Modern Uses of Cultivated Algae

By Steve L. Morton

Algae are a "group of plants" that dominate the aquatic environment (Raymount, 1984). Organisms that make up the algae include representatives from three kingdoms and seven divisions: cyanochloranta and prochorophyta (from Kingdom Monera), pyrrhophyta, chrysophyta, phaeophyta, and rhodophyta (from Kingdom Protista), and chlorophyta (from Kingdom Plantae). All seven divisions are called algae because of a lack of roots, stems, and leaves; and most algal cells are fertile. The basic metabolic processes are located in the individual cell and all lack the xylem/phloem transport system of "higher plants". These different plant-like organisms have been used for human food and animal follage.

Macroalgae

The "macroalgae", usually referred to as seaweed, have been commercially cultured for over 300 years (Tseng, 1981). Representatives of macroalgae include red, brown, and green algae. Most people in the United States ingest red or brown algae products everyday in chocolate milk, toothpaste, candy, cosmetics, ice creams, salad dressing, and many other household and industrial products (McCoy, 1987). Macroalgae are rich in protein, carbohydrates, amino acids, trace elements, and vitamins (Waaland, 1981).

Historically, records have established that people collected seaweeds for food beginning 2,500 years ago in China (Tseng, 1981). European peoples have collected seaweeds for food for 500 years. Today, only in the Far East are macroalgae eaten directly in large quantities as food by humans.

Of the macroalgae, the most widely consumed throughout the world has been the membranaceous red alga Porphora. This algae is called "Nori", "amanori" or "hoshinori" in Japan and "purple laver" in the West. This one genera of red algae represents the largest tonnage aquacultural product in the world (McCoy, 1987) and was the first marine macroalgae to be cultivated by man. Nori has been grown in Tokyo Bay for nearly 300 years (Lobban et al, 1985).

Nori is eaten directly in soups or as a vegetable or used as a condiment. The Japanese grow over 500,000

tons of Nori per year and consume over 100,000 tons directly per year. The Nori industry in Japan employs over 60,000 people and is estimated to support over 300,000 people (McCay, 1987). The Chinese also have a very large Nori industry but no estimation on the number of employees have been given. Major commercial centers for Nori include Marinan Islands, Saipan, and Guam. However, the world's largest and most technically-advanced Nori farms are facilities in the Philippines (McCoy, 1987).

Nori is also eaten in Europe, mainly in salads. The algae has also been fried in fat, boiled, and even baked into bread. The British used to seal the fresh algae in barrels for use as food by whaling crews (Lerman, 1986). In the United States, Nori is commonly found in health food stores. Nori is also used in the preparation of sushi. The algae is wrapped around the raw seafood and rice to hold the two together.

The majority of the macroalgae that is under cultivation are used for their phycocolloids. There are three major commercial groups of phycocolloids: agar-agar, algins and caregeenans. The total wholesale worldwide of these three products is about one million tons per year, at a value of $250 million.

The primary agar producing genera are *Euchema*, *Gelidium*, *Gracilaria*, *Hypnea*, *Gigartina*, and *Marocystis* (Chapman, 1970). The name agar comes from the native Malaysian name for Euchema, "agar-agar" (Tseng, 1981). Agar is a group of complex entities mad up of calcium or magnesium salts of a sulfuric acid ester of a linear galactan. This substance is a major constituent of the cell wall of some red algae. Agar has been used extensively in microbiology for culturing instead of gelatins because of its ability to remain a semi-solid at O degrees C to 70 degrees C, it has a low viscosity when melted, ease of mixing and pouring, and firmness and clarity of agar gels (Humm and Wolf, 1946). Unlike gelatins, most species of bacteria can not digest agar.

With the advent of modern molecular biology and genetic engineering, agar gums producing an "agrarose" factor is used extensively in electrophoresis and chromatography. Agrarose gel electrophoresis is replacing starch gel electrophoresis in most laboratories around the world.

