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Proximate and mineral composition of brown seaweed from Gulf of Mannar

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Abstract
Seaweeds are marine macro algae growing abundantly in the shallow waters of sea, estuaries and backwaters up to a depth of 118 m where 0.1% photosynthetic light is available. Seaweeds possess different nutritive components like protein, lipid, carbohydrate and minerals. More than 30% of the dry weight of marine algae is ash which contains various kinds of minerals, vitamins and related substances. The nutritional value of seaweeds is really great and they are used as human food in different countries. Presently, there are 42 countries in the world with reports of commercial exploitation of seaweeds. Among them, China holds first rank, followed by North Korea, South Korea, Japan, Philippines, Chile, Norway, Indonesia, USA and India. Commercial utilization of seaweeds includes: Human food, fodder, fertilizer, drugs, paper production and the food industry. The industrial utilization of macroalgae is at present largely confined to extraction for phycocolloids and to a much lesser extent, certain fine biochemicals.

Keywords: Seaweeds, Proximate composition, Gulf of Mannar

Introduction
Seaweeds are marine macro algae growing abundantly in the shallow waters of sea, estuaries and backwaters up to a depth of 118 m where 0.1% photosynthetic light is available (Chapman, 1970; Okazaki, 1971) [20, 71]. They are primitive type of plants can be very tiny, or quite large, growing up to 30 meters long. Seaweeds found attached to rocks in the intertidal zone, washed up on the beach and floating on the ocean's surface Depending upon the photosynthetic pigments in seaweeds, they classified in to four major divisions such as Chlorophyta (green algae), Phaeophyta (brown algae), Rhodophyta (red algae) and Cyanophyta (blue green algae) (Chapman, 1980) [21]. More than 20,000 seaweeds are distributed throughout the world, of which only 221 (1.1%) are commercially utilized, which includes 145 species for food and 110 species for phycocolloid production (Sahoo, 2000, Chennubhotla *et al*., 2013) [80, 24]. The recorded diversity of 842 seaweed species from Indian waters comprised of 68 families and 271 genera, which includes 217 Chlorophyta, 191 Phaeophyta and 434 Rhodophyta species (Oza *et al*., 2001) [74]. Seaweeds grow abundantly along the 8118 km long Indian coastline particularly in rocky shore regions. Rich seaweed beds occur around Visakhapatnam in the eastern coast (25 spp), Mahabalipuram, Gulf of Mannar, Tiruchendur, Tuticorin and Kerala in the southern coast; Veraval and Gulf of Kutch in the western coast; Andaman and Nicobar Islands and Lakshadweep (Umamaheswara, 1970; Sahoo, 2000) [85, 80]. Tamil Nadu was recorded with 302 species of seaweeds comprised of 33 chlorophyta, 31 phaeophyta and 35 rhodophyta (Canciyal *et al*, 2014) [17].

Background
The world total seaweeds production in 2011 was 17.3 million metric tons. Seaweed aquaculture is second in volume to the farming of freshwater fish. The majority is grown in Asia, which accounts for 17.1 million metric tons (wet weight) or 98.8 percent of total production, with China the largest producer (Holmyard, 2011) [38]. Over the past 50 years, the utilization of algae has increased considerably, with the consequent increase in applied research in various related fields (Jimenez –Escrig and Sanchez-muniz, 2000) [42]. Seaweeds are used as animal fodder.

They are also used to extract agar, carrageenan, sodium alginate and minerals like iodine, potassium etc. which has greater application in pharmacology and food industries. In food industries, they are used as stabilizers, emulsifiers, thickeners, preservatives and gelling agents. Agar is widely used for the manufacturing of photographic film, shoe polish, shaving soaps, hand lotion (Chennubholla *et al*., 1991) [23]. Seaweed provides a rich and diverse source of raw material for the manufacture of cosmetics, fertilizers and extraction of industrial gums and chemicals (Abbott, 1988; Cadee, 1992) [1, 16] which have wide application in the food, pharmaceuticals and industrial sectors. Further, a range of macro algae had been screened for various bioactive compounds possess strong anti-inflammatory and anti-pain activities (Khan *et al*., 2007) [48] and also high antioxidant properties (Zubia *et al*., 2008) [95].

Seaweeds possess different nutritive components like protein, lipid, carbohydrate and minerals. More than 30% of the dry weight of marine algae is ash which contains various kinds of minerals, vitamins and related substances (Nisizawa, 2002) [69]. The nutritional value of seaweeds is really great and they are used as human food in different countries. Presently, there are 42 countries in the world with reports of commercial exploitation of seaweeds. Among them, China holds first rank, followed by North Korea, South Korea, Japan, Philippines, Chile, Norway, Indonesia, USA and India. These top ten countries contribute up to 95% of the world's commercial seaweed utilization (Khan *et al*., 2007) [48].

Human consumption of green algae (5%), brown algae (66.5%) and red algae (33%) is higher in Asia, mainly in Japan, China and Korea. In Asian countries, seaweeds are often consumed as marine vegetables (Marinho-Soriano *et al*., 2006) [59]. China and Japan are the two major seaweed harvesting countries, where more than 70 species of seaweeds are consumed as salads directly or after cooked. Around 150 species of seaweeds are well consumed as human food. Seaweeds such as Porphyra (for Nori), Laminaria (for Kombu), Undaria (for Wakame) are harvested annually throughout the world for consumption (Kumari, 2010) [51].

Inclusion of whole seaweed as a functional food ingredient to prepare delicious items like chocolates, pates, seaweed cookies, bread, crackers and smoothies (Rathigan, 2008) [78]. Seaweed can play a vital role in earning foreign currency and livelihood development for thousands of poor coastal communities.

There are many technologies used by different food industries in the creation of numerous and unique products for global agricultural and food industries. There are many industries all over the world that are manufacturing seaweed based food products like seaweed cookies, bread, crackers, jelly, soup, sauces etc. Although seaweeds are utilized for different kinds of products in many countries, the information on the use of seaweed powder in the bakery products like cookies, breads, cakes etc. is very scanty.

Commercial utilization of seaweeds includes: Human food, fodder, fertilizer, drugs, paper production and the food industry. The industrial utilization of macroalgae is at present largely confined to extraction for phycocolloids and to a much lesser extent, certain fine biochemicals (Mansilla & Avila, 2011) [57]. The use of macroalgae in Asia as food source is well known and established. During the last decade they are attracting increasing attention as a valued food source in western societies (MacArtain *et al*., 2007) [53]. Many macroalgal species have been used traditionally as ingredients in both medicinal and food preparations in different regions across the world (Anggadiredja, 1992; Novaczek & Athy, 2001; Kumari *et al*., 2010) [6, 70, 51], but in general, the nutritional properties of macroalgae are not known completely yet (Mabeau & Fleurence, 1993) [52].

Compositions and nutritive value of seaweeds

Algae contain 80–90 percent water and on a dry weight basis approximately 50 per cent carbohydrates, 1-3 percent lipids and 7-38 percent minerals. Protein content is highly variable (10-47 per cent) with a high proportion of essential amino acids. Algae have high concentration of vitamins and minerals that provide an obvious health benefit Berna *et al*., (2013) [12]. Algae contain more vitamin A, B-12, C, ß-carotene, pantothenate, folate, riboflavin and niacin than fruits and vegetables. Edible seaweed has historically been consumed by coastal populations across the globe. As seaweeds and seaweed isolates have the potential benefit to both health and improve food acceptability, they offer exciting potential as ingredients in the development of new food products. Consumption of seaweeds is not so popular despite its abundance in Indian coastal areas. In India people consume seaweeds indirectly in the form of phycocolloids added in chocolate, ice cream, jellies and as stabilizers in food products Coppen (1991) [26]. As consumer health and nutrition become more influential in the food industry, the use of seaweed as an ingredient is on the rise and product development involving salads and wraps appears to be slowly evolving. As dried seaweed is high in dietary fiber, along with a range of other potentially bioactive components, this addition has the potential to enhance the nutritional quality of a product Juhi and Sirimavo (2012) [43]. Habitual consumption of seaweed may offer a nutritionally rich addition to the diet (Madhu *et al*., 2015; Mitali *et al*., 2016) [54, 65].

Eun-Sun *et al*. (2013) [33] collected Porphyra from Korea and China and evaluated the proximate composition, amino acids, minerals, trace heavy metals and color. They found dried lavers were good source of amino acids, such as asparagine, isoleucine, leucine, and taurine and γ-aminobutyric acid. They have tested lavers for minerals like K, Ca, Mg, Na, P, I, Fe, and Se. They concluded that a clear regional variation existed in the amino acid, mineral and trace metal contents of lavers, further they suggested the regular consumption of lavers may have heath benefits because they are relatively low in fat and high in protein and contain functional amino acids and minerals.

Nutritional evaluation

Moisture and ash

Moisture content is an important criterion in determining the shelf-life and quality of processed seaweed meals as high moisture may hasten the growth of microorganisms (Ghadikolaei *et al*., 2012) [35]. Ghadikolaei *et al*., (2012) [35] recorded the highest ash content in the brown seaweed Sargassum ilicifolium (29.9%). Ahmed *et al*, (2012) the highest ash value (45.04%) was recorded in Padina gymnospora and the results of this study showed that brown seaweeds contain high amounts of ash (21.37% to 45.04%) followed by red seaweeds (6.05% to 28.79%) and green seaweeds (10.64% to 14.10%). High ash content invariably indicates the presence of appreciable amounts of diverse mineral components (Matanjun *et al*., 2008) [62].

Protein

Marsham *et al*., (2007) [60] found a high level of protein in 11 species of algae (6.9 -44%). Burtin (2003) [15] reported that the protein content of brown seaweeds was reported to be low (5-15% of the dry weight) compared with those of red and green seaweeds (10-30% as dry weight). The proximate composition of different seaweeds collected from Gulf of Mannar showed highest protein content in Padina gymnospora (17.08%) of Phaeophyceae family and minimum protein concentration in Ulva lactuca (3.25%) of Chlorophyceae family of Mandapam coast. The high protein content in Turbinaria ornata (14.68%) followed by Sargassum tennerimum (12.42%) of Phaeophyceae were found in Tuticorin coast (Dave *et al*., 1975) [27]. Haque *et al*., (2009) [37] reported that Sargassum coriifolium has the highest protein (16.07%), while padina tenuis was low 8.32%. The Sargassum longifolium (18.65 ± 1.21) was found to have highest percentage of protein content compared to Turbinaria conoides (15.9 ± 1.22) (Murugaiyan *et al*., 2012) [66]. Ghadikolaei *et al*., (2012) [35] reported the lowest protein content in Sargassum ilicifolium (8.9%). Sargassum schimperii, the one species of brown algae, had the lowest protein content (1.12%) (Polat and Ozogul, 2008) [76].

Carbohydrate

Carbohydrates comprise 50 – 60% of dry weight of seaweed (Arasaki and Arasaki, 1983) [9]. The typical carbohydrates in brown macroalgae are fucoidan, laminaran, cellulose and alginates (Dawczynski *et al*., 2007) [28]. Manivannan *et al*., (2009) [30] reported maximum carbohydrate concentration in Turbinaria conoides (23.9%), followed by Sargassum tennerimum (23.54%) and Sargassum wightii (23.50%) from Mandapam coast. The highest carbohydrate concentration (17.49 ± 1.18%) was recorded from brown seaweed Turbinaria ornata and the lowest value was observed in brown seaweed Padina pavonica (14.73 ± 0.07%) of Vedalai coastal waters in Gulf of Mannar (Manivannan *et al*., 2009) [30]. Maximum carbohydrate content was observed in Sargassum wightii (25.5±1.37%) and the seasonal variation of carbohydrate content in S.wightii which varied from 6.65% in march to 15.18% in January (Murugaiyan and Narasimman 2012) [66]. They also reported the carbohydrate content of Sargassaceae members Sargassum longifolium (16.8±0.7%) and Turbinaria conoides (14.9±1.08%).

