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# COMPARISION OF NUTRITIVE VALUE OF SEAWEED WITH OTHER TERRESTRIAL FOODS—A REVIEW

Swarnalatha G[1]*

*Corresponding Author: Swarnalatha G, ✉ swarna2411@gmail.com

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Seaweeds are low calorie food from nutritional point of view as they have high concentration of minerals, vitamins, proteins and indigestible carbohydrates. They have low content of lipids but they are of high quality in terms of nutritional value. Seaweeds also exhibit antioxidant; antimutagenic, anticoagulant, antitumor and they also play important role in modification of lipid metabolism in the human body. Seaweed, being a rich source of structurally diverse bioactive compounds with valuable nutraceutical properties, can be used as an ingredient to supplement food with functional compounds. Seaweed gums exploit for their multifunctional properties such as thickeners, stabilizers and gelling agents in milk products, sweets and confectionary, meat products, beverages and bakery industries. As seaweeds and seaweed isolates have the potential to both benefit health and improve food acceptability, seaweeds and seaweed isolates offer exciting potential as ingredients in the development of new food products. This article presents information on comparison of nutrient level of seaweeds with terrestrial foodstuffs with respect to selected nutrients.

***Keywords:*** Seaweed, Bioactive compounds, Terrestrial foods, Nutrients

## INTRODUCTION

Seaweeds are macroalgae living in sea or brackish water, often called as ocean kelps or benthic marine algae which means attached algae that live in the sea (Chandini *et al.,* 2008). Seaweeds possess a good nutritional quality and could be used as an alternative source of dietary fiber, protein, and minerals. Moreover, bioactive sulfated polysaccharides are the main components of soluble fiber in seaweeds and also bioactive peptides can be prepared from seaweed protein (Paul *et al.,* 2007; and Jimenez-Escrig *et al.,* 2011). About 150 species of seaweeds are used as food worldwide and over 100 species for seaweed gums production. Seaweeds are rich and diverse sources of raw material for the manufacture of Seaweed gums/ Phycocolloids/Hydrocolloids. Seaweeds are great potential producer of secondary metabolites that responsible for bioactivities which have commercial application in pharmaceutical, medical, cosmetic, nutraceutical and agricultural industries (Noer *et al.*, 2016).

Nowadays, seaweeds consumption is increasing due to their natural composition. They were recorded to have many beneficial nutritive bioactive compounds such as vitamins (ascorbic and â carotene), polyphenols, pigments, minerals, fibers and polysaccharides (Lahaye, 1991). They were also low in fat and in calorific value with high levels of essential fatty acids and essential amino acids in addition to about 80-90% water. In many studies, these bioactive compounds confirmed antioxidant, antimicrobial, antitumor and antiviral activities (Mabeau and Fleurence, 1993; Ortiz*et al.*, 2006; and Seenivasan *et al.*, 2012).

The present article quantifies the nutritional impact of seaweeds as a source of essential nutrients as well as their

[1] Department of Dairy Chemistry, College of Dairy Technology, P V Narasimha Rao Telangana Veterinary University, Kamareddy, India.

key bioactive molecules and activities; it also describes the individual benefits ascribed to the main types of edible seaweeds with other foods. The nutrient levels of seaweeds are also shown in comparison with terrestrial foodstuffs with respect to selected nutrients.

## Classification of Seaweed

Seaweeds are classified taxonomically as algae and they represent a food group that is not normally ingested in unprocess form to any great extent in Western societies. Biologically, seaweeds are classified as macroalgae, with subclassification as brown (Phaeophyta), red (Rhodophyta) or green algae (Chlorophyta) (Gomez *et al.*, 2010).

## SEAWEED RESOURCES

**Brown Seaweeds:** The brown colour of these algae results from the dominance of the xanthophylls pigment fucoxanthin, which masks the other pigments, chlorophyll a and c, beta carotene and other xanthophylls.

**Green Seaweeds:** The green algae are classified in the phylum Chlorophyta. Green seaweeds are usually found in the intertidal zone (between the high and low water marks) and in shallow water where there is plenty of sunlight. They are thought to be the algae most closely related to plants, due to the similarity of their pigments.

**Red Seaweeds:** Red algae are the most abundant, and commercially valuable, of the marine algae. They are classified in the phylum Rhodophyta. The term Rhodophyta represents the group of algae which owns red color due to the accessory pigments phycoerythrin and phycocyanin; this masks the other pigments, chlorophyll a (no chlorophyll b), β-carotene and a number of unique xanthophylls (Oritz *et al.*, 2006; and Shahin *et al.*, 2016). Some examples of these edible algae are outlined in Table 1.

**Table 1: Examples of Edible Algae**

| Subclassificaton | Genus/Latin Name | Common Name* |
|---|---|---|
| Brown algae (Phaeophyta) | *Alaria* | Kelp/bladderlocks |
| | *Himanthalia elongata/ Bifurcaria* | Sea spaghetti, fucales |
| | *Laminaria digitata* | Kelp/kombu/ kumbu/sea tangle |
| | *Saccharina* | Sugar wrack |
| | *Undaria pinnatifida* | wakame |
| | *Ascophyllum nodosum* | Egg wrack |
| | *Fucus* | Bladder wrack, rockweed |
| | *Sargassum wightii* | Mojaban/Indian brown seaweed |
| | *Hizikia* | Hijiki |
| Red algae (Rhodophyta) | *Rhodymenia/ Palmaria palmata* | Dulse or Dillisk |
| | *Porphyra umbilicalis* | Nori/haidai/kim/gim |
| | *Chondrus crispus* | Irish moss or Carrigeen |
| | *Mastocarpus/ Gigartina* | Stackhouse, Guiry |
| | *Gracilaria Asparagopsis* | Limu Kohu |
| Green algae (Chlorophyta) | *Ulvaria actuca/ Enteromorpha* | Laver/sea lettuce/ sea grass/nori |
| | *Caulerpa racemosa, Caulerpa taxifolia* | |

**Note:** * Data from Paul *et al.* (2007), Gomez *et al.* (2010), Romarís *et al.* (2010) and Murugaiyan *et al.* (2012).

## ASSESSMENT OF NUTRIENT VALUE OF SEAWEEDS WITH TERRESTRIAL FOODS

The nutrients in our daily diet or those synthesized in the human body using the precursor molecules play a vital role in regulating the body functions, essential for normal growth and development. Carbohydrates, proteins, lipids, and vitamins are provided to the human body through different food sources. Like most of the terrestrial plants, marine algae are also a rich source of above nutritional elements. In comparison with many common vegetables, high levels of fiber, minerals, ω-3 fatty acids and moderate concentrations of lipids and proteins available in most of the edible seaweed help it to be considered as an important food source for human nutrition. However, the available amounts of the above nutrients may vary basically depending on the variety, season, and the area of production (Murata and Nakazoe, 2001).

Since seaweeds are normally consumed and tested as a dried foodstuff, this can make comparison with land-based foodstuffs difficult. Thus, the present analysis consists of two forms: 1) a comparison of 100 g wet-weight seaweeds with 100 g of common foods, and 2) the nutrient levels found in an g/100 g dry-weight with g/100g of common foods. Generally eight grams of seaweed is a typical daily portion size consumed in Asian cuisine (Paul *et al.,* 2007).

## Dietary Fibre

The fibre content in various seaweeds are compared with terrestrial foods are presented in Table 2. The main components in seaweeds are depends upon the type of seaweed. Red seaweeds varieties consist of different typical carbohydrates kinds including: floridean starch ($\alpha$-1, 4-bindingglucan), cellulose, xylan, and mannan. Moreover, their water-soluble fiber fraction is formed by sulfur-containing galactans, e.g., agar and carrageenan (Jimenez-Escrig and Sanchez-Muniz 2000). On the other hand, the typical carbohydrates in brown seaweeds varieties consist of fucoidan, laminaran ($\beta$-1, 3-glucan), cellulose, alginates, and mannitol. Brown seaweeds, fibers are mainly cellulose and insoluble alginates. In contrast, the amorphous, slimy fraction of fibers consists mainly of water-soluble alginates and/or fucoidan. The typical seaweeds' carbohydrates are not digestible by the human gastrointestinal tract and,

**Table 2: Fiber Content of Seaweeds Compared to Terrestrial Foods**

| Food Type | Total Fiber | Soluble Fiber | Insoluble Fiber | Carbohydrate |
|---|---|---|---|---|
| **Seaweed (g/100 g Wet Weight)*** | | | | |
| *Ascophyllum nodosum* | 8.8 | 7.5 | 1.3 | 13.1 |
| *Laminaria digitata* | 6.2 | 5.4 | 0.8 | 9.9 |
| *Himanthalia elongate* | 9.8 | 7.7 | 2.1 | 15 |
| *Undaria pinnatifida* | 3.4 | 2.9 | 0.5 | 4.6 |
| *Porphyra umbilicalis* | 3.8 | 3 | 1 | 5.4 |
| *Palmaria palmate* | 5.4 | 3 | 2.3 | 10.6 |
| *Ulva* sp. | 3.8 | 2.1 | 1.7 | 4.1 |
| *Enteromorpha* sp. | 4.9 | 2.9 | 2.1 | 7.8 |
| **Whole Food (g/100 g Weight)†** | | | | |
| Rice dry | 1.3 | 1 | 0.3 | 80 |
| Peas, green frozen | 3.5 | 3.2 | 0.3 | 14 |
| Kidney beans, canned | 6.3 | 4.7 | 1.6 | 23 |
| Potato no skin | 1.3 | 1 | 0.3 | 22 |
| Spinach raw | 2.6 | 2.1 | 0.5 | 11 |
| Tomato raw | 1.2 | 0.8 | 0.4 | 6 |
| Apple, unpeeled | 2 | 1.8 | 0.2 | 15 |
| Bananas | 1.7 | 1.2 | 0.5 | 24 |
| Peanut, dry roasted | 8 | 7.5 | 0.5 | 21 |
| Cashew, oil roasted | 6 | - | - | 28 |

