Nutritional Marine Life

RAMASAMY SANTHANAM

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PREFACE

Nutritive marine fisheries resources generally account for about 16% of the protein attributed to the animal group of fish and crustaceans. This group provides high-quality sources of amino acids, which are nutritionally important types of protein that are found in only small amounts in cereals and grains. The nutrients and minerals in seafood improve brain development and reproduction. Doctors have known of strong links between fish consumption and healthy hearts because fish-eating populations have low levels of heart disease. Similarly, other groups such as phytoplankton and invertebrates possess several nutrients of importance to human health. It is always important to know the nutritional facts regarding different seafood organisms, which we have consumed from time immemorial. Although several books are available on seas and oceans, no books on the nutritional qualities of edible marine life have been available. Keeping this in consideration, an attempt has now been made. This book deals with nutritional facts of different groups of edible marine life: phytoplankton, seaweeds and marsh plants, jellyfish, crustaceans (shrimps, crabs, and lobsters), mollusks (oysters, mussels, clams, scallops, conches, abalones, limpet, squids, cuttlefish, and octopus), echinoderms (starfish, sea urchins, and sea cucumbers), prochordates (sea squirts), fish, turtles, and mammals, along with their characteristics such as classification, common names, habitats, global distribution, and biological features. The outstanding features of this publication are the easy identification of nutritionally and commercially important marine species along with their characteristic features and the nutritional facts regarding different groups of marine life. This book is of great use for undergraduate and postgraduate students belonging to the fisheries science, marine biology, aquatic science, and marine biotechnology disciplines, besides serving as a standard reference in the libraries of colleges and universities. Furthermore, because this publication provides an overview of the nutritional content of marine organisms, it is a useful reference for dietitians and doctors who are interested in knowing about the health benefits of seafood.

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Ramasamy Santhanam

ABOUT THE AUTHOR

Dr. Ramasamy Santhanam is the former dean of the Fisheries College and Research Institute, Tamilnadu Veterinary and Animal Sciences University, Thoothukudi, India. His fields of specialization include fisheries environment and marine biology. He is presently serving as a consultant for Advanced Aquatic Environmental Research Services (AAERS), Sultanate of Oman, and as a fisheries expert for various government and nongovernmental organizations in India. Dr. Santhanam has published 10 books on various aspects of fisheries science and 70 research papers. He was a member of the American Fisheries Society, World Aquaculture Society, and Global Fisheries Ecosystem Management Network, United States, and the International Union for Conservation of Nature's (IUCN) Commission on Ecosystem Management, Switzerland.

1
INTRODUCTION

The ocean covers approximately 70% of the Earth's surface, and it is the largest environment for living things on Earth. It is an important source of food and other resources. Although only 5% of the protein consumed by world populations comes from the marine animals of the sea, it is still an important contribution to the diet of millions of the world's inhabitants.

At present, more than 30% of humanity is suffering from malnutrition in the form of insufficient nutrient intake (undernourishment) and food-related diseases. The global magnitude and consequences of hunger and malnutrition are profound and long-lasting. Nowadays, many suffer from specific dietary micronutrient deficiencies, including deficiencies in iron, iodine, vitamin A, and zinc. In this context, marine food products derived from fish, crustaceans, mollusks, and edible aquatic plants or seaweeds could be an integral part of the human diet.

NUTRITIONAL COMPOSITION OF MARINE FOODS: FISH, CRUSTACEANS, AND MOLLUSKS

In terms of nutrient composition, marine animal food products represent one of the world's most healthy and nutritious food sources (Albert, Taconi, and Metian, 2013).

Proteins

Marine animal foods have higher protein content on an edible fresh-weight basis (mean: 17.3%) than most terrestrial meats (mean: 13.8%). Marine animal food proteins are highly digestible and have a high biological value due to their excellent essential amino acid (EAA) profile, which closely approximates the recommended human dietary EAA requirement pattern. In particular, marine animal proteins are rich dietary sources of methionine (5.9% total EAAs in mollusk proteins, 6.1% total EAAs in crustacean proteins, and 6.4% total EAAs in fish proteins) and lysine (18.2% total EAAs in mollusk proteins, 19.1% total EAAs in crustacean proteins, and 19.6% total EAAs in fish proteins). Since these EAAs are usually limited within most edible plant proteins consumed by humans, aquatic food products constitute a perfect addition to the typical plant-based diets consumed by the rural poor.

