SEN FOUNDATION

Algae Farming

Overview

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Introduction

Algae is not yet a well-known source for the needs of humans. In the last decades however, increasing numbers of people see the advantages of this very versatile organism. Scientists across the world are trying to develop different techniques to use algae for food, fodder, medicine, bio fuel or environmental purification. The aim of this paper is to show how algae can be used. How can algae help solve the water and food shortage especially in the developing world?

Identification of algae

The algae are photosynthetic plants that live in water. Most species are small to very tiny; many can only be seen with a microscope and often float or swim as plankton in fresh or salty water. Some algae, what we often call pond scum or seaweed, are conspicuous plants that can form dense mats of vegetation. The largest of these, the kelp, can be hundreds of feet in length and form impressive underwater forests. Algae have been adapting and evolving for more than 3 billion years, with an estimated 10 million algal species. Up to 90 percent have special chemical and nutritional compounds which are not yet fully known. Algae are chlorophyll-containing organisms that range from one-celled organisms to large, multicellular seaweeds. Unlike plants, algae don't have true roots, stems and leaves. Algae contain high levels of protein, minerals, vitamins and trace elements. Algae are one of the few vegetable sources of vitamin B-12, one reason they are often included in vegetarian diets to avoid deficiencies. They have a significant iodine content, and calcium and iron tend to accumulate at much higher levels in seaweed than in terrestrial plants. Algae are low in fat but high in fiber.

The current usage of algae

Algae have already found their way into our lives as food and ingredients in commercial products. Algae components enhance about 70% of the products in modern supermarkets, including dairy, beer, soft drinks, jams, bakery products, soups, sauces, frostings, colorings, ulcer remedies, digestive aids, eye drops, dental creams, skin creams and shampoos. Algae are used to thicken foods and boost healthy bacteria. A type of algae called carrageenan is commonly added to dairy products to give them a denser consistency. The most common algae containing products are sour cream, chocolate milk and cheese. (Ibid, 2001) Algae are put in shakes and malts to thicken them. It is also added to mayonnaise to prevent it from becoming runny. The green paper-like substance used to wrap sushi rolls is algae. (Ibid, 2001) This is a special "leafy" variety of algae grown on farms in Asia and shipped throughout the world. The leafy algae is grown on strings and dried in the sun. This types is especially high in vitamins and nutrients. Gelatin contains a type of algae called agar. It can solidify just about anything that comes in a liquid form. (Ibid, 2001) Agar was first used in China in the 17th century and is now found in hundreds of foods sold in grocery stores.

Algae as solution for many problems

An increasing number of scientist see algae as solution for sustainable and affordable food. Any food, fibers or materials that can be made from land-based crops can be made from algae, because land plants evolved from algae 500 million years ago. Algae offer a much wider array of colors, textures, tastes and compounds than land plants. Any fuels, plastics or other materials made from fossil fuels can be made from algae because fossil fuels are simply fossilized algae or based on organisms that ate algae. (Ibid, 2010) The most useful algal attribute is not that we can make just about anything from algae. What sets algae apart from terrestrial plants and fossil fuels is how the algal food, energy and co-products are made. Our atmosphere is overloaded with CO2, which is naturally recycled or sequestered by algae production. Many food crops will have difficulties with global warming, but algae flourish in heat and high CO2. Our world has insufficient cropland for food crops, yet algae can produce supplemental food and energy on non-cropland. (Ibid, 2010) Globally, societies are experiencing a dearth of fresh water, yet algae flourish in waste water, brine or ocean water. Algae could provide liquid transportation fuels at a lower cost than mining crude oil. Farmers face a severe shortage of natural resources such as phosphorus that algae can recover, as well as recycle and reuse nutrients from animal and human waste streams. (Ibid, 2010) Our current food and transportation systems are massively pollutive to air, soils and water. Algae can produce carbon neutral food with a positive ecological footprint. Algae produce far more compounds than found in land plants or animals because there are so many more species of algae. Algae benefit from over 3 billion more years of adaption and evolution than land plants and have with ingenious survival strategies to maximize their growth and vitality and to repel predators. (Ibid, 2010)

Alternatives to the use of algae

Nature's first food production system on earth, algaculture, offers extraordinary benefits. Algal food products can create an abundance of food and energy while reducing demand for food products that require extensive cropland and fresh water. Food production that adds only oxygen to the atmosphere and does not pollute local ecosystems will provide a very positive net yield to the environment. (Edwards & Algae Industry Magazine, 2010) Scientist have many ideas about the usage of algae since this organism is very versatile. Solutions to commercial and small-scale growing systems will produce high-value and affordable food, fuels, fodder, fertilizers and medicines from algae. (Edwards & Algae Industry Magazine, 2010) The next few ideas are according to scientist not all used yet and some are not yet feasible. Investing in algae technology will further develop algae for food, fuels, fodder, fertilizers and medicines.

Food

Algae supply high-protein, low-fat, nutritious and healthy human foods. Algae provide also many vitamins, minerals and nutrients. Algae do not provide a complete solution for malnutrition as they do not contain many calories. Furthermore, solutions have to be found for two key issues: making hard cell walls better digestible, and producing fewer nucleic acids. All other promises of algae possibilities await application of cultivated algal production systems in an economic fashion. (Edwards & Algae Industry Magazine, 2010)

Fodder

Algae produce high-protein, low-cost animal feed with numerous vitamins, minerals and nutrients. Replacing half the food grains fed to animals would save several trillion gallons of fresh water. Local algae production in villages would feed millions of animals and save many million acres a year of forests and grasslands from desertification due to animal forage. (Edwards & Algae Industry Magazine, 2010)

Fisheries

Algae provide low-cost fish feed. Algae can be grown in-situ, in the water with the fin fish and shell fish. Fish tend to grow faster and with more vitality on algae than land grains, because fish eat algae in their natural habitat. (Edwards & Algae Industry Magazine, 2010)

Fuel

Algal oils pressed directly from algal biomass produce renewable and sustainable, high energy biofuel from sunshine, C02 and wastewater. In the United States corn for ethanol production takes much agricultural land, water and farm input. Replacing corn with algae as a biofuel feedstock would save millions of acres, trillions of liters of irrigation water, and it would vastly reduce soil erosion and water pollution. (Edwards & Algae Industry Magazine, 2010) Algae can produce a variety of high energy liquid transportation fuels including gasoline. Refining underground oils requires more energy input than squeezing out oil from algae. Algae can be refined in fossil fuel refineries into the same products made from fossil fuels, because fossil fuels are simply fossilized algae. (Edwards & Algae Industry Magazine, 2010)

Ecological Solutions

Fresh water

Running wastewater through algaculture feeds the plants and cleans the water. Producing fuel, fodder or fertilizer using wastewater or brine water saves water that would otherwise be used for land-based crops. According to research of alga industries in the United States, foods based on algae would save 30 million acres of cropland, 2 trillion gallons of water and 5 billion gallons of fossil fuel. (Edwards & Algae Industry Magazine, 2010)

Fresh air

Flueing smoke stack gasses through algaculture removes CO_2, nitric oxides, sulfur and heavy metals such as mercury from power plants or industrial plants, sequesters greenhouse gasses and cleans the air. Algae represent only a partial solution since the plant only grows with sunshine, while power plants operate 24 hours a day. Some producers have reported success with grow lights for night production. (Edwards & Algae Industry Magazine, 2010)

Fertilizer

Nitrogen-fixing algae may provide high nitrogen fertilizers at very low cost in both production and energy inputs. The product is natural, supports organic food production and can provide cheap local fertilizer to subsistence farmers globally. The algal ash retains fertilizer value after being burned in cooking fires. (Edwards & Algae Industry Magazine, 2010)

Forests

High energy algal-oil fuel can end the need to denude forests and grasslands for cooking and heating fuel. Villagers may replant their forests with nut trees or legumes for food to offset the low calories provided by algal foods. (Edwards & Algae Industry Magazine, 2010)

Novel Solutions

Fabrics

Algal carbohydrates are similar to wood and may be made into textiles, paper and building materials. Algal paper and building materials save forests. Fabrics from algae save cropland for food crops. Algae may be made into biodegradable plastics, biofuels or other refined products. (Edwards & Algae Industry Magazine, 2010)

Food for the hungry

American and European foreign aid provides subsidized food, undermines or destroys local food production because farmers cannot compete with subsidized food. Gifting food fails to address the root cause of hunger and poverty – local lack of domestic control over food resources and poor community engagement. Helping hungry populations with algae techniques would led to growing algal foods, fuels, fodder, fertilizer and medicines locally. (Edwards & Algae Industry Magazine, 2010)

Fine medicines

High-quality, affordable medicines, vaccines and pharmaceuticals may be made from algal co-products or grown in algae, which are bioengineered to produce advanced compounds such as antibiotics, vitamins, nutraceuticals and vaccines. These compounds are grown today in land plants and animals. Algae offer prospects of significantly faster and lower cost production. (Edwards & Algae Industry Magazine, 2010) Designer algae grown locally in villages could save millions of lives by providing low cost vaccines or other medicines that need no packaging or distribution. (Edwards & Algae Industry Magazine, 2010)

Algae farms

Scientists see future algaefarms as a solution to hunger and lack of drinking water. Plants need a specific temperature, climate or land and fresh water to grow. Some algae grow well in brackish or salty water, eliminating demand for freshwater. Private industry, national labs and universities such as the University of Texas at Austin and the University of California, San Diego, have testing and pilot programs. (Algae Food & Fuel, 2012) Although algal it may take many years before large-scale commercial application, the promise of algae warrant additional research. Innovative technologies for algae growth, process control and harvesting result in cost efficient, productive and improve the stability of algae processes. (Ibid, 2012) Using local resources for algae growth, such as waste water one can create effective systems for algae farms. Every industry that has excess heat, flue gasses and residual nutrients can be the starting point of an algae farm.

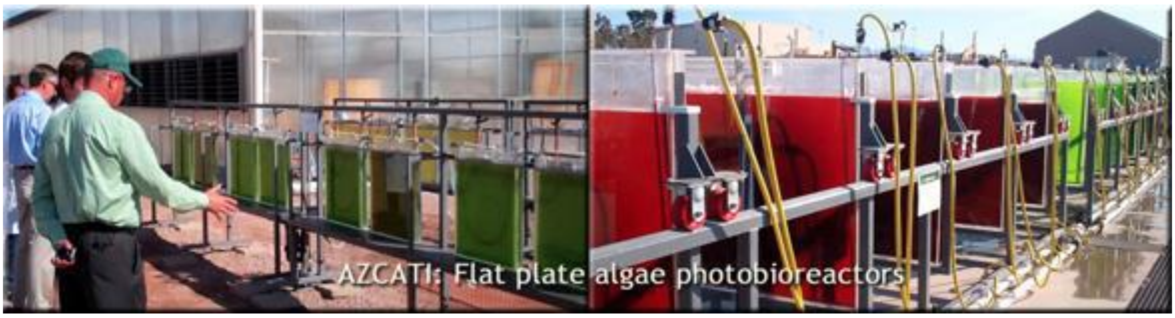
Algae production in practice

Algae is already produced in many countries. In outdoor ponds, greenhouses, photo bioreactors, fermenters and hybrid systems combining bioreactors and ponds. Some algae like dunaliella are grown in deep saline ponds with little mixing. Algae like spirulina are grown in shallow raceway ponds mixed with a paddlewheel or compressed air that keeps the culture moving around the raceway. This turbulence moves algae cells to the surface where they absorb sunlight. Algae biomass is harvested by micro-screen, filter, centrifuge or flocculation. (AlgaeIndustryMagazine, 2013)

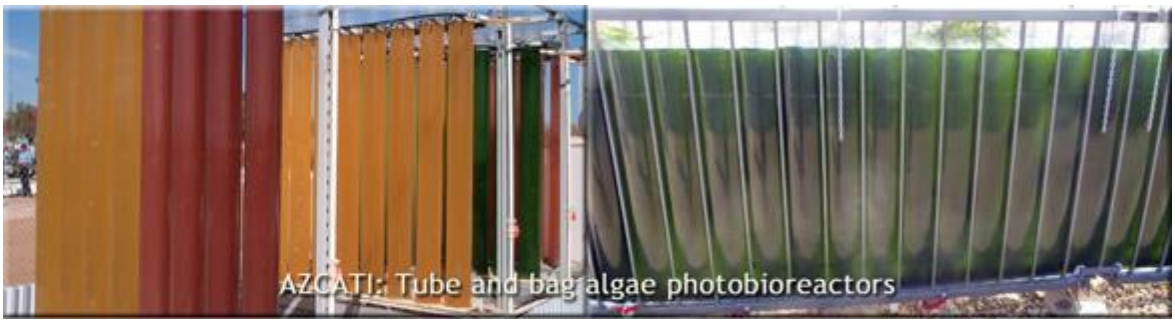
Most algae production today is in open raceways because such ponds are cheap to build and operate. Ponds are more productive in tropical, subtropical and temperate areas with warm temperatures, low rainfall and little cloud cover. (Ibid 2013)

Outside ponds have less stable algae production because of lack of temperature control, water loss from evaporation, and salt formation. In outdoor ponds it is difficult to control algae predators such as amoeba, ciliates, bacteria, rotifers, viruses, fungi, and zooplankton, that can decimate the algae biomass within hours. Open ponds are vulnerable to contamination from dust, windborne organisms, insects, and birds. (Ibid 2013) For the different algae growing methods and considerations, new research centres and algae incubators are testing various pond types and photobioreactor systems on a small scale to compare results and develop automation systems. One of the most impressive research centres is the Arizona Centre for

Algae Technology and Innovation in the US. The AZCATI works on biofuels, pharmaceuticals, nutraceuticals and other algae biomass products. (Arizona Center for Algae Technology, 2013)



Production ponds and photobioreactors studied here may one day be important source for local food and energy. (Ibid, 2013)



In Wageningen is The Algae Production and Research Centre engaged in developing knowledge, technology and process strategies for sustainable production of microalgae as feedstock for fuel, chemicals, food and feed on an industrial scale. (AlgaePARC WageningenUr, 2013)

The pilot facility comprises 7 photo-bioreactors. Those are compared on technical, economic and sustainability performance. Results will be used to build up knowledge for commercial production of microalgae for bulk products. (Ibid, 2013)

Algae2Omega is already growing commercially haematococcus for astaxanthin in Florida in indoor photo-bio reactors. Solar tