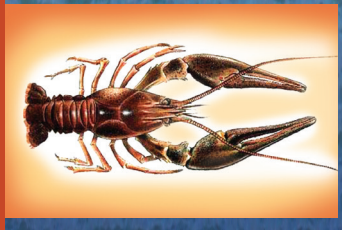
Nutritional Freshwater Life

Ramasamy Santhanam



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PREFACE

Today, fishing is considered to be the largest extractive use of wildlife in the world. Freshwater fisheries provide food and a livelihood for millions of the poorest people, and also contribute to the overall economic well-being by means of export commodity trade, tourism, and recreation. It is estimated that freshwater fishes make up more than 6% of the world's annual animal protein supplies for humans. It is the major and often only source of animal protein for low-income families. Global freshwater supports at least 100,000 species out of approximately 1.8 million—almost 6% of all described species. Inland waters and freshwater biodiversity constitute a valuable natural resource in economic, cultural, aesthetic, scientific, and educational terms. It is always important to know the nutritional facts of freshwater flora and fauna occupying different habitats.

Although several books are available on limnology and aquatic biology, no books on the nutritional aspects of edible freshwater life are available presently. Keeping this in consideration, an attempt has now been made. This book deals with nutritional facts of different groups of edible freshwater life, viz., algae and plants, crustaceans (prawns, crayfish, and crabs), molluscs (bivalves and gastropods), fish, and frogs, along with their characteristics, such as classification, common names, habitats, global distribution, and biological features. When published, this book will be of great use for the undergraduate and postgraduate students of disciplines such as fisheries science, aquatic biology, biotechnology, environmental science, and life sciences, besides serving as a standard reference in the libraries of colleges and universities.

I am highly indebted to Dr. P. Velayutham, professor and head of the Department of Fish Processing Technology, Fisheries College and Research Institute, Tamilnadu Fisheries University, Thoothukudi, India, for his valuable comments. I also sincerely thank Mrs. Albin Panimalar Ramesh for her help in photography.

Ramasamy Santhanam

ABOUT THE AUTHOR

Dr. Ramasamy Santhanam is the former dean of Fisheries College and Research Institute, Tamilnadu Veteri nary and Animal Sciences University, India. His fields of specialization are aquatic biology and fisheries environment. He was the principal investigator for research schemes relating to freshwater nutritional life, viz., energy and nitrogen balance in the nutrition and growth of Indian major carps (Indian Council of Agricultural Research, New Delhi, India) and nutrient chemistry and proper utility of sewage (plan scheme of Tamilnadu Veterinary and Animal Sciences University). He served as an expert for the Environment Management Capacity Building, a World Bank–aided project of the Department of Ocean Development, India. He has been a member of the American Fisheries Society, United States; World Aquaculture Society, United States; Global Fisheries Ecosystem Management Network (GFEMN), United States; and the International Union for Conservation of Nature's (IUCN) Commission on Ecosystem Management, Switzerland. To his credit, Dr. Santhanam has 12 books on fisheries science and 70 research papers.

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INTRODUCTION

Freshwater habitats such as ponds, lakes, streams, rivers, bogs, swamps, and marshes are important components of the world. The diversity of organisms in these biotopes is important both ecologically and economically. Freshwater biomes are large communities of plants and animals centered around water with less than 1% salt concentration. Aquatic plants, such as algae, diatoms, and rooted macrophytes, use nutrients, light, and carbon dioxide to produce oxygen that, once released, is dissolved directly into the water. They also remove unwanted toxins found in the water, which could be harmful to the surrounding fish. The structure and composition of benthic communities in freshwater ecosystems is an excellent bioindicator of pollution and habitat quality.

PLANTS AND ANIMALS IN FRESHWATER BIOMES

There are many diverse flora and fauna in freshwater biomes. Algae, although not very pretty or fun to swim in, is a favorite snack for most of the animals that live in a freshwater biome. Plants are not just a snack for the freshwater animals. They provide oxygen through the process of photosynthesis. There is no shortage of animals or plants living in a freshwater biome. It is believed that more than 700 species of fish and 1200 species of amphibians, molluscs, and insects all live in these areas. There are plenty of macro animals that live in the water of the freshwater biome. They include crabs, shrimps, frogs, and turtles. Fish are very common in the freshwater biome. However, where there is freshwater, one can often find a huge number of different types of mammals.

MALNUTRITION, A GLOBAL PROBLEM

At present, more than 30% of humanity is suffering from malnutrition and food-related diseases, either in the form of malnutrition and undernourishment or in the form of excessive nutrient intake and obesity. The global reach of malnutrition and food insecurity is such that hunger is still the world's number one health risk, killing more people every year than acquired immunodeficiency syndrome (AIDS), malaria, and tuberculosis combined (Tacon et al., 2010; World Food Programme (WFP), 2012). The global magnitude and consequences of hunger and malnutrition are profound and long-lasting, with 925 million chronically undernourished people within the developing world and over 6.6 million child deaths every year

related to malnutrition. Further, more than 2 billion people in the world suffer from specific dietary micronutrient deficiencies, including iron, iodine, vitamin A, and zinc (WFP, 2012). In terms of per capita food supply, total aquatic animal food supply (live weight equivalent) has grown from 11.1 kg in 1970 to 18.6 kg in 2010, and per capita aquatic meat supply has grown from 8.7 kg in 1970 to 13.2 kg in 2010 (FAO/FAOSTAT, 2012).

IMPORTANCE OF FRESHWATER FISHERIES

Today, fishing remains the largest use of wildlife in the world. Ninety-four percent of all freshwater fisheries occur in developing countries, and freshwater fishes make up more than 6% of the world's annual animal protein supplies for humans (FAO, 2007). They provide food and a livelihood for millions of the world's poorest people, and also contribute to the overall economic well-being by means of export commodity trade, tourism, and recreation. Some people derive great aesthetic pleasure from recreational activities in freshwaters, such as fishing, swimming, kayaking, and canoeing. Recreation and tourism help the entire industry of skilled craftspeople.

IMPORTANCE OF FRESHWATER FISH

Freshwater fish make up an important portion of aquatic organisms that are used as human foodstuffs. In many regions of the world, freshwater fish are a significant source of animal protein. They also contain considerable quantities of valuable lipids as well as minerals and vitamins.

Protein Content

In the dry matter of muscle or flesh, protein is the main component. The protein content generally amounts to 15 to 20% of wet weight in the muscle. In lipid-rich fish species, the protein level is lower than in species with poor lipid content in their flesh. The amino acid composition of the protein in different freshwater fish species is more or less similar.

Lipid Content

Depending on species, size, and nutrition, the lipid level of the flesh in freshwater fish can vary considerably. There are freshwater fish species like pike (*Esox lucius*), perch (*Perca fluviatilis*), and pike-perch (*Sander lucioperca*) with exceptionally lean meat, while other species are characterized by medium or even high lipid levels in their muscle, e.g., eel (*Anguilla anguilla*). Lipid content varies between less than 5% and more than 50% in the dry matter of muscle. With growing fish size, the lipid level in the muscle generally increases. The lipid content of large rainbow trout (*Oncorhynchus mykiss*) weighing more than 1000 g frequently is about 10% of wet weight.

