7

Economic Aspects

7.1 ALGAE: BENEFICIAL AND DETRIMENTAL

Although the use of algae as food is very old, as even mentioned "in the poetic literature of the Chinese, about 600 B.C." (Prescott, 1969), they are still considered less economically important than fungi and bacteria. Phycologists in different parts of the world, besides investigating morphological, cytological, physiological and other details of algae, are also exploring continuously the beneficial aspects of these tiny, adventurous and wonderful plants of the beautiful nature. Their uses in various aspects (production of agar, carrageenin, alginic acid, antibiotics, funori, many minerals; as human food; as fodder, in sewage disposal; in water purification; and also in biological research, etc.) provide a brief idea of their utility for the mankind. But this does not mean that they are only beneficial. In some aspects they are detrimental too. Some of their major beneficial and harmful aspects are discussed briefly.

7.2 BENEFICIAL ASPECTS

7.2.1 As Primary Source of Food and Energy[1]

The most important use of algae is that they are the "primary producers of organic matter in aquatic environment because of their photosynthetic activity" (Bold and Wynne, 1978). Animal life in aquatic environment mainly depends on algae because they form the primary source of energy and food for them. In aquatic ecosystems the algae constitute the main part of the food chain. Because of their photosynthetic activity they continuously oxygenate (give out oxygen) their surrounding aquatic environment, which is beneficial directly to the other aquatic organisms.

7.2.2 Algae as Food[2]

More than 100 species, mostly of Phaeophyceae and Rhodophyceae, are used as food by man in different parts of the world. A few species of Chlorophyceae are also used as human food because of the presence of minerals, vitamins, carbohydrates and proteins, either in their cell wall or in their cytoplasm. Some of the important genera with their uses are mentioned below.

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[1]The detailed information on this aspect may be gathered from the contributions of Trench (1971) and Aaronson (1973).

[2]For detailed study of the uses of the algae as food and other ways see Tilden (1935), Boney (1965), Dawson (1966), Dixon (1973) and Johnston (1965,1966, 1970, 1976)

1. Among *Phaeophyceae*. some of the genera used as human food are *Alaria, Laminaria, Sargassum, Durvillea* and *Pelvetia*. In Japan, the food prepared from *Laminaria* is called *kombu*, and the food from *Alaria* is called *sarumen*. In South America, *Durvillea* is collected, dried, salted and sold as *Cachiyago*.

According to Prescott (1969), the contents of food value of brown algae include 6.15% protein (with 17 amino acids), 1.56% fat and 57.04% carbohydrates. Many minerals along with carotene, thiamin and subflavin are also found in brown algae.

2. Among *Rhodophyceae* the important genera used as food are *Porphyra, Palmaria, Chondrus, Gigartina* and *Rhodymenia*.

(a) *Porphyra* is most important red alga used as human food. It is variously "called *nori* in Japan, *laver* in England and United States, *sloke* in Scottland, and *luche* in Southern Chile" (Bold and Wynne, 1978). *Porphyra* preparations are very rich in vitamins B and C. In Japan alone, 29.5 million kg of *Porphyra* per year is used.

(b) *Palmaria* is also eaten under different trade names in different countries, such as 'dulse' in Canada, 'sol' in Iceland and 'dillisk' in Ireland.

(c) *Chondrus crispus* is commonly called 'Irish moss' and used in ice-creams and various other foods.

(d) *Gigartina stellata* is used for the production of mucilage, which contains galactose sulphuric acid.

(e) *Rhodymenia palmata* is used as a common food 'dulse' by fishermen.

(f) Glycerol, sorbitol and dulcitol are some of the carbohydrates found in red algae.

(g) Floridean starch, produced from Rhodophyceae, is a glucose.

3. Among *Chlorophyceae*, the important algae used as food are *Monostroma, Ulva, Codium* and *Chlorella*.

(a) *Monostroma* is used as a common food "aonori" in Japan.

(b) *Ulva* is dried, salted and sold as 'cachiyugo' similar to *Durvillea*. It is also used as salad.

(c) *Codium* is used as salad in Japan and many other countries.

(d) *Chlorella* is well known for its high percentage of lipids and proteins. "As much as 8.5% dry weight may be lipid content" (Prescott, 1969). The *Chlorella* protein has all essential amino acids, and therefore it is used as a food in space-flights. Although *Chlorella* can be a good substitute for food in crisis, its culture is very expensive. According to Thacker and Babcock (1957), production of *Chlorella* is not economic. As it has an antibiotic, chlorellin, its use as a food is also discouraged.

