

Chapter - 7
**Novel Protein Foods: Alternative Sources of Protein for
Human Consumption**

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Abstract

Proteins are a major macronutrient of the human diet needed for survival. Its crucial function in nourishment is to provide sufficient amounts of amino acids to the body as these amino acids work as anaplerotic substrates in the building block of the body. As the growth of population increases continuously, the demand for protein also increases over the next decades, and it is very important to search alternative sources of protein for human consumption. The present food industrialists aim to develop a cheaper, protein rich that have almost essential amino acids with highest bioavailability and more convenient food products. Single cell protein from algae and fungi, leaf protein extract and many insects could be an alternative of protein, because they have almost all the essential amino acids required for the human body for the survival.

Introduction

Proteins are a vital nutrient element of the human diet needed for survival. Its crucial function in nourishment is to provide sufficient amounts of amino acids to the body as these amino acids work as the building block of the body. The quality of protein also known as the nutritive value of the product, which is mainly, depends on its amino acid content and its physiological application after digestion, absorption. Metabolism of amino acids is determined by the number of amino acids used in protein synthesis. Accessibility of amino acids varies with the protein source, processing methods, and interaction with other components of the food like fat, minerals etc.

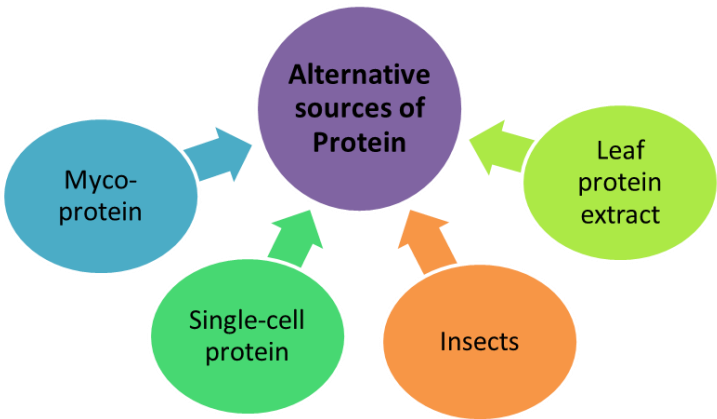
As the growth of population increases continuously, the demand for protein also increases over the next decades, and it is very important to search alternative sources of protein for human consumption. Proteins that are not currently used as animal feed, and proteins that are currently used as

animal feed modified and improved for human consumption. The problem of obtaining sufficient protein is further compounded because the mean daily protein requirement for consumers also increased. Major conventional sources of protein in the diet in developing and developed countries are cereals, meat, Pulses, milk and dairy, fish, seafood, oil crops, vegetables, starchy roots, eggs, offals, fruit; but they will not be sufficient enough in next decades. So it's very important to search the alternative sources of good quality of protein for human consumption.

Some novel protein sources like insects, algae, duckweed, microbial protein, my coprotein, leaf protein, and rapeseed are expected to enter in food market as replacers for animal-derived proteins. A wide variety of vegetarian alternatives is also available on the market like seitan, tofu, soy meat, tempeh, Quorn and meatless based on lupins, canola. However, food safety aspects of these alternative sources of protein are not well-known.

The aspire of this article is to review the state of the art on the safety of major novel protein sources for food production, in particular insects, rapeseed, duckweed, microalgae, and seaweed.

Various Sources of Protein are as Follows



1. Mycoprotein

Mycoprotein is a form of single-cell protein, also known as fungal protein. Fungi have been influencing human affairs for thousands of years, whether as a direct food source, as a medicine, or in a food. Fungi have provided food for man, primarily in the form of fruit bodies of basidiomycetes and/or ascomycetes. The process of bringing mycoprotein into the marketplace began in 1985. The nutritional value of mycoprotein, is found to be comparable with eggs in amino acid composition, but contained no cholesterol and had a substantial fiber content. Mushrooms are one of the most common fungi which can be used as the source of protein as they have the high protein content, usually around 20-30% by dry weight.

