Algal Biorefinery and Industrial Trends: Food, Feed, Dietary Supplements, and Other Applications

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The use of algal biorefineries and industry to produce food, feed, dietary supplements, and other products from algal resources involves multiple disciplines. Diverse species of seaweed have been cultivated extensively in the Asia-Pacific region. Thalli of seaweeds are popular health foods and sources of polysaccharides. As food products, in addition to their use in traditional salads and soups, many healthy snacks mixed with different nut chips are manufactured. Value-added abalone production involves simply changing the feed to bioactive phlorotannin-rich brown seaweeds such as *Ecklonia cava*, *Ecklonia stolonifera*, or *Eisenia bicyclis* about 2 weeks before harvesting.

The production of pharmaceuticals from new materials usually takes a long time and requires expensive human trials and toxicity tests. It is relatively easier to obtain approval for dietary supplements and ingredients. The use of the phaeophyte *U*ndaria *pinnatifida* (known as Miyok or Wakame) to cure fevers, urination problems, lumps, and swellings was recorded in the Donguibogam, an oriental medical textbook published in 1613. These signs and symptoms are related to anti-inflammatory actions. An ethanol extract of *U. pinnatifida* showed potent anti-inflammatory activities; anti-edema, anti-erythema, analgesic, and antipyretic activities. In a screening test evaluating the ability of seaweed and freshwater fish extracts to enhance exercise capacity, the rhodophyte *Gloiopeltis furcata* and leather carp had the most potent enhancing effects on swimming endurance and forelimb grip strength. Traditionally, a hot water extract of leather carp has been used as a nourishing tonic soup and as a health food to recover from physical fatigue. Double-blind, randomized, placebo-controlled human trials are ongoing. Hippocampal neuronal outgrowth and arborization are the anatomical basis of learning and memory, and these are largely regulated by neurotrophic factors. Of 56 seaweed species examined, ethanol extracts of *Gelidium amansii* (GAE), *U. pinnatifida*, *Gracilariopsis chorda*, and *Kappaphycus alvarezii* exhibited potent neuritogenic activity in developing rat hippocampal neurons. The GAE promoted neuronal differentiation significantly from stage I to stage II, and it increased axonal and dendritic development indices such as length, the number of primary processes, and branching frequency by at least two fold compared with the vehicle control. These findings suggest that seaweed is a good source of neurotrophic compounds for enhancing memory and learning ability, and that it has potential for use in dietary supplements to prevent or treat dementia-related disorders.

In other applications, several seaweed extracts and deep seawater have been used to make hydrating skincare toners, emulsions, and cream products in the cosmetics industry. A kelp sheet mask made of *Saccharina japonica* blades moistens, soothes, and confers elasticity to skin. The sticky mucous polysaccharides in the kelp also remove automobile exhaust fumes and dust from the skin. Red tides are an escalating, worrisome trend. Current control techniques involve the use of yellow loess to sediment red tide organisms; however, this method has secondary effects on bottom dwellers. Microalgal blooms may be controlled biologically by cultivating kelp-like and allelopathic macroalgae in season. As antifouling agents, research on biomimetic surface structures and compounds inspired by natural systems has become important as an environmentally friendly marine application. The surface of

Corallina pilulifera is covered with unique dimples measuring ~7.9 µm. The surfaces of mussels are covered with regular ripples at 1.4-µm intervals; the major antifouling compound in the periostracum is oleamide, a slipping agent. Finally, seaweed resources can be used as raw materials to produce bioethanol as a renewable biofuel. *K. alvarezii* possesses large amounts of bioethanol-producible carrageenan, a polymer of D-galactose-4-sulfate and 3,6-anhydro-D-galactose-2-sulfate, which are potentially fermentable D-type carbohydrates. When the seaweed is hydrolyzed and fermented, the actual ethanol yield is relatively low because of impurities (e.g., inhibitors, incomplete hydrolysates, non-fermentable sugars, and salts). For any bioethanol commercialization of seaweed, the material price and alcohol productivity issues will always be a problem. Unless those issues can be addressed in an economical fashion, the dream of renewable bioethanol from seaweed will falter.

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