4. Among the blue-green algae, *Nostoc commune* is used as a food called 'yuyucho' in China, Java, etc.

5. Diatoms are also used as food in some parts of the world.

7.2.3 Agar-Agar

It is a jelly-like substance, obtained from some genera of Rhodophyceae. It is universally used as a base for different culture media in laboratories for culturing many fungi, bacteria and some algae. It is often called simply "agar". Important agar-producing genera in different parts of the world are *Gelidium, Gracilaria, Ahnfeltia, Hypnea, Campylaephora, Pterocladia, Eucheuma, Gigartina, Chondrus* and *Phyllophora* (Prescott 1969, Round 1973).

The universal use of agar-agar in culture media is mainly because it contains galactose and a sulphate, melts between 90-100 °C and becomes solid at low temperatures.

It is also used in packing canned foods, in treatment of constipation, and in cosmetic, leather and textile and paper industries. It is also often given as a laxative.

Dried agar-agar is used for prolapsed stomach by the physicians. Many pills and ointments are also prepared by using agar-agar.

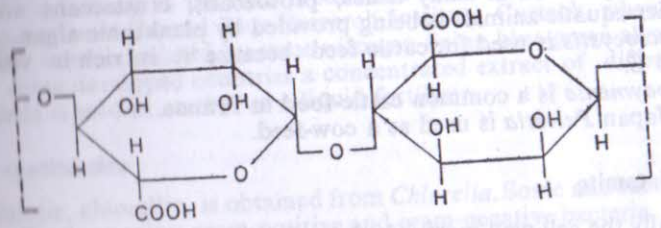
7.2.4 Carrageenin

It is a complex of D-galactose-3, 6-anhydro-D-galactose and monoesteric sulphuric acid found in the cell wall of a red alga, *Chondrus crispus*. It is used in the preparation of tooth-pastes, cosmetics, paints, and in leather finishing, textile, brewing and pharmaceutical industries. Physicians also use carrageenin as a blood coagulant. It is also used as a clearing agent in juices, liquors, beet sugar, etc. Rarely, *Gigartina* is also used for the extraction of carrageenin.

7.2.5 Alginates

Alginate derivatives and alginic acid are extracted from the cell wall of some brown algae. Different genera are used in different parts of the world, the important among which are *Laminaria, Macrocystis, Durvillea, Ascophyllum, Ecklonia, Lossonia, Fucus, Cystoseira, Eisenia*, etc.

Algin, with a formula of $(C_6H_8O_6)_n$, is a carbohydrate originating in the cell wall. Alginic acid (Fig. 7.1) occurs in the middle lamella and primary walls of some members of Phaeophyceae.



ALGINIC ACID

Fig. 7.1 Chemical Structure of alginic acid.

Alginates are used in rubber tyre-industry, paints, ice-creams and also in the preparation of flame-proof fabrics and plastic articles. For stopping the bleeding effectively, alginic acid is used. Alginic acid derivatives are also used in the preparation of soups, creams, sauces, etc.

7.2.6 Funori

It is a type of glue obtained from a red alga, *Gloiopeltis furcata*. In Japan it is called 'funori'. It is used as an adhesive as well as a sizing agent for paper and cloth. Chemically it is similar to agar-agar except that there is no sulphate ester group. Some species of *Ahnfeldtia, Chondrus, Grateloupia* and *Iridaea* are also used for the preparation of funori (Round, 1973).

7.2.7 As a Source of Minerals

1. For manufacturing soap and glassware, 'kelp' has been used as a source of soda.
2. Potash and iodine are still extracted from 'kelps', which are the members of Laminariales of Phaeophyceae.
3. Bromine (3-6%) is extracted from some red algae such as *Polysiphonia*, *Rhodymenia*, etc.
4. On being carefully processed, ammonia and charcoal are prepared from kelps.
5. Some seaweeds are a rich source of iron, zinc, copper, manganese, boron, copper, etc.

7.2.8 As Fodder

Algae constitute a source of "permanent food" for many animals, specially in coastal countries. These include mainly the members of Phaeophyceae, Rhodophyceae and some green algae.

