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Biochemical composition of selected seaweeds from intertidal shallow waters of Southern Red Sea, Eritrea

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Seaweeds are marine plants also known as sea vegetables, used as an alternative food source with high nutritional value. Consumption of seaweeds in East Asian countries like China, Thailand and Japan had begun since ancient times. In some countries, seaweeds are consumed as raw vegetables, in the form of salad and as an additive in manufacturing of various food products. The biochemical composition of seaweeds varies with environmental state of marine ecosystem. Eritrea, with long coastline bears diversified ecosystems and abundant seaweeds. But limited knowledge on nutritional importance and processing methods mitigate the dietary utilization of seaweeds by coastal community in the country. The present study focuses mainly on the analysis of biochemical composition of various seaweeds collected around the Massawa coast of Red Sea, Eritrea. The major biochemical components like proteins, carbohydrates, fats, fibre and ash were determined to establish the nutritional importance of the seaweeds. The high protein content was found in green seaweed *Enteromorpha clathrata* (13.64 %), whereas the brown seaweed *Sargassum subrepandum* has reported with high carbohydrates (28.11 %) and *Cystoseira myrica* has shown high fibre (32.39 %) content. The green seaweed *Entermorpha compressa* was found to be rich in fats (1.83 %), and high ash content (50.91 %) was recorded in brown seaweed *Dictyota ciliolata.*

[**Keywords**: Chlorophyta, Eritrea, Phaeophyta, Proximate composition, Red Sea, Rhodophyta, Seaweeds]

Introduction

Seaweeds are macrobenthic forms of marine algae, with thalloid body typically consisting of holdfast, stipe, blade, and reproductive structures[1]. Some species bear gas-filled structures to provide buoyancy[2]. These grow and inhabit intertidal shallow waters, deep sea, backwaters and estuaries on solid substrates like rocks, coral reefs, shells, pebbles and other plant materials[3]. Along with phytoplankton, mangroves and sea grasses; seaweeds also serves as major primary producers of marine environment. Utility of seaweeds as an important source of food, fodder, fertilizer and medicines dates back to many decades. Some seaweeds like red and brown algae have regarded as a good source of concentrated iodine as they have the ability to accumulate good amount of iodine in their tissues. In ancient Chinese medicine, seaweed *Laminaria* species was used to cure Goiter, which had been given as vegetable[4,5].

Seaweeds also contain various colour pigments, which give colour to the algae including chlorophyll, carotenoids, xanthophylls, phycocyanin and phycoerythrin. All these pigments have great potential for their application in food, pharmaceutical and cosmetics industry. Depending on their colour, seaweeds are mainly classified as Rhodophyta (red algae), Phaeophyta (brown algae) and Chlorophyta (green algae)[6]. There are around 8,000 different species of seaweeds inhabiting along the world's coastline and their distribution may extend as deep as 270 m in the ocean[7]. Among the seaweeds, 221 species are used commercially; from these 145 species including 79 species of Rhodophyta, 28 species of Chlorophyta and 38 species of Phaeophyta are known to be used as food[8]. Some of the edible seaweeds contain significant amount of macro and micronutrients which are essential for growth and maintenance of body such as polypeptides, lipids, minerals and vitamins[9]. The quantity of nutrients in seaweeds differs from species to species, and with geographical location, season, humidity and temperature[10].

Seaweed has been a staple food in Japan, China, Philippines and Indonesia for a very long time; they have been commonly utilized in human alimentation[11]. Seaweeds contain high amount of polyunsaturated fatty acids and they are rich in Omega 3 fatty acids like DHA (docosahexanoic acid) and EPA (eicosapentanoic acid). These seaweeds are consumed by smaller marine organisms; which in turn are eaten by large fish. Therefore, DHA and EPA are transferred along the food chain to the largest fishes in marine environment. The EPA content is found to be highest in Australian seaweeds among the world[12]. Literature suggested that, seaweeds are also rich in copper, zinc, magnesium, chromium, lead, nickel, cadmium, manganese, sodium, potassium and cobalt[13]. Seaweeds of the genera *Hydroclathrus*, *Caulerpa*, *Eucheuma*, *Gracilaria* and *Acanthohora* are used in salads and are also consumed as vegetables; whereas coarser seaweeds *Gracilaria* and *Eucheuma* spp. are pickled and consumed. *Porphyra* (Nori), *Laminaria* (Kombu) and *Undaria* (Wakame) are highly consumed seaweeds as a staple food and accompaniments[14].

Eritrea is a young African nation situated in the Southern part of Red Sea, with diversified marine ecosystem along its 1200 km long coastline. The oceanic ecosystem mainly consists of soft substrate and shallow waters with less than 50 m depth. The high salinity and warm water extending to the deep sea is oceanographically unique to the Red Sea and the average sea surface temperature is over 36 °C in the shallow reef flat. The salinity of seawater is around 40.5 ‰ across all seasons. Red sea harbours high level of endemism, including 9 % for macroalgae[15]. According to Atewberhan and Prud[16], the Eritrean coastal waters are diversified with 286 infraspecific taxa of seaweeds. Though seaweeds are abundant in coastal waters, lack of knowledge on processing and nutritional benefits mitigates the utilization of seaweeds as human food and to reduce malnutrition problems. In Eritrea, seaweeds of *Sargassum* and *Gracilaria* species are currently used in the preparation of fish and poultry feed.

Materials and Methods

Sampling site

The samples were collected from the Eritrean Red sea coast of Gurgussum and Hirgigo bay (Fig. 1). Gurgussum is located 12 km North (15°67′ N, 39°45′ E) of Massawa, the port city of Eritrea; whereas the Hirgigo is located 8 km South (15°53′ N, 39°45′ E) of Massawa city.

Collection and identification of samples

Different marine algae samples were collected from the study sites during February to July 2016 from intertidal and sub-tidal areas by hand picking. All the samples were packed in polyethylene bags and transferred to the laboratory. The taxonomic classification of the samples was done by following the identification keys of Trono[1], Ateweberhan and Prud[16], Coppejans[17], Dhargalkar & Kavlekar[18], Kaliaperumal[19], and Lipkin & Silva[20]. In the present study, four green seaweeds (Chlorophyta) belonging to three genera including, *Halimeda opuntia*, *Enteromorpha clathrata*, *Caulerpha sertularioides* and *Enteromorpha compressa*; five seaweeds belonging to four genera including *Padina borengesnii*, *Dictyota dichotoma*, *Dictyota ciliolata*, *Sargassum subrepandum*, and *Cystosoria myrica* of Phaeophyta; and one seaweed *Gracillaria canaliculata* of class Rhodophyta were investigated.

Biochemical composition

Moisture content of seaweeds was determined by conventional drying method[21], the dried samples were pulverized to reduce the size. Total protein content was estimated by determining Nitrogen following Kjeldhl method[21] and by multiplying the total nitrogen value with 6.25. Crude fibre was determined by sequential extraction of seaweed samples with 1.25 % H_2SO_4 and 1.25 % NaOH[21]. After complete extraction by acid and alkali digestion, the remaining residue was dried in an oven at 105 °C for 5 hours, then the crucible was placed in a muffle furnace (Model: Carbolipe Euro Pherm) and

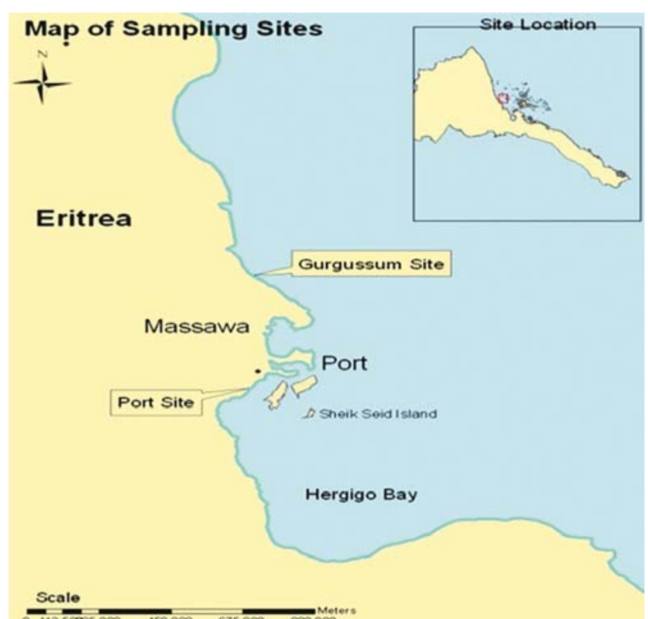

Fig. 1 — Map showing the sample site in Red sea coast of Eritrea

ashed at 525 °C overnight. Ash content was determined by using muffle furnace as described in AOAC[21]. The total fat content was estimated by Folche method[22] using Chloroform-Methanol mixture, solvent extraction method and soluble carbohydrates was determined by subtracting all the proximate components from 100 as described in Nielsen[22]. The proximate components of seaweeds were expressed on dry weight basis (%).

Results and Discussion

The proximate composition of selected seaweed species belonging to families Chlorophyta (four species), Phaeophyta (five species) and Rhodophyta (one species) were analyzed and the results are shown in Table 1. Seaweeds contain large amount of water; when fresh, they contain approx. 75 – 85 % water and 15 – 25 % of organic components and minerals[23]. The water content of the analyzed samples ranged between 76 – 90 %, with highest water content in *E. clathrata*, followed by *H. opuntia*; whereas the lowest moisture content was found in *C. myrica*.

The total protein content of the samples ranged between 13.64 to 6.45 %, with highest protein content in green seaweeds, *E. clathrata* (13.64 %), *C. sertulario ides* (13.28 %), and *E. compressa* (11.15 %), followed by red seaweed *G. canaliculata* (11.18 %). The protein content sometimes reflects the age of seaweeds, as the maturity of plants increases the Nitrogen content declines. The protein content also varied with collection site, depth and nutrient availability, since the amount of nitrogen levels reflects the protein content of the seaweeds[24]. The protein content of *E. compressa* reported from east coast of India (23.8 %) by Kalaiperumal *et al.*[19] is contradictory to the present study of the same species suggesting the spatial variability in protein content. Kasimala *et al.*[25] have reported 8.15 % of protein from *G. canaliculata* collected from Gugusum site, which is lower than the values reported from Hirgigo bay in present study. The underlying reason for such reduction in protein percentage in *G. canaliculata* from Gurgusum is due to the regular exposure of Gurgusum beach to anthropogenic inputs. There have been reports on relation between the growth of marine plants and light intensity[26]. The sediments deposited on the seaweed thallus due to anthropogenic activities reduces the irradiance rhythm which show adverse effect on growth and mineral absorption in seaweeds, thereby reduction in the protein content.

The carbohydrate content of the seaweeds ranged between 19.11 and 28.11 %. The highest amount was recorded in *S. subrepandum* and the lowest in *G. canaliculata*. The carbohydrate content in *D. dichotome* collected from Saint Martin's Island, Northeastern part of Bay of Bengal was 38.94 %[ref. 5] and from southeast Tuticoran coast of India was 10.63 %[ref. 27]. But the results obtained in the present study of the same species were contradictory to both the records and showing 22.02 % of carbohydrates. Haroon *et al.*[28] recorded the seasonal variation in carbohydrate content of *Enteromorpha* species and found that, the carbohydrate content was high in summer after reaching the maximum growth stage. Eritrean coast is one of the high temperature regions of the world having an average seawater temperature is 31.9 °C in hot season (southwestern monsoon), 25.4 °C in cold season (Northeastern monsoon) with irradiance[15]. The high solar radiation makes optimal conditions for photosynthesis and therefore, results in high carbohydrates content in Red sea seaweeds.

The fat content of the investigated seaweeds was ranged from 0.29 to 1.83 %. The maximum amount of fat content was recorded in *E. compresa* (1.83 %) and minimum in *G. canaliculata* (0.29 %). Haque *et al.*[5] have reported 0.5 % of fat content in *D. dichotoma*, which is almost similar to the results of same species in the present study (0.67 %). The present results of fat

Table 1 — Biochemical composition of seaweeds mg g^{-1} dry weight

Name of the species	Proteins	Carbohydrates	Fats	Fibre	Ash
Halimeda opuntia	7.20	24.85	1.42	23.49	37.28
Enteromorpha clathrata	13.64	22.97	1.79	27.89	31.28
Enteromorpha compressa	11.15	24.05	1.83	25.37	29.10
Caulerpha sertularioides	13.28	21.23	1.30	26.17	34.12
Padina borengesnii	7.08	26.25	0.56	14.74	30.30
Dictyota dichotoma	8.16	22.02	0.67	10.94	45.19
Dictyota ciliolate	7.66	24.25	0.51	10.13	50.91
Sargassum subrepandum	6.93	28.11	1.42	19.97	26.86
Cystosoria myrica	6.45	20.56	0.92	32.39	36.75
Gracillaria canaliculata	11.18	19.15	0.29	29.12	37.52