Fat and Fatty Acids

Marine animal foods are generally leaner on an edible fresh-weight basis (average of fat: 2.7%). Compared with terrestrial meats (average of fat: 16.6%), they have a lower saturated fat content (average of 0.16% in crustaceans, 0.32% in mollusks, and 1.19% in fish) and have a lower calorific density (average of 101.3 Kcal/100 g).

Marine animal food products contain the highest concentrations of long-chain omega-3 (n-3) polyunsaturated fatty acids of any foodstuffs, including eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA; average amounts of EPA and DHA are, respectively, 130 and 84 mg per 100 g of crustaceans, 149 and 162 mg per 100 g of mollusk, and 279 and 467 mg per 100 g of fish). The highest levels of EPA and DHA have been reported in small pelagic fish species (average of EPA/DHA: 778/966 mg/100 g), including Atlantic mackerel, Pacific herring, Atlantic herring, and European anchovy.

In health terms, the fish-derived omega-3 (n-3) fatty acids EPA and DHA have been shown to have a positive role in infant development (including neuronal, retinal, and immune functions), cardiovascular diseases (including a reduced incidence of heart disease in adults), cancer, and various mental illnesses (including depression, attention-deficit hyperactivity disorder, and dementia).

Minerals and Trace Elements

Marine animal food products are a richer source of most essential minerals and trace elements than most terrestrial meats, including the following:

- Calcium (average of 68.2 mg/100 g in crustaceans, 39.7 mg/100 g in mollusks, and 26.0 mg/100 g in fish)
- Phosphorus (average of 230.5 mg/100 g in fish, 208.3 mg/100 g in mollusks, and 204.0 mg/100 g in crustaceans)
- Magnesium (average of 34.7 mg/100 g in crustaceans, 33.0 mg/100 g in fish, and 26.8 mg/100 g in mollusks)
- Iron (average of 3.72 mg/100 g in mollusks, 0.69 mg/100 g in fish, and 0.40 mg/100 g in crustaceans)
- Potassium (average of 367.6 mg/100 g in fish, 249.0 mg/100 g in crustaceans, and 218.8 mg/100 g in mollusks)
- Sodium (average of 394.2 mg/100 g in crustaceans, 254.9 mg/100 g in mollusks, and 73.8 mg/100 g in fish)
- Zinc (average of 11.31 mg/100 g in mollusks, 3.08 mg/100 g in crustaceans, and 0.61 mg/100 g in fish)
- Copper (average of 0.92 mg/100 g in mollusks, 0.72 mg/100 g in crustaceans, and 0.06 mg/100 g in fish)
- Manganese (average of 0.56 mg/100 g in mollusks, 0.08 mg/100 g in crustaceans, and 0.02 mg/100 g in fish)
- Selenium (average of 42.6 µg/100 g in mollusks, 41.9 µg/100 g in crustaceans, and 32.5 µg/100 g in fish)

Higher levels of mineral elements have been observed in small pelagic fish species (including European anchovy, Atlantic and Pacific herring, and Atlantic and Spanish mackerel) compared to other fish species, including calcium (average of 75 mg/100 g), iron (average of 1.8 mg/100 g), magnesium (average of 45 mg/100 g), potassium (average of 362 mg/100 g), zinc (average of 0.97 mg/100g), copper

(average of 0.11 mg/100 g), manganese (0.04 mg/100 g), and selenium (mean: 38.4 µg/100 g). In addition to the mineral elements, marine animal food products are also rich dietary sources of other important essential trace elements that are generally lacking in terrestrial meat products, including iodine (<1 to 700 µg; average of 84.7 µg/100 g of 20 fish and shellfish products).