Table 1: Protein content of mushrooms (Kalac, 2009)

S. No	Species of Mushrooms	Protein Content (%)
1.	Button Mushrooms	56.3
2.	Porcini Mushrooms	26.5
3.	Portobello Mushrooms	25
4.	Enoki Mushrooms	22
5.	Oyster Mushrooms	19
6.	<i>Hericium erinaceus</i>	22
7.	Shiitake Mushrooms	28
9.	<i>Morchella esculenta</i> ,	32.7

Another fungus *Fusarium venenatum* strain PTA-2684 also used as protein source. It has 42% protein. Quorn'M is a meat substitute product originating in the UK, which is composed of *Fusarium* with mixed with egg albumen and vegan is the product of dried fungus with potato protein where egg albumen and potato work as binding agents. The PDCAAS for mycoprotein is 0.99, better than beef at 0.92.



Fig 1: Mushroom varieties

The essential amino acid of mycoprotein and other foods are given below in table 2.

Table 2: Essential Amino Acid Content of mycoprotein and other protein foods (g amino acids per 100g)

Essential Amino Acids	Mycoprotein	Cow's Milk	Egg	Beef	Soy Isolate	Peanuts	Wheat
Histidine	0.35	0.09	0.30	0.66	0.6	0.65	0.32
Isoleucine	0.52	0.20	0.68	0.87	1.1	0.91	0.53
Leucine	0.86	0.32	1.10	1.53	1.8	1.67	0.93
Lysine	0.83	0.26	0.90	1.60	1.4	0.92	0.30
Methionine	0.21	0.08	0.39	0.50	0.3	0.32	0.22
Phenylalanine	0.49	0.16	0.66	0.76	1.1	1.30	0.68
Tryptophan	0.16	0.05	0.16	0.22	0.3	0.25	0.18
Threonine	0.55	0.15	0.60	0.84	0.8	0.88	0.37
Valine	0.62	0.22	0.76	0.94	1.1	1.08	0.59

2. Single Cell Protein

The shortage of protein-rich food and global survival of millions of people have forced researchers to look for alternative sources of protein that can replace traditional and other expensive sources like soymeal or fishmeal. Therefore, the center of attention has shifted towards microbes as food sources for consumption as single cell protein (SCP). The term ‘single cell protein’ was given in 1968 at the Massachusetts Institute of Technology by replacing microbial protein and petroprotein (Mateles and Tannenbaum, 1968; Tannenbaum and Wang, 1975). Currently, SCP is being produced from many species of microorganisms like algae, fungi, and bacteria. It is suitable to use fungi and bacteria for the production of SCP when grown on economical waste products. Their quick growth and high protein content have made them the major sources of SCP.

2.1 Sources

Algae, fungi, and bacteria are the main sources of SCP. They are as follows-

Algae as the Source of SCP: *Caulerpa racemosa*, *Chlorella salina* CU-1(28), *Chlorella* spp., *Chlorella* spp. (M109, M121, M122, M138, M150), *Dunaliella* *Laminaria*, *Sargassum*, *Spirulina maxima*, *Spirulina* spp., *Gracilaria changgi* (Fig 2).

Algae also contain 40–60% protein, 7% mineral salts, chlorophyll, bile pigments, and fiber.

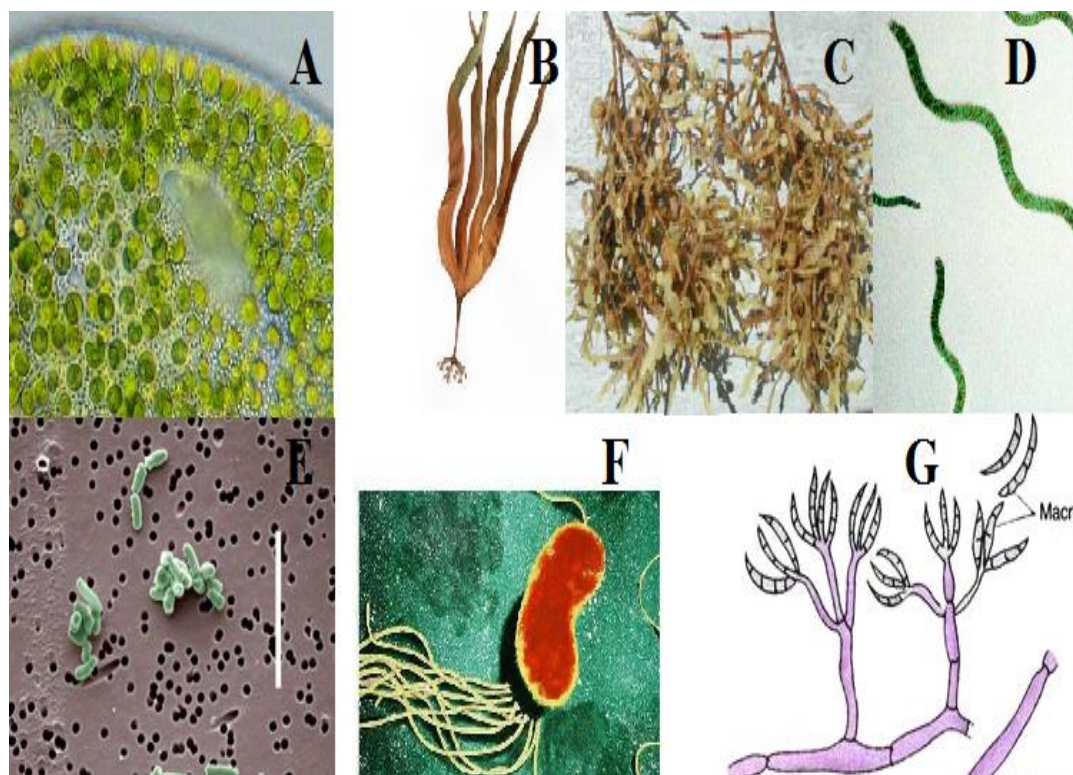


Fig 2: A. *Chlorella*; B. *Laminaria*; C. *Sargassum*; D. *Spirulina*; E. *Brevibacterium*; F. *Pseudomonas fluorescens*; G. *Fusarium*.

Fungi as Source of SCP: *Aspergillus niger*, *Sporotrichum pulverulentum*, *Candida krusei* SO1& *Saccharomyces spp.*, *Candida tropicalis* ceppo, *Chrysonilia sitophila*, *Fusarium graminearum*, *Paecilomyces variolii*, *Penicillium cyclopium*, *Penicillium roqueforti*, *Penicillium camemberti*, *Pichia pastoris*, *Saccharomyces cereviceae*, *Schwanniomyces occidentalis*, *Scytalidium acidophilum*, *Trichoderma reesei*, *Kluyveromyces marxianus*, White rot, Yeast.

Bacteria as the Source of SCP: *Brevibacterium spp.*, *Cellulomonas spp.*, *Methanomonas methanica*, *Methylophilus methanotrophus*, *Pseudomonas fluorescens*, *Rhodopseudomonas gelatinosus*, *Streptomyces spp.*

Bacterial SCP has high protein content and certain essential amino acids. The crude protein content is around 80% of the total dry weight. The essential amino acid compositions of different *Lactobacillus* bacteria are comparable to the FAO reference protein and SCP from other sources.

Although algae are very nutritious there are some limitations which are somewhat unfit for human consumption. The most important is the algal cell wall which cannot be digested by humans because of lack of the cellulase enzyme. To overcome this problem algal wall must be digested before the

final product is eaten. The fungus produces many allergic reactions, diseases, and liver cancer in humans as they have mycotoxins in certain fungal species especially *Aspergillus parasiticus* and *A. flavus*. Hence, it is a requirement that mycotoxins are eliminated before fungal SCP is consumed.

Table 3: Comparison of SCP production from algae, fungi, and bacteria (Singh, 1998.)

Parameter	Algae	Bacteria	Fungi (Yeast)	Fungi (Filamentous)
Growth rate	Low	Highest	Quite high	Lower than bacteria and yeast
Substrate	Light, carbon dioxide or inorganic sample	Wide range	Wide range except carbon dioxide	Mostly Lignocellulosics
pH range	Up to 11	5–7	5–7	3–8
Cultivation	Ponds, Bioreactors	Bioreactors	Bioreactors	Bioreactors
Contamination risks	High and serious	Precautions needed	Low	Least if pH is less than 5
S-containing amino acids	Low	Deficient	Deficient	Low
Nucleic acid removal	–	Required	Required	Required
Toxin	–	Endotoxins from gram-negative bacteria	–	Mycotoxins in many Species

The chemical composition of any SCP product must be characterized clearly in terms of percentage protein, type of amino acids, nucleic acid, lipids, fats, toxins, and vitamins.

