *Eucheuma cottonii, Caulerpa lentillifera* and *Sargassum polycystum*. J. Appl. Phycol., DOI 10.1007/s10811-008-9326-4.
20. Polat, S. and Y. Ozogul, 2008. Biochemical composition of some red and brown macro algae from the Northeastern Mediterranean Sea. Intl. J. Food Sci. Nutrition, 59: 566-572.
21. Chapman, V.J. and D.J. Chapman, 1980. Seaweed and their uses, 3^{rd} ed. Published in the U.S.A. Chapman and Hall Ltd., II New Fetter Lane, London EC4P4EE, 83: 1-333.

22. Koryakova, M.D. and G.N. Soenko, 1958. Okeanodogiya (Moscow), 21(2): 273-279.
23. Burtin, P., 2003. Nutritional value of seaweeds. EJEAFChe, 2(4): 498-503.
24. Guidel-Urbano, M. and I. Goni, 2002. Effect of edible seaweeds (*Undaria pinnitafida* and *Porphyra tenera*) on the metabolic activities of intestinal microflora in rats. Nutr. Res., 22: 323-331.
25. Guidel-Urbano, M. and I. Goni, 2002. Effect of edible seaweeds (*Undaria pinnitafida* and *Porphyra tenera*) on the metabolic activities of intestinal microflora in rats. Nutr. Res., 22: 323-331.
26. Misurcova, L., S. Kraemar, B. Klejdus and J. Vacek, 2010. Nitrogen content, dietary fibre and digestibility in algal food products. Czech. J. Food Sci., 28(1): 27-35.
27. Brown, M.R. and S.W. Jeffrey, 1992. Biochemical composition of microalgae from the green algal classes Chlorophyceae and Prasinophyceae. I. amino acids, sugars and pigments. J. Exp. Mar. Biol. Ecol., 161: 91-113.
28. Wikfors, G.H., G.E. Ferris and B.C. Smith, 1992. The relationship between gross biochemical composition of cultural algal foods and growth of the hard clam, *Mercenaria mercenaria* (l.). Aqua Culture, 108: 135-154.
29. Leonardos, N. and I.A.N. Lucas, 2000. The nutritional value of algae grown under different culture conditions of *Mytilus edulis L.* larvae. Aquaculture, 182: 301-315.
30. Manivannan, K., G. Thirumaran, G.K. Devi, A. Hemalatha and P. Anantharaman, 2008. Biochemical composition of seaweeds from Mandapam coastal regions along southeast coast of India. American-Eurasian Journal of Botany, 1(2): 32-37.
31. Abdahllah, M.A.M., 2007. Chemical composition and trace element concentration of marine algae *Entemorpha compressa* as a potential food source. Proceeding of the 3rd Mediterranean Symposium on marine vegetation, pp: 225-227.
32. Nirmal Kumar, J.I., R.N. Kumar, M. Kauramb, A. Bora and S. Chakraborty, 2010. Variation of biochemical composition of eighteen marine macroalgae collected from Okha coast, Gulf of Kutch, India. J. Indian Bot-Soc., 89(1 and 2): 105-110.
33. Dere, S., N. Dalkiran, D. Karacaoglu, G. Yildiz and E. Dere, 2003. The determination of total protein, total soluble carbohydrate and pigment contents of some macroalgae collected from Gemlik-Karacaali (Bursa) and Erdek-Ormanli (Balikesir) in the Sea of Marmara, Turkey. Oceanologia, 45(3): 453-471.
34. Norziah, M.H. and C.V. Ching, 2000. Nutritional composition of edible seaweed *Gracilaria changgi*. Food Chem., 68: 69-76.
35. Lewin, R.A., 1974. Biochemical taxonomy. In Algal physiology and biochemistry (Ed. W.D.P. Stewart).
36. Chu, W., M. Norazmi and S. Phang, 2003. Fatty acid composition of some Malaysian Seaweeds. Malaysian J. Sci., 22(2): 21-27.
37. Banerjee, K., R. Ghosh, S. Homechaudhuri and A. Mitra, 2009. Seasonal variation in the biochemical composition of red seaweed (*Catenelle repens*) from Gangetic delta, northeast coast of India. J. Earth Syst. Sci., 118(2): 497-505.
38. Bligh, E.G. and W.J. Dyer, 1959. A rapid method of total lipid extraction and purification. Can. J. Biochem. Physiol., 37: 912-917.
39. Manivannan, K., G. Thirumaran, K. Devi, P. Anantharaman and T. Balasubramanian, 2009. Proximate composition of different group of seaweeds from Vedalai coastal waters (Gulf of Mannar); Southeast coast of India. Middle-East J. Scientific Res., 4(2): 72-77.
40. Borowit Zka Zka, M.A., 1988. Microalgal Biotechnology (Ed.) Borowitzka. Michael and Lesley. Cambridge University press, pp: 477.
41. Prugar, J., 2008. Sinice a řasy, kvalita rostlinnıch produktù na prahu 3. tisýciletý. Vızkumnı ústav.
42. Mackereth, F.J., 1953. Phosphorus utilization by *Asterionella formosa*. Hass. J. Exp. Bot., 4: 296-313.
43. Ruperez, P., 2002. Mineral content of edible marine seaweeds. Food Chem., 79: 23-26.
44. Ortega-calvo, J.J., C. Mazuelos, B. Hermosin and C. Saiz-Jimenez, 1993. Chemical composition of Spirulina and eukaryotic algae food products marketed in Spain. J. Appl. Phycol., 5: 425-435.