Vitamins

Marine animal food products are a richer source of several key water-soluble and fat-soluble vitamins than most terrestrial meats, including the following:

- Vitamin A (average of 263.7 IU/100 g in fish, 151.0 IU/100 g in mollusks, and 69.8 IU/100 g in crustaceans)
- Vitamin C (average of 4.0 mg/100 g in mollusks, 1.6 mg/100 g in crustaceans, and 0.8 mg/100 g in fish)
- Vitamin B_{12} (average of 10.0 µg/100 g in mollusks, 5.1 µg/100 g in crustaceans, and 3.3 µg/100 g in fish)
- Folic acid (average of 29.3 µg/100 g in crustaceans, 15.0 µg/100 g in mollusks, and 10.0 µg/100 g in fish)
- Vitamin E (average of 1.1 mg/100 g in fish and crustaceans and 0.80 mg/100 g in mollusks)
- Vitamin D (average of 44.9 IU/100 g in fish)
- Choline (average of 75.6 mg/100 g in crustaceans, 68.6 mg/100 g in fish, and 65.0 mg/100 g in mollusks)

Higher vitamin levels were observed in small pelagic fish species (including European anchovy, Atlantic and Pacific herring, and Atlantic mackerel) compared to other fish species, including riboflavin (average of 0.25 mg/100 g), niacin (7.13 mg/100 g), vitamin B_{12} (8.25 µg/100 g), vitamin A (104 IU/100 g), and vitamin D (405 IU/100 g).

SEAWEEDS

Protein

Red seaweeds such as *Porphyra* spp. (nori) have the highest levels of protein (up to 47% on a dry-weight basis); these are followed by green seaweeds, such as *Ulva lactuca* (sea lettuce), with protein levels ranging between 10% and 25% on a dry-weight basis).

Amino Acids

Aspartic acid and glutamic acids constitute a large part of the amino acid makeup of edible seaweed proteins. Amino acids are highest within brown seaweed proteins. Moreover, edible seaweeds such as *Palmaria palmata* (dillisk, or dulse) and *Ulva* spp. (sea lettuce) are good sources of essential amino acids such as histidine, leucine, isoleucine, methionine, and valine. The levels of isoleucine and threonine in *P. palmata* are similar to the levels found in legumes, and the histidine levels in *Ulva pertusa* are similar to the levels found in egg proteins.

Lipids and Fiber

The lipids present in seaweeds are rich in omega-3 polyunsaturated fatty acids, in particular EPA and to a lesser extent DHA, which are important to human health. Edible seaweeds are also a good source of dietary fiber (range: 3.4 to 9.8 g/100 g), including insoluble fiber (range: 0.5 to 2.3 g/100 g) and soluble fiber (range: 2.1 to 7.7 g/100 g on a fresh-weight basis).

Minerals and Trace Elements

Seaweeds are a rich dietary source of biologically available minerals and trace elements (compared with most other terrestrial plant food sources), including (measured as mg/100 g wet weight): iodine, 1.3–97.9 mg/100 g; iron, 3.9–45.6 mg/100 g; zinc, 0.3–1.7 mg/100 g; copper, 0.1–0.8 mg/100 g; magnesium, 78.7–573.8 mg/100 g; potassium, 62.4–2013.2 mg/100 g; and calcium, 30–575.0 mg/100 g.

Vitamins

Edible seaweeds are a rich source of many water-soluble and fat-soluble vitamins, including vitamin C (range: 8.17–184.7 mg/100 g dry weight), vitamin E (range: 0.36–17.4 mg/100 g dry weight), vitamin B_{12} (range: 1.64–78.7 g/100 g wet weight), thiamin (range: 0.14–5.04 mg/100 g dry weight), riboflavin (range: 0.14–11.70 mg/100 g dry weight), niacin (range: 0–100 mg/100 g dry weight), pyridoxine (range: 0.01–6.41 mg/100 g dry weight), inositol (range: 0.01–6.41 mg/100 g dry weight), and folic acid (range: 0–45.6 mg/100 g dry weight).

Pharmaceutical Compounds

Edible seaweeds are known to contain a variety of different species-specific bioactive chemicals with potential pharmaceutical and health-enhancing properties, including bromophenols, phytosterols, photosynthetic pigments, and immune-enhancing polysaccharides.

Among all marine food products, fish has always been considered a food necessary for good health. It is also recognized as a "brain food," owing to its importance in the development of a healthy brain. In addition, it has these benefits:

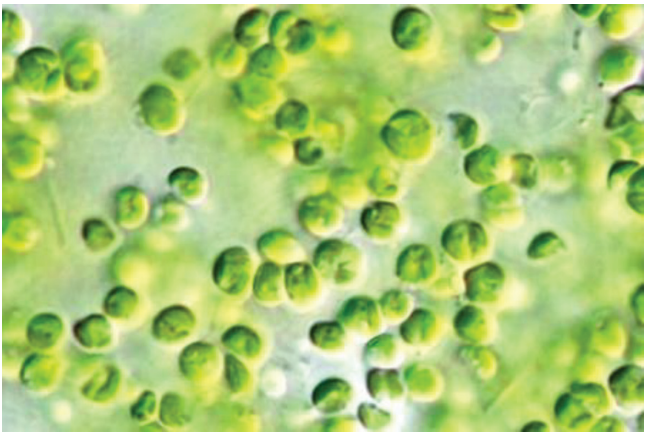
- Fish consumption reduces the risk of death from coronary heart disease, and fish consumption by women reduces the risk of suboptimal neurodevelopment in their offspring.
- Fish consumption may reduce the risk of multiple other adverse health outcomes, including ischemic stroke, nonfatal coronary heart disease events, congestive heart failure, atrial fibrillation, cognitive decline, depression, anxiety, and inflammatory diseases.
- Fish consumption may provide a greater nutritional impact than the sum of the health benefits of the individual nutrients consumed separately.

In order to alleviate the problems relating to malnutrition among the people of developing and under-developed countries, there is an urgent need to identify new species rich in nutrients from different marine biotopes. In this regard, assessment of the nutritional quality of marine flora and fauna of edible value would be of great use to add new and cheap sources of animal proteins. Further, by applying knowledge of nutritional status, one can select the needed species to harvest. This may help conserve marine ecosystems and their biodiversity, which is an urgent need presently. In the book, an attempt has been made to present detailed information on the nutritional facts of different groups of marine life. While presenting the information relating to proximate composition, mean values have been considered. Readers may refer the sources (references) concerned for detailed information.

Finally, it is important to mention that small pelagic fish species represent one of the best aquatic animal foods from a nutritional perspective.

2
PHYTOPLANKTON

Nannochloropsis oculata (Droop) D.J. Hibberd, 1981



Phylum: Ochrophyta

Class: Eustigmatophyceae

Order: Eustigmatales

Family: Monodopsidaceae

Common name: Unknown

Distribution: Europe: Britain

Habitat: Marine habitats

Description: This species measures 1–2 µm in length and width. It is unicellular and free-floating. Cells are spherical and lack chlorophyll pigments other than chlorophyll *a*. This species has been proposed as a commercial source for the dietary supplement omega-3 fatty acid.

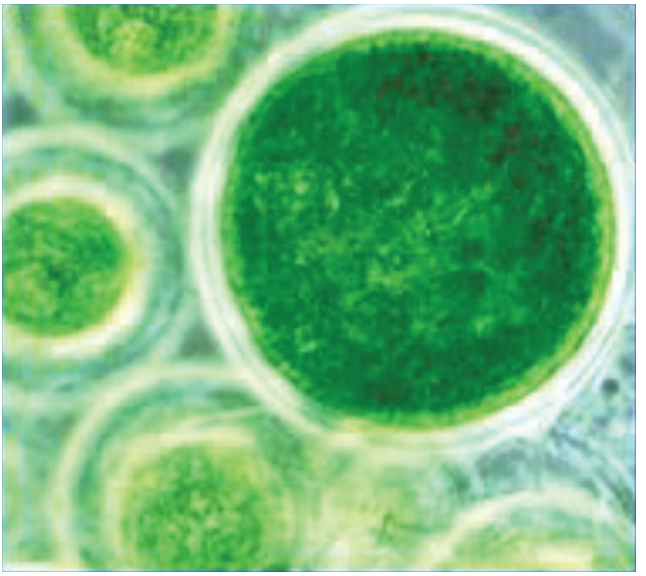
Nutritional Facts

Proximate Composition (% Dry Weight [DW])

Protein	Lipid	Carbohydrate
32.82	13.02	26.13

Source: Data from Banerjee et al. (2011).