3. Leaf Protein Extract

Now a day’s researcher processed study to extract protein from various fresh leaves of plants. The protein content of the dried product from the sources is about 50-70%. The major problem face during leaf protein production its keeping quality, shelf life, acceptability, and taste. the concentrated form of the proteins extracted from the leaves of plants known as Leaf protein concentrate (LPC). Leaf protein concentrate (LPC) are very nutritious food made by separating mechanically indigestible fiber and soluble anti-nutrients from much of the protein, vitamins, and minerals in certain fresh green plant leaves. They are rich in β-carotene, iron, and high-quality protein so it will be very effective in fighting malnutrition. The amino acid profile of leaf protein concentrate indicates that it is nutritionally superior to most cereal and legume seed proteins; it can also compare positively with animal proteins except egg and milk.

Protein content of LPC was found to be higher in the leaves in *Achyranthes aspera* (19.9%), *Aerva javanica* (31.9%), *Pulicaria angustifolia* (21.2%), *Sesbania sesban* (15.2%), *Solanum nigrum* (24.6%), *Tephrosia purpurea* (32.3%), *Withania somnifera* (22.9%). LPCs are also rich in polyphenols. Ribulose-1, 5-bisphosphate carboxylase oxygenase, is an enzyme generally known as RuBisCO. It catalyzes the first major step of carbon fixation, for the production of glucose with atmospheric carbon dioxide, water, and sunlight. RuBisCO can make up to 50% of the total amount of the protein fraction of green plants. It is found inside the mobile phase of the chloroplast.

4. Insects

Edible insects contain high-quality protein, vitamins and amino acids for humans. Insects, a traditional food in many parts of the world, are highly nutritious and especially rich in proteins and thus represent a potential food and protein source. Insects, a traditional food in many parts of the world, are highly nutritious and especially rich in proteins and these represent a potential food and protein source. The ethnic people of India also consume insects as food, eating insects known as entomophagy. Figure 3 shows various insects which can be used as the source of protein and their protein content in table 4.

In this context, edible insects are an important and promising food resource to be developed in the near future. Indeed, even though insects are considered a nonconventional food and often a low-prestige food by occidental cultures, they form an integral part of the daily diet of many ethnic groups in the world. Insects are eaten in their different developmental stages, including eggs, larvae and pupae, and even the adults. However, most insects are eaten in immature stages when the exoskeleton is reduced and soft. Insects generally have a crunchy consistency, often enhanced by frying or roasting, so when they are ingested salivation and mastication occurs which produces a sensation of satisfaction. Insects are cooked, roasted, fried or boiled and they are generally eaten in combination with other food items. They can preserve and store during periods of abundance, when insect collection occurs, them for later consumption.