**Note:** * Values for seaweeds from the Institut de Phytonutrition (2004); † Value for whole food from Punna *et al.* (2003) and Devinder *et al.* (2012).

therefore, they are dietary fiber (Ghada and Amany, 2013). In addition, the fibers can increase feelings of satiety and aid digestive transit through their bulking capacity. (Brownle *et al.*, 2005).

*Himanthalia elongate* (brown algae), when compared with other selected whole foods contains slightly more fibre than Kidney beans canned, Peanut, dry roasted and Cashew oil roasted (9.8% versus 6.3%, 8.0% and 6.0%) respectively. By comparing *Laminaria digitata* (brown algae) contain more fibre content than rice dry, potato without skin, tomato raw and bananas (6.2% versus 1.3%, 1.3%, 1.2% and 1.7%) respectively. The seaweeds also rich in soluble fibre and insoluble fibre (*Himanthalia elongate*.7.7 and 2.1) when compared with terrestrial foods. According to the guideline daily amount of dietary fiber is 25 g per day (Susan and Robin, 2002). Based on this amount, seaweeds can provide up to 12.5% of a person's daily fiber needs in an 8 g serving. This is relatively large amount when compared with other terrestrial foods.

## PROTEIN

Indian seaweeds are of great food value and certain of them contain 16-30% protein on dry weight basis and have all essential amino acids which are not available in vegetable food materials (Murugaiyan *et al.*, 2012). In general, seaweed protein is rich in glycine, arginine, alanine, and glutamic acid, and contains all the essential amino acids, the levels of which are comparable to those of the FAO/WHO requirements of dietary proteins (Anonymous, 2006). However, when compared with the other protein-rich food sources, seaweed is appeared to be limiting with lysine and cystine. With respect to the protein level and amino acid composition, the amino acid score and the essential amino acid index were higher in red seaweed than those in brown and green seaweeds (Holdt and Kraan, 2011).

The Protein content of brown seaweeds is generally low (5-15% of the dry matter), whereas higher protein contents are recorded for green and red seaweeds (10-30% of the dry weight) (Chandini *et al.*, 2008). In some red seaweeds, such as *Porphyra tenera* (47%) and *Palmaria palmata* (35%) of the dry matter. These levels are comparable to those found in soybean. Protein content varied among different genera and also in different species of the same genus. These levels varied depending on algal species, season and environment (Rajasulochana *et al.*, 2012). Red seaweed contains the highest protein content, which is comparable in quantitative terms to legumes at 30-40% of dry matter, and brown and green seaweeds contain only 15% and 30%, respectively (Murata and Nakazoe, 2001). The protein content of brown seaweeds *Laminaria japonica* and *Undaria pinnatifida* ranged from 7% to 16% (Marsham *et al.*, 2007).

From the Table 3 the seaweeds exhibit amino acid composition close to that of traditional proteins from cereals and leguminous plants. Essential amino acids such as histidine, leucine, isoleucine, and valine are present in many seaweeds, such as *Palmaria palmata* (Dillisk/Dulse) and *Ulva* spp. (sea lettuce). The levels of isoleucine and threonine in *Palmaria palmata* are similar to the levels found in legumes, and histidine is found in *Ulva pertusa* at levels similar to those found in egg proteins (Paul *et al.*, 2007).

## Lipids

Marine macro algae varieties contained low amount of lipids, they are the sources of poly unsaturated fatty acids. The fatty acid distribution of seaweed products showed high level of omega-3 fatty acids and demonstrated a nutritionally ideal omega-6/omega-3 free fatty acid ratio (Paul *et al.*, 2007; and Misurcova *et al.*, 2011). Seaweed lipids consist of 1-3% of dry algal matter. Glycolipids a formed the major lipid class in all seaweeds.