Lipid Quality

Lipids of freshwater fish are characterized by high levels of n-3 polyunsaturated fatty acids, e.g., eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). But they also contain considerable amounts of n-6 fatty acids, especially linoleic acid and arachidonic acid. While the essential fatty acid ratio (n-3/n-6) of marine fish generally varies between 5 and 10, the essential fatty acid ratio of freshwater fish is 1 to 4. This seems appropriate for human nutrition. Because of their favorable fatty acid composition, the lipids of freshwater fish are of outstanding nutritional significance. It is well known that not only the n-6 fatty acids are essential for human nutrition, but the n-3 fatty acids are just as necessary and must also be supplied in the diet. Both series of essential fatty acids cannot be synthesized by other animals or humans. Clinical tests with hypertensive patients in many countries proved the effectiveness of eating freshwater fish in lowering blood pressure and plasma lipids. Hypertensive patients were put on a 2-week diet of 100 g silver carp meat (*Hypophthalmichthys molitrix*) per day. This resulted in a significant drop in systolic blood pressure by 15 mmHg and diastolic pressure by 9 mmHg. In blood plasma, the level of triacylglycerols was reduced by 0.6 mmol/L, the HDL cholesterol increased by 0.26 mmol/L, and the phospholipid concentration remained constant.

Mineral and Vitamin Content

Freshwater fish are also a good source for several minerals and vitamins in human nutrition. Their meat is rich in potassium, phosphorus, sodium, magnesium, and calcium. The flesh of freshwater fish also contains some trace elements, e.g., iron and anganese. Freshwater fish can also meet the demand for several vitamins, such as vitamin A and some B vitamins.

FRESHWATER FISH IN HUMAN NUTRITION

Freshwater fish are a nutritious choice for lunch or dinner, as they are low in fat and high in protein. It has been reported that the average freshwater fish consumption is 56.6 kg/person/year, and one serving of most freshwater fish provides more than 30% of the dietary reference intake of protein for adults. Freshwater fishes form the major and often only source of animal protein for low-income families. Although not as high in healthy omega-3 fatty acids as some saltwater fish, one serving of most freshwater fish provides more than 30% of the dietary reference intake of protein for adults.

Freshwater fish are therefore considered to be wholesome foodstuffs of high nutritive value. As freshwater fish flesh has good digestibility, it is also well suited as a healthy diet for children and seniors (Steffens, 2006).

FRESHWATER CRUSTACEANS

Among freshwater crustaceans, crayfish assume greater importance, as they have a super healthy combination of nutrients. From an almost pure form of protein to a healthy amount of omega-3 fatty acids, they are the most beneficial fats to eat for human nutrition. Crayfish protein has large amounts of the amino acid tyrosine that mentally energizes the brain. In addition, there is a healthy supply of vitamins D and A, as well as calcium, potassium, copper, and zinc in crayfish. Iodine is also often mentioned as an important ingredient. Further, crayfish are a very low carbohydrate food, and you can safely eat crayfish without putting on unwanted weight. Next to crayfish, freshwater crabs are important, as their meat is nutritionally good, being high in vitamins, high-quality proteins, and amino acids. It is also rich in minerals such as calcium, copper, zinc, phosphorus, and iron, while having lower levels of fat and carbohydrates.

FRESHWATER MOLLUSCS

Freshwater bivalves, the class of molluscs that includes clams and mussels, are extremely rich in a unique combination of nutrients that promote men's health. These organisms are a superior source of low-calorie protein loaded with minerals such as potassium, phosphorus, manganese, iron, selenium, and zinc and vitamins such as B3, B12, C, and riboflavin. Three ounces of raw clams will cost you only 63 calories, but you get 11 g of protein, 66% of the daily recommended amount of iron, and 700% of the daily recommended amount of vitamin B12. Chinese medicine recommends clams for treating hemorrhoids. The importance of freshwater gastropods (snails) in mitigating the protein deficiency in poor countries, such as Bangladesh, cannot be overlooked.

FROGS

A number of species of frogs, including the bullfrog (*Rana catesbeiana*) and green frog (*Rana clamitans*), are nowadays harvested from the wild, and their legs are sold as a luxury food in expensive restaurants of several countries.

A summary of compositional data of nutritional facts of major freshwater faunal groups is given below.