Carrageenan is a phycocolloid much like agar. The compound is a family of sulfated galactan polymers obtained from various red algae especially *Chondrus*, *Sigartina*, *Iridaea*, *Hypnea*, and *Eucheuma*. Originally, carrageean was processed from Irish Moss, *Chondrus crispis* (Humm and Wolf, 1946). Carrageenans are generally employed for their physical functions in gelation, viscous behavior, stabilization of emulsions, suspensions and foams, and control of crystal growth (Chapman, 1970). Other applications of carrageenans include uses in pharmaceutical, cosmetics, and various coatings such as paints and inks. Common food uses of carrageenans are in ice cream and pudding.

The third class of phycolloids are the algins or algenic acids. Algins is a major constituent of all brown algae. Chemically it is a polymer of d-mannuronic and I- guluronic acids. There are some 897 known chemical members of this family. Alginic acids are commercially important in the production of rubber and textiles. Before World War II, Japan was the only major producer of algenic acid. During the war, the California algenic acid industry was made. The salts of algins produce a clear, tough film which is

used extensively as thickeners, coagulants, or flocculants in many foods. Examples include soups, mayonnaise, sauces, and sausage casings (McCay, 1987). There are over 30 species of brown algae harvested today; most commercially important algins come from the giant kelp, *Macrocystis* and *Nerocystis*. These species are harvested mechanically by a kind of "underwater hay bailer".

Microalgae

Microalgae is generally referred to as organisms that are less than 2mm in diameter. Today, microalgae are cultivated directly for food or for products produced by the algal cell. The history of cultivation of these small plants date back to the Aztecs (Sommer, 1988). Like macroalgae, microalgae are high in protein, carbohydrates, amino acid, trace elements, and vitamins (Waaland, 1981).

The blue-green algae (=cyanobacteria), *Spirulina*, as traditionally harvested from natural lakes as a protein source by the Aztec Indians and some North American tribes. Spirulina was initially regarded as a nuisance in the ponds of Mexico. But it was not until the late-1960s that this species was rediscovered as a valuable food source. First experimental wide spread harvesting of *Spirulina* was in Mexico to feed the poor people of this country. However, a much more lucrative market existed in the United States and Japan as a health food. Unfortunately, some outrageous claims made about the curative properties of *Spirulina* caused a steady decline in the mass market of this algae in the early 1980s (Sommer, 19BB). Today the major use of *Spirulina* is for the extraction of phycocyanin, a blue photosynthetic pigment. The pigment has commercial uses as a natural food coloring and cosmetic ingredient.

Another microaglae used as food is the green algae *Chlorella*. In the 1950's the Carnegie Institute made a major research program to study the potential for mass culturing of *Chlorella* to feed the world's hungry. The algae has fantastic growth rates and a very high yield, approximately 30 tons of dried cell powder is produced for a one acre pond (Hills and Nakamura, 1978). This algae has never lived up to this promise. Today *Chlorella*, like *Spirulina* is mainly sold in health food stores and as a fish food. The major economic important product of Chlorella are several by-products that are used in fruit and vegetable preservatives (Hills and Nakamura, 1976).

The most important microalgae under modern cultivation is *Dunaliella salina*. This species is grown for a source of the photosynthetic pigment, beta-carotene. Beta-carotene is used as an orange dye and as a vitamin C supplement. *Dunaliella* is grown in high salinity ponds in California, Hawaii, and Australia. In California, aquaculturalists "rotate" farming *Dunaliella* with brine shrimp.

Historically, both macroalgae and microalgae have been collected from the wild. Today with the need for a more reliable source of these plants, full cultivations of some of these plants are underway. Most of these plants are very hard to cultivate under artificial conditions because of the complex life cycles of some important species. The future of algae cultivation looks bright. Products being examined are the use of the brown algae, *Sargassum*, and the green algae, *Chlorella*, as sources of a renewable source of an energy source (Hannacack, per. com.). As synthetic, petroleum-based dyes are becoming banned in the use in food products, the market for all- natural pigment dyes such as orange from *Dunaliella* and

blue from *Spirulina* will increase.

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