Lipid

Seaweeds are relatively low in lipid (1–5% of dry weight) (Burtin 2003; Polat and Ozogul 2008) [15, 76]. Carrillo *et al*, 2002 [18]; McDermid and Stuercke, 2003 [63]; Manivannan *et al*, (2009) [30], reported that lipid content of S.wightii was 2.337% and low in S. tennerimum it was 1.46%. Sargassum longifolium (8.2±1.57%) found to have highest percent of lipid content followed by Turbinaria conoides (3±0.56%) (Murugaiyan *et al*., 2012) [66].

Fiber

As seaweed polysaccharides cannot be entirely digested by human intestinal enzymes, they are regarded as a new source of dietary fiber and food ingredients (Fleury and Lahaye, 1991; Mabeau & Fleurence, 1993) [34, 52]. Dawczynski *et al*., (2007) [28] reported that macroalgae are also potentially good sources of dietary fiber.

Minerals

The mineral content in macroalgae is higher compared to that of terrestrial plants and animal products (Mabeau and Fleurence, 1993; Rupérez, 2002; MacArtain *et al*., 2007) [52, 79, 53]. They found that seaweeds were the richest source of various minerals and it has high iron content compared to the terrestrial plants and more calcium than milk Nascimento (2011) [67]. Seaweeds are the richest source of vitamins like B-12, C, D, E and K. (Nascimento, 2011) [67]. The highest and lowest level of copper was reported in the brown algae Colpomenia sinuosa (0.51 mg/100 g) and Sargassum ilicifolium (0.28 mg/100 g) (Ghadikolaei *et al*., 2012) [35].

Seaweeds as human food

Incorporation of seaweed in daily diet is the best natural food source of biomolecular dietary iodine, where no other land plants are reliable sources of dietary iodine (Drum, 2011) [31]. Edible red seaweed Eucheuma (Kappaphycus alvarezzi) was used as an ingredient in the preparation of spice adjunct to enhance its nutritional quality. Amudha *et al*. (2010) [5] analyzed the sensory and consumer acceptability for various level of incorporation of Euchema in the preparation of spice adjunct. Enone (2013) [32] developed hot and spicy dried pickled seaweeds, light dried pickled seaweed and honey dried pickled seaweed

Jayasinghe *et al*., (2016) [41] conducted a study to develop nutritious instant vegetable soup mixture incorporated with cereals, legumes and seaweed extracts such as agar and carrageenan to replace the pectin. They reported that agar and carrageenan which are industrial food substitutes enriched with protein, minerals, vitamins and amino acids improved the overall nutritive values and viscosity of the soup.

Junio *et al*., (2011) [44] used seaweed flakes as main ingredient in the preparation of seaweed candies, seaweed ice cream, seaweed ice candy and gelatin as thickener in soups, meat and vegetable dishes. They also used seaweed flakes for making seaweed bath soap.

Kadam and prabhashankar., (2010) [47] prepared pasta with Wakame (Undaria pinnatifida) as an ingredient at different levels and analysed the major bio-functional characteristics of pasta and studied the *in-vitro* antioxidant properties, total phenolic content, fatty acid composition, fucoxanthin and fucosterol contents. They concluded that incorporation of seaweed in pasta is not only resulted in value addition in terms of improved amino acid and fatty acid profile, but also increased the nutritional value of the pasta due to higher content of bio-functional components such as fucoxanthin and fucosterol.

Winberg (2008) [90] reported that inclusion of whole seaweed as a functional food ingredient is a diversified way to prepare delicious items like seaweed cookies, bread, crackers, pates and smoothies.