Nannochloropsis gaditana L.M. Lubián, 1982



Phylum: Ochrophyta

Class: Eustigmatophyceae

Order: Eustigmatales

Family: Monodopsidaceae

Distribution: Unknown

Habitat: Marine habitats

Description: It is a small species with cells measuring about 2 to 3 µm diameter. Cells have a very simple ultrastructure with reduced structural elements. It has chlorophyll *a* and completely lacks chlorophyll *b* and *c*. It is able to build up a high concentration of a range of pigments, such as astaxanthin, zeaxanthin, and canthaxanthin.

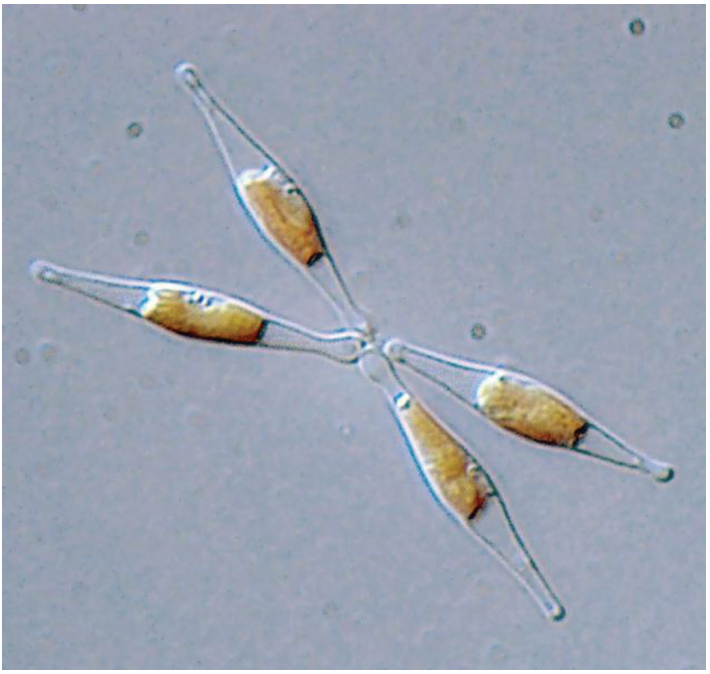
Nutritional Facts (per 100 g Freeze-Dried Powder)

Protein	30–50%
Fat	15–30%
Minerals	10–15%
Chlorophyll *a*	1.5–3%
Total carotenoids	1.2–2%
Linoleic acid (C18:2ω3)	450–1800 mg
Linoleic acid (C18:3ω3)	17–50 mg
Eicosatrienoic acid (C20:3ω3)	800–2400 mg
EPA (C20:5ω3)	3600–10,000 mg

EPA: eicosapentaenoic acid.

Source: Data from Green Harmony Living (2014).

Phaeodactylum tricornutum Bohlin, 1897



Phylum: Heterokontophyta

Class: Bacillariophyceae

Order: Naviculales

Family: Phaeodactylaceae

Common name: Unknown

Distribution: Europe and North America

Habitat: Marine habitats

Description: This species can exist in different morphotypes (fusiform, triradiate, and oval), and it can be stimulated by environmental conditions. This feature can be used to explore the molecular basis of cell shape control and morphogenesis. Unlike most diatoms, *P. tricornutum* can grow in the absence of silicon, and the biogenesis of silicified frustules is facultative.

Nutritional Facts

Proximate Composition %

Chlorophyll *a*	Protein	Cholesterol
76.7	0.41	23

Fatty Acids

(% DW)	(pg/per cell)
10.7	4.9

DW: dry weight; pg: picogram.
Source: Data from Siron et al. (1989).