content of *E. compressa* (1.83 %), and *E. clathrata* (1.79 %) does not agree with the results of the seaweeds collected from East coast of India. Kalaiperumal *et al.*[19] have recorded 11.4 % of fats from *E. compressa*; whereas Manivannan *et al.*[29] have reported 4.6 % of fats in *E. Clathrata*, and Parthiban *et al.*[27] reported 4 % of fats in *E. compressa* and *D. dichotoma*, which is higher than reported values of same species in present study. The fat content of seaweeds varies throughout the year. In seaweeds the fatty acids are tightly bound to the cell wall fabric and with the increase in temperature, the level of unsaturation of acyl side chain will be increased, resulting in slowdown of the metabolism and transport[28-30]. Consequently, the high temperatures along the Massawa coastline are responsible for decrease in the fat content of seaweeds.

The fibre content of the seaweeds ranged between 32.39 and 10.13 %. The highest fibre was recorded in *C. myrica*, and the lowest was recorded in *D. Ciliolate* (10.13 %), *D. dichotoma* (10.94 %) and *P. boergesenii* (14.74 %). Seaweeds contains large amount of polysaccharides including floridean starch, sulphated fucose, xylans and cellulose in its cell wall structures[31]. These typical polysaccharides are indigestible to human gastrointestinal tract and therefore, can function as dietary fiber. Seaweed fiber content is greater than fiber found in higher plants[32]. The high photon flux of radiation along Eritrean coast increase the rate of photosynthesis and conversion of photosynthetic products into polysaccharides and cell wall constituents, which further increase the fiber content of seaweeds. The brown seaweed *C. myrica* collected from Massawa coast of Red sea has recorded high amount (66.16 %) of calcium alginates[33] which is a derivative of polysaccharide alginic acid contributing to high quantity of fiber.

Ash content represents the total minerals present in foods[22]. Seaweeds contain all essential minerals; quantity of which is much higher than any other plants on land. The wide range of mineral content varies with seaweed phylum, geographical origin, and with seasonal, environmental and physiological variations[31]. The ash content of the seaweeds in the present study ranged from 50.91 % to 26.86 %. The highest amount was recorded in *D. ciliolata* (50.91 %) and *D. dichotoma* (45.19 %) followed by *G. canaliculata* (37.52 %). The lowest ash content was recorded in *S. sabrepandum* (26.86 %) followed by *E. compressa* (29.10 %). Seaweeds are much capable of accumulating minerals and the higher salinity of the Red sea contributes well to the deposition of sodium, potassium, calcium, magnesium and other minerals. The ash content of brown seaweeds is observed to be higher than red and green seaweeds. Some of the brown seaweeds contains high amount of iodine, hence such seaweeds can be used as seasoning rather than direct consumption as vegetables to minimize the excess intake of other minerals[34]. The seaweeds are also capable of accumulating good amount of calcium from the calcareous bases during the growth[35], hence calcium is also one of the major constituent in the ash.

Conclusion

The seaweeds can be regarded as an underexploited source of some of the health-benefit molecules for food processing and neutraceutic industry. The results of the present study have shown that seaweeds contain almost all the proximate components required for the human body. They can be used as potential healthy diet for human consumption. *Entermorpha clathrata* and *Caulerpa sertularioides* have recorded with high protein contents. All other seaweeds investigated in this study have reported high quantity of minerals recorded as ash; hence they can be utilized as additives in common traditional foods. Therefore with the utility of seaweeds, the community can acquire sufficient quantity of nutrients including minerals, which play a vital role as co-factors, strengthening of bones (calcium) and maintenance of endocrine system (iodine). The Eritrean coast is conducive for the better growth, along with elevated physicochemical and nutritional composition of seaweed species. Therefore, these seaweeds can be promoted as a dietary alternative and its commercial value can be enhanced by promoting the seaweed-based products.

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Conflict of Interest

The Authors declare no conflict of interest.

Author Contributions

MK: The Principle investigator of the work, supervised the team in formal analysis, report writing,

and in acquisition of funding; GGM: The co-investigator of the project to coordinated the team in laboratory analysis and maintaining the financial documents; KTN: Report writing and editing of the manuscript; GAB, MMA and HSM: sample collection, laboratory analysis and report writing.

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