Sumayaa and Kavitha (2015) [83] prepared common recipes viz, pickle, pakoda and halwa incorporated with seaweed powder which helped in enriching the nutrient quality. The nutrient analysis for the prepared recipe found to be higher in all levels of incorporation. From their studies they recommended to prepare various recipes using Sargassum wightii, Ulva reticulate and Eucheuma which contain no toxicity and found safe for human consumption.

Thahira and Uma (2015) [84] formulated and standardized seaweed incorporated chocolate, tested for consumer acceptability and *in vitro* iron bioavailability and supplemented to the selected group of people. Their research findings pointed out that seaweed contains substantial amount of protein, fat, carbohydrate and essential minerals like iron, calcium, selenium, phosphorus, zinc, sodium and magnesium and essential vitamins C and A. The work resulted with increase in hemoglobin level in the blood of all children.

Product development

Bender (1982) [11] defined Cookies or biscuit is essentially a bakery confectionery, dried down to low moisture content and the name derived from Latin. It is usually made from wheat flour, mostly rich in fat and sugar and consequently having high energy content. Arti *et al*. (2016) [10] examined the effects of whole Amaranth substitutions at various proportions and evaluated the cookies baking behavior. Cookies were prepared with different proportion of Amaranth and evaluated for physical (thickness, diameter, spread ratios), textural and organoleptic attributes. Sensory data indicated that the amaranth inclusion up to 60% were acceptable, while additional amaranth flour resulted in a decreased mean score of overall acceptability.

Ranjana *et al*., (1998) [77] studied the physical, chemical and sensory properties of biscuits prepared from wheat flour with 0-50% replacement by defatted soybean flour. They observed that thickness of biscuits was increased as inclusion of soya flour increased. Sensory properties indicated that there was no substantial adverse effect on overall quality up to 20% replacement of defatted soya flour in biscuits formulation. Hozova *et al*., (1995) [39] formulated biscuits from amaranth flour and examined the microbial quality and sensory characteristics for a storage period of 6 months at 20 ºC and 62% RH. They found that prepared biscuits were found satisfactory and no micro organisms were detected for the first four months of storage. Bottcher *et al*., (1995) [14] developed flour suitable for manufacture of biscuits. Rye and corn flour were used as substitute for wheat flour at 10 – 30% level, thus reducing protein content. Addition of rye flour to wheat flour did not result in acceptability of the biscuits. But addition of corn flour to wheat flour gave suitable acceptability for the biscuits.

Seaweed Cookies and conclusion

Sophie (2010) [82] reported that the Countryside Japanese Seaweed Onion Biscuits is crispy and full of flavor and each 100g biscuits contain 520 calories, saturated fat 30g, protein 10g, carbohydrate 60g, sodium 400mg, potassium 50mg and different types of vitamins.

An Irish Private Industry, Marigot Ltd. (1999) [58] reported that seaweed may be incorporated into biscuits at a level of 1.5-2.0% without any adverse effect on the taste or functionality of the biscuits. At this level of fortification up to 50% of the Calcium RDI (Recommended daily intake) may be administered in one serving of biscuits (3 biscuits/20g per biscuit). Taste panels could not detect the presence of extra calcium in the biscuit. Analytical tests, friability, water activity and color measurement confirmed that the addition of calcium to the biscuits did not produce any negative effects.

Shahid and Bin, (2012) [81] formulated seaweed cookies from Hypnea musciformis. Four types of cookies were prepared by incorporating various levels (0-6%) of seaweed powder and the final products were evaluated to understand the biochemical properties and sensory properties. To identify the amount of seaweed powder that should be incorporated in the preparation, sensory test was done by 12 test panelists. Recommended levels of inclusion of seaweed powder were found to be 2%.

Cookies were of high energy product, where seaweed cookies are mineral rich bakery product. There were several seaweed products and seaweed cookies in existence all over the world. But there is no Indian food industry came forward to undertake such kind of step to manufacture seaweed based products though they are nutritionally attractive and a very profitable business.

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