1. *Laminaria*, *Sargassum*, *Fucus* and *Ascophyllum* are used as fodder in many areas of the UK and Japan.
2. Hens which feed on *Ascophyllum*-meal and *Fucus*-meal produce eggs with increased iodine content.
3. Seaweed-meals also increase the butter-fat content of the milk in feeding cattles.
4. A fish named *Tilapia* uses only the members of Cyanophyceae and Chlorophyceae as its food.
5. Many fishes depend for their food only on diatoms.
6. Stock-feed and commercial feed are regularly processed for many cattles, specially sheep, from species of *Laminaria*, *Ascophyllum* and *Fucus*.
7. The major food of many fishes, protozoans, crustaceans and many other aquatic animals is being provided by planktonic algae.
8. *Macrocystis* is used for cattle-feed because it is rich in vitamins A and E.
9. *Rhodymenia* is a common cattle-food in France.
10. In Japan *Pelvetia* is used as a cow-feed.

7.2.9 Diatomite

It is actually the cell-wall material of diatoms. The economic importance of diatoms and diatomite has been discussed in detail by Prescott (1969) and Round (1973). The siliceous deposits consisting of "sedimentary build up of diatom frustules" is called diatomaceous earth (Bold and Wynne, 1978). Actually, the diatomaceous earth is mounds of deposits of fossil frustules of diatoms.

The diatomaceous earth's mounds are white, firm, soft and light. Some known diatomaceous deposits are 91.2 m or more in height, more than 1.6 km in length and even more than 608 m deep. They can be cut in big blocks. The diatoms and diatomite may be used in many different ways, as specified below:

1. They form a permanent food of many aquatic animals along with some important fishes (Werff and Medded, 1984).
2. Cod-oil of the livers of many fishes was originally present in diatom cells, from where it passed through the continuous food chain (Prescott, 1969).

3. Diatomaceous earth is useful in: (i) industrial filtration processes, (ii) sugar refining and brewing industry, (iii) production of antibiotics as a filter, (iv) production of light-weight bricks which have a constant temperature in rooms, (v) car- and silver-polishing powders, (vi) manufacture of water-glass and (vii) preparation of bleaching powders, etc.
4. According to Round (1973), Alfred Nobel used "diatomite as an absorbent for nitroglycerin in the manufacture of dynamite."
5. Its powder is sprinkled on the floor and walls of coal mines to reduce the danger of secondary explosions.
6. Because of the presence of about 11% oil (by volume) in the diatom cells, some workers are even of the opinion that "world's oil supply is of diatom origin" (Prescott, 1969). Being oil-producers, diatoms, "form the food for many fat-producing organisms" (Werff and Medded, 1984).
7. It is also used as an adulterant in the flour by some unsocial elements.
8. According to Werff and Medded (1984) the "fossilized diatom shells are valuable indicators for oil and bitumen".

7.2.10 As Fertilizer[3]

Because of the presence of phosphorus, potassium and some trace elements, the seaweeds in many coastal regions of the world are used as fertilizer. They are either mixed with some other organic materials or are allowed to rot in the field as such.

1. Genera like *Lithophyllum*, *Lithothamnion* and *Chara* are used in the deficiency of calcium in the field.
2. *Fucus* is used as a common manure by Irish people.
3. *Abelmoschus esculentus* (*bhindi*) becomes more productive if seaweed manure is used (Thivy, 1960).
4. A 30% increase in the total production of rice grains was reported by algologists at Central Rice Research Institute, Cuttack, when the rice fields were inoculated by some nitrogen-fixing blue-green algae.
5. In some developed countries a concentrated extract of different seaweeds is sold in market as a liquid fertilizer.

7.2.11 Antibiotics

An antibiotic, chlorellin, is obtained from *Chlorella*. Some antibacterial substances, effective against gram-positive and gram-negative bacteria, were also recorded from *Ascophyllum nodosum*, *Rhodomela larix*, *Laminaria digitata* and some species of *Pelvetia* and *Polysiphonia*. An antibiotic, effective against some bacteria, has been prepared from a diatom *Nitzschia palea*. It is said to be specially effective against *Escherichia coli*.

7.2.12 Other Medicines

"Tse-ko-Tsoi", an antihelmitic drug, is prepared from a red alga *Digenia simplex* in South China.

Fucoidin and sodium laminarin sulphate, obtained from some brown algae, are used as anticoagulant of blood. Some algae are also used in the treatment of the diseases of kidney, urinary bladder and lungs.

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[3]For a detailed discussion of algae in relation to soil fertility, see Shields and Durrell (1964).

Relation between algae and medicine has been discussed by Schwimmer and Schwimmer (1964).

7.2.13 In Biological Research

In many physiological researches, specially in the investigation of photosynthesis, the cultures of *Chlorella*, *Scenedesmus*, *Anacystis*, etc. are widely used.