Nutritional Status of Major Freshwater Groups (per 100 g (Fresh Weight Basis))

	Protein (g)		Fat (g)		Ca (mg)		Fe (mg)		Vitamin A (µg)	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Fish	9.7	22.7	0.8	8	17	1751	0.6	9.2	5	1800
Crustacean	10.7	21.2	0.9	3.3	75	5000	0.6	7.5	0	133
Mollusc	7	20.2	0.3	1.4	16	2500	7	26.6	0	243
Frogs	15.1	20.5	0.2	2	19	1293	0.7	3.8	Low	

Source: Data from James (2006); Nurhasan (2008).

MICROALGAE

Algae have been used as a food source and for treatment of various ailments for over 2000 years. They form numerous compounds that are presently used in the development of new nutraceuticals and have the potential to become more intensively exploited. Different types of algae, specifically microalgae, are more prevalent in food supplements and nutraceuticals due to their capability of producing necessary vitamins, including A (retinol), B1 (thiamine), B2 (riboflavin), B3 (niacin), B6 (pyridoxine), B9 (folic acid), B12 (cobalamin), C (L-ascorbic acid), D, E (tocopherol), and H (biotin). Also, these organisms concentrate essential elements, including potassium, zinc, iodine, selenium, iron, manganese, copper, phosphorus, sodium, nitrogen, magnesium, cobalt, molybdenum, sulfur, and calcium. Algae are also high producers of essential amino acids and omega 6 (arachidonic acid) and omega 3 (docosahexaenoic acid, eicosapentaenoic acid) fatty acids. Due to their abundant production of beneficial compounds and nutritive contents, the market for increased algae production for nutraceuticals is lucrative and imminent.

AQUATIC PLANTS

Some aquatic plants have a long tradition as human food. *Oryza sativa* is an emergent aquatic plant and the only vascular hydrophyte that is a major agronomic species. It is one of the world's main crops and forms the staple diet of over half the world's population. A small but important number of other aquatic crops exist, such as water chestnut (*Trapa* spp.), lotus (*Nelumbo nucifera*), and watercress (*Nasturtium officinale*). *Ipomoea aquatica* is one of the few aquatics grown as a green vegetable.

Aquatic macrophytes present organs that, due to their accumulated food reserves, are of potential nutritional value to man: among them, seeds, fruits, and swollen vegetative perennating organs are the most important. A variety of fruits and seeds are rich in oil, starch, or protein and can be eaten raw or dried and ground to flour, which can be baked with water or milk to give a kind of bread or cake. Numerous rhizomes and tubers are similarly rich in carbohydrates, especially starch, sugar, and mucilage, and are wholly edible when raw or cooked. The foliage of many macrophytes provides acceptable salad ingredients or cooked vegetable dishes. In the Amazon, Indians used to utilize water hyacinth ashes as salt, and in the Northeast region of Brazil, the leaves of several species of macrophytes are often used in salads due to their high nutritional value and good palatability. The rhizomes of many other macrophytes are also used in the production of cookies, cakes, and other products. In Brazil, one of the most used macrophytes with nutritional value to man is the watercress (*Nasturtium* sp.), and it is often used in fresh or cooked dishes (Thomaz et al., 2009).

In general, aquatic plants are somewhat low in lysine and methionine when compared to meat proteins. Phenylalanine is present in very small quantities in *Alternanthera philoxeroides* and *Sagittaria latifolia*. Otherwise, amino acid levels are similar to those for meat proteins and crop plant leaf

protein isolates. Hence, leaf protein from aquatic plants is of sufficiently high amino acid quality to be useful as a dietary supplement. As the nutritive value of aquatic plants often contains "as much or more crude protein, crude fat, and mineral matter, than many conventional forage crops," such plants could be used as food and temporarily help alleviate food shortages until lasting agricultural and social solutions are found (Boyd, 1968a, 1968b).

In order to alleviate the problems relating to malnutrition among the people of developing and underdeveloped countries, there is an urgent need to identify new species rich in nutrients. In this regard, assessment of the nutritional quality of freshwater flora and fauna of edible value would be of great use to add new and cheap sources of animal proteins. Further, by applying the knowledge of nutritional status, one can select the needed species to harvest. This may help conserve the freshwater ecosystems and their biodiversity, which is presently an urgent need (Virginia Tech, 2009). In the present report, an attempt has been made to present detailed information on the nutritional facts of different groups of freshwater life. All table information relates to mean values of fresh weight (FW) (wet weight (WW)) or dry matter (DM) (dry weight (DW)) adult specimens.

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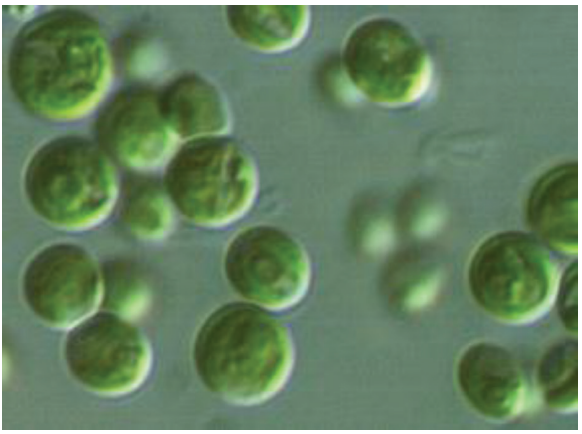
ALGAE AND PLANTS

ALGAE

Phylum: Chlorophyta (Green Algae)

Chlorella vulgaris (Beyerinck) Beijerinck 1890



Phylum: Chlorophyta

Class: Trebouxiophyceae

Order: Chlorellales

Family: Chlorellaceae

Common name: Chlorella.

Distribution: Atlantic islands, North America, South America, Southwest Asia, Southeast Asia, Australia and New Zealand, Europe (AlgaeBase).

Habitat: Freshwater and terrestrial habitats.

Description: This species is small, unicellular, and nonmotile, about 2–15 µm in diameter. Cells are spherical or ellipsoidal with a single, parietal, cup-shaped (sometimes plate-like) chloroplast with or without a pyrenoid. Cell wall is generally thin and smooth. Cells contain green photosynthetic pigments, viz., chlorophyll *a* and *b* in the chloroplast. It is an attractive potential food source because it is high in protein and other essential nutrients. It is also a popular dietary supplement (van Vuuren et al., 2006).

Nutritional Facts

Proximate Composition (g/100 g DM)

Moisture	Ash	Protein	Lipid	CHO[a]	Fiber
9.95	6.87	48.19	5.60	29.85	17.06

[a] Carbohydrate.

Minerals (mg/100 g)

Ca	Mg	Zn	Na	K	Cu	Fe
1425	851	293	101	1197	48	82

Vitamins

Retinol (µg/g)	C (mg/g)	E (mg/g)
132.15	0.39	27.87

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

Amino Acids (g/16 gN)

Isoleucine	3.8
Leucine	8.8
Valine	5.5
Lysine	8.4
Phenylalanine	5.0
Tyrosine	3.4
Methionine	2.2
Cysteine	1.4
Tryptophan	2.1
Threonine	4.8
Alanine	7.9
Arginine	6.4
Aspartic acid	9.0
Glutamic acid	11.6
Glycine	5.8
Histidine	2.0
Proline	4.8
Serine	4.1

Fatty Acids (% of Total Lipids)

12:0	0
14:0	0.9
14:1	2.0
15:0	1.6
16:0	20.4
16:1	5.8
16:2	1.7
17:0	2.5
18:0	15.3
18:1	6.6
18:2	1.5
20:2	1.5
20:3	20.8

Source: Data from Becker (1994).

Chlorella pyrenoidosa H. Chick 1903

Order: Chlorellales

Family: Chlorellaceae

Common name: Chlorella.

Distribution: Worldwide; Europe, Asia, Australia and New Zealand (AlgaeBase).

Habitat: Freshwater bodies.

Description: This species is small, unicellular, and nonmotile, about 2–15 µm in diameter. Cells are spherical or ellipsoidal with a single, parietal, cup-shaped (sometimes plate-like) chloroplast with or without a pyrenoid. Cell wall is generally thin and smooth. Cells contain green photosynthetic pigments, viz., chlorophyll *a* and *b* in the chloroplast. Over 24 vitamins and minerals (plus vital trace elements) and 19 amino acids (including all 8 essential ones) are available in this species. Further, highly digestible, complete protein and essential fatty acids—omega-3, omega-6, and gamma-linolenic acid (GLA)—are also present. Hence, this species is considered a popular food supplement (van Vuuren et al., 2006).

Nutritional Facts

Proximate Composition (% DM)

Protein	CHO[a]	Lipids
57	26	2

[a] Carbohydrate.

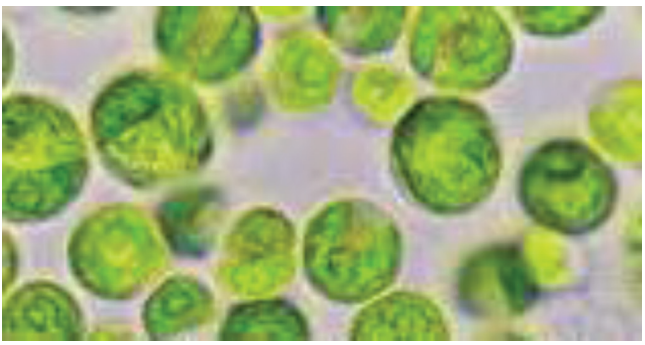
Source: Data from Becker (1994).

Amino Acids (g/16gN)

Isoleucine	3.4
Leucine	4.0
Valine	5.1
Lysine	7.9
Phenylalanine	4.5
Tyrosine	2.7
Methionine	1.8
Cysteine	0
Tryptophan	1.4
Threonine	3.2
Alanine	5.9
Arginine	5.6
Aspartic acid	5.9
Glutamic acid	9.3
Glycine	4.8
Histidine	1.4
Proline	4.0
Serine	2.2

Source: Data from Becker (1994).

Chlorella ellipsoidea Gernceck 1907



Order: Chlorellales

Family: Chlorellaceae

Common name: Chlorella.

Distribution: Europe, Southwest Asia, Caribbean islands, Australia and New Zealand (AlgaeBase).

Habitat: Freshwater and terrestrial areas.

Description: Cells of this species are 1.5–13 µm wide and 2–15 µm long. Chloroplast is more lobed with age. Margins are irregularly undulate and occasionally incised. Pyrenoid is associated with numerous starch grains. Autospores are ellipsoidal. This species serves as a food supplement (van Vuuren et al., 2006).

Nutritional Facts

Proximate Composition (% DM)

Protein	Fiber	Ash	Moisture
22.39–39.91	3.66–5.19	10.10–11.11	8.15–9.45

Source: Data from Mondal et al. (2005).

Amino Acids (g/16 gN)

Isoleucine	4.5
Leucine	9.3
Valine	7.9
Lysine	5.9
Phenylalanine	4.2
Tyrosine	1.7
Methionine	0.6
Cysteine	0.7
Threonine	4.9
Alanine	12.2
Arginine	5.8
Aspartic acid	8.8
Glutamic acid	10.5
Glycine	10.4
Histidine	1.7
Proline	5.0
Serine	5.2

Source: Data from Becker (1994).

Prasiola japonica Yatabe 1891

Order: Prasiolales

Family: Prasiolaceae

Common name: River nori.

Distribution: Asia: China, Japan (AlgaeBase).

Habitat: Freshwater habitat, river streams.