When compared with other whole foods as presented in Table 4 seaweeds are rich in PUFA. The major commercial sources of $\omega$-3 PUFAs are fish, but their wide usage as food additives is limited for the typical fishy smell, unpleasant taste, and oxidative nonstability. Nevertheless, growing requirements of healthy functional foods have led to produce PUFAs as nutraceuticals in controlled batch culture of marine microalgae, especially Thraustochytrium and Schizochytrium strains. PUFAs are the important components of all cell membranes and precursors of eicosanoids that are essential bioregulators of many cellular processes. PUFAs effectively reduce the risk of cardiovascular diseases, cancer, osteoporosis, and diabetes. Because of the frequent usage of seaweeds in Asia and their increasing utilization as food also in other parts of the world, seaweeds could contribute to the improvement of a low level of $\omega$-3 PUFAs, especially in the Western diet (Misurcova *et al.*, 2011).

## Minerals

Marine algae contain more than 60 trace elements in a concentration much higher than in terrestrial plants and have various pharmacological activities (Jimenez *et al.*, 2011;

**Table 3: Essential Amino Acid Composition of Different Seaweeds and Some Terrestrial Foods**

| Type of Food | Essential Amino Acids | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| **Seaweeds*** | | | | | | | | | |
| *Ulva pertusa* # | 4 | 3.5 | 6.9 | 4.5 | 1.6 | 3.9 | 3.1 | 0.3 | 4.9 |
| *Ulva armoricana* # | 2.1 | 3.6 | 6.7 | 4.4 | 2.6 | 7.1 | 6.8 | - | 5.2 |
| *Undaria pinnatifida* $ | 2.5 | 3.3 | 5.9 | 5.6 | 1.7 | 4.7 | 4.4 | 0.7 | 5.2 |
| *Laminaria* sp$ | 2.2 | 2.7 | 4.9 | 3.9 | 0.9 | 3.2 | 3.5 | 0.5 | 3.8 |
| *Poryphera* sp$ | 2.6 | 3.1 | 5.5 | 4.9 | 1.8 | 3.3 | 5.3 | 0.7 | 5.2 |
| **Whole Foods** g/100 g Protein** | | | | | | | | | |
| Wheat (hard) | 2 | 3 | 6.3 | 2.3 | 1.2 | 4.6 | 2.4 | 2.4 | 3.6 |
| Brown Rice | 2.5 | 4.1 | 8.6 | 4.1 | 2.4 | 5.2 | 4 | 1.4 | 5.8 |
| Barley | 2.1 | 3.6 | 6.6 | 3.5 | 2.2 | 5.2 | 3.2 | 1.5 | 5 |
| Oats | 2.4 | 4.2 | 7.5 | 4.2 | 2.3 | 5.4 | 3.3 | - | 5.8 |
| Leguminous plants | 4 | 3.6 | 7.3 | 6.5 | 1.4 | 2.4 | 4 | 1.9 | 4.5 |
| Ovalabumin | 4.1 | 4.8 | 6.2 | 7.7 | 3.1 | 4.1 | 3 | 1 | 5.4 |

**Note:** 1: Histidine; 2: Isoleucine; 3: Leucine; 4: Lysine; 5: Methionine; 6: Phentyalanine; 7: Threonine; 8: Tryptophan; 9: Valine. #: g per 100 g dry weight, $: g per 16 g nitrogen.* Mabeau and Fleurence (1993), Sanchez-Machado *et al.* (2004), Ortiz *et al.* (2006) and Dawczynski (2007). ** Macrae *et al.* (1993) and Chandini *et al.* (2008).

**Table 4: Fatty Acid Composition of Different Seaweeds and Some Terrestrial Foods**

| Type of Food | Fatty Acids | | | | |
|---|---|---|---|---|---|
| | Saturated (%) | MUFA (%) | PUFA (%) | ω6 PUFAs | ω3 PUFAs |
| **Seaweed*** | | | | | |
| *Ulva Lactuca* | 23.5 | 38.8 | 13.7 | 8.3 | 4.4 |
| *Porphyra sp* | 33.5 | 2.2 | 43.1 | 7.97 | 7.2 |
| *Palmaria sp* | 60.5 | 10.5 | 24.1 | 2.14 | 25.52 |
| *Sargassum marginatum* | 50 | 17.8 | 24.1 | 4.9 | - |
| *Laminaria ochroluca* | 33.5 | 19.2 | 45.6 | 20.99 | 25.08 |
| *Himanthalia elongate* | 39.06 | 22.75 | 38.16 | 15.08 | 18.7 |
| *Udaria pinnatifida* | 20.39 | 10.5 | 69.11 | 22.1 | 44.7 |
| **Whole Food (g/100 g Food) †** | | | | | |
| Barley, pearl, raw | 0.29 | 0.14 | 0.77 | 0.7 | 0.07 |
| Oat meal | 1.61 | 3.34 | 3.71 | 3.52 | 0.19 |