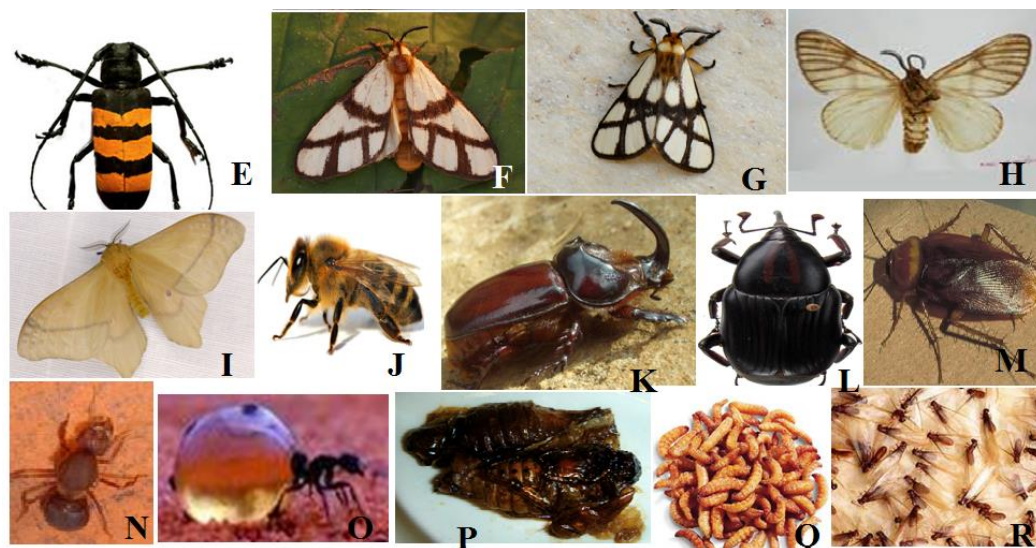


Fig 3: A. *Macrotermes bellicosus*; B. *Macrotermes notalensis*; C. *Brachytrypes spp.*; D. *Zonocerus variegates*; E. *Analeptes trifasciata*; F. *Anaphe infracta*; G. *Anaphe reticulata*; H. *Anaphe venata*; I. *Cirina forda*; J. *Apis mellifera*; K. *Oryctes boas*; L. *Rhynchophorus phoenicis*; M. *Blattodea*; N. Leafcutter ants; O. Honey pot ants; P. Dung Beetle; Q. Waxworm; R. Termites (Redford & Dorea 1984)

From total nitrogen content of insects, approximately 93% is unbound. The biological quality of insect protein is good, having chemical scores from amino acid profiles, compared to the WHO/FAO/UNU pattern, that range from 10% to 96%. The calcium, iron, and potassium contents are higher than those of most food products of vegetable and animal origin. Insects are also rich in vitamins of the B group such as niacin, riboflavin, and thiamin. Thus, insects have the potential to improve people's diet by significantly contributing to their protein intake and by reducing deficiencies of minerals and vitamins. Hemiptera (true bugs) being low in isoleucine, lysine, phenylalanine + tyrosine, and valine and the order Diptera (flies) being low in leucine and cysteine, in general, most edible insects satisfactorily provide the essential amino acids required for human nutrition according to the WHO. High amino acid values have been found for phenylalanine + tyrosine in some species, and some insects are rich in tryptophan, lysine, and threonine.

Table 4: Protein content of insects (Banjo *et al.*, 2006)

S. No.	Insects	Protein content (% dry basis)
1.	<i>Macrotermes bellicosus</i>	20.4
2.	<i>Macrotermes notalensis</i>	22.1
3.	<i>Brachytrypes spp.</i>	6.25
4.	<i>Cytacanthacris aeruginosus</i>	12.1

	<i>unicolor</i>	
5.	<i>Zonocerus variegates</i>	26.8
6.	<i>Analeptes trifasciata</i>	29.62
7.	<i>Anaphe infracta</i>	20.0
8.	<i>Anaphe reticulata</i>	23.0
9.	<i>Anaphe venata</i>	25.7
10.	<i>Cirina forda</i>	20.2
11.	<i>Apis mellifera</i>	21.0
12.	<i>Oryctes boas</i>	26.0
13.	<i>Rhynchophorus phoenicis</i>	28.42
14.	Cockroaches (<i>Blattodea</i>)	57.30
15.	Beetles (<i>Coleoptera</i>)	40.69
16.	Flies (<i>Diptera</i>)	49.48
17.	Beetles (<i>Hemiptera</i>)	48.33
18.	Bees, wasps, ants (<i>Hymenoptera</i>)	46.47
19.	Termites (<i>Isoptera</i>)	35.34
20.	Caterpillars (<i>Lepidoptera</i>)	45.38
21.	Dragonflies (<i>Odonata</i>)	55.23
22.	Grashoppers, locusts, crickets (<i>Orthoptera</i>)	61.32

This review showed that several insects which are known as pests also having high nutritional qualities. All the non-toxic insects are indeed a good source of protein and other nutrients for human consumption, therefore, should be encouraged. Insects are already being used traditionally in the diet in the different culture. They can be reared for larger production, therefore; their nutritional value can be utilized in various products and could be industrialized.

Conclusion

There are various non-general sources of protein and other nutrients which are being used by the certain group of culture and community like fungi, algae, leaf protein extract and the large variety of insects. These are providing the high quality of proteins and supplements (minerals and vitamins) even when dried. Therefore it could be the best area for the production of proteins and minerals that could be incorporated into various products to make it more nutritious. So, this is recommended to explore these areas for the better results and make it possible reduce the malnutrition

among the consumers. The major problem for the use of these as food include legal restrictions and it is supposed to lack consumer acceptance can also a barrier. Both issues could be defeat with the help of scientific exploration on beneficial properties and also on safety risks as well as the development of effective safety measures. Production of high-quality non general protein source based food products also requires studies on the impact of farming conditions and processing methods on nutritional quality and functional properties.

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