7.2.14 In Sewage Disposal

Sewage consists mainly of domestic and industrial wastes. It contains many organic and inorganic constituents in dissolved or suspended stage. The disposal of this sewage is mainly an aerobic process, and this oxygenation is facilitated mainly by some algae, e.g. *Chlamydomonas*, *Chlorella*, *Euglena*, *Scenedesmus*, etc. The aeration of sewage is essential, specially in smaller sewage bodies or ponds, to avoid unpleasant odour. Thus algae are helpful in sewage disposal also.

7.2.15 Algae and Land Reclamation

Land reclamation is effected mainly by algae. After rains, the members of Chlorophyceae and Cyanophyceae develop and check soil erosion on disturbed or burned soils. On the alkaline *usar* land of north India, extensive growth of blue-green algae was reported by Singh (1961). This increased the nitrogenous content and ultimately made the soil satisfactorily fertile.

7.3 NEGATIVE ASPECTS

7.3.1 Role in Water Supply

Algae grow luxuriently in water reservoirs meant for domestic water supplies. They produce bad tastes to the drinking water, and also interfere with the filtration process of the water. To check the development of the algal population in water reservoirs sometimes becomes a big problem. Common algae found in reservoirs of the water supply are diatoms such as *Asterionella*, *Cyclotella*, *Fragilaria*, *Melosira*, *Synedra*, etc.; green algae such as *Chlamydomonas*, *Volvox*, etc ; and Cyanophyceae such as *Nostoc*, *Anabaena*, *Microcystis* and *Oscillatoria*.

7.3.2 Death of Fishes and other Animals

Algae decay, and the decayed by-products are poisonous to fishes and some other animals. Some of the algae liberate poisonous toxins in the water, making the latter unsuitable for some of the inhabiting animals. *Microcystis aeruginosa* produces a toxin which is highly toxic to animals which ingest this alga (Hughes et al., 1958). Gorham (1964) and Loeblich and Loeblich (1975) worked on the algae which are toxic to animals. According to Stephens (1948), *Microcystis toxica* contains "one of the most potent and destructive liver poison known."

Deaths of fishes, shellfishes, some other aquatic animals and sometimes even human-being are known because of ingestion of dinoflagellates (species of *Gymnodinium*, *Gonyaulax* and *Pyrodinium*). Because of the dinoflagellates, "it has been estimated that in eight months one-half billion fish were killed in the Gulf of Mexico alone" (Prescott, 1969). Algae may also cause the death of fishes and other animals by suffocation.

Besides *Microcystis*, some other blue-green algae (*Anabaena*, *Gloeotrichia*, *Nodularia* and *Aphanizomenon*) may also bring about death to animals. Deaths of sheep, horses, cow and even some birds have also been recorded by drinking such infected waters. *Prymnesium parvum* is the most toxic alga of Israeli ponds.

7.3.3 Death of Human-beings

Sometimes the algae become the main cause of the death of human-beings. The endotoxin present in *Gonyaulax catanella* is harmless to the fishes which ingest it, but it accumulates and ultimately causes death of the persons who eat such fishes. Besides this, the water "infected" by *Microcystis* and *Anabaena* causes gastric trouble. Respiratory disorders are seen by drinking water having *Gymnodinium brevis*.

Lyngbya and *Chlorella* are responsible for some skin-infections (Moikeha and Chu, 1971). Some algae cause allergy in human-being (Bernstein and Safferman, 1970).

7.3.4 Algae and Water-blooms

Sometimes some microscopic or semi-microscopic algae grow so profusely that they form macroscopic and quite apparent bodies called water-bloom. Besides causing suffocation to the animals living in that area, water-blooms emit foul odour. They are also sometimes responsible for checking the speed of the ships as much as 50%. According to Harris and James (1974), they liberate some substances which are deleterious to the aquatic animals. Sometimes they deplete oxygen for the water animals at night because thick growth of algae form a barrier between water and outer atmosphere. Water-blooms are mainly formed by Cyanophyceae in freshwaters and Dinoflagellates in sea.

7.3.5 Parasitic Algae

Some algae are even parasites on other plants or animals (Chapter 1). Fan and Papenfuss (1959) reported four more red algal parasites occurring on Gelidiales. They are *Pterocladiophila hemisphaerica* on *Pterocladia lucida*, *Gelidiocolax mammilata* on *Pterocladia*, *G. suhriae* on *Suhria vittata* and *G. margaritoides* on *Beckerella pinnatifida*.

Yadava (1952) also reported some new hosts (*Mimusops hexandra* and *Psidium guajava*) of parasitic alga *Cephaleuros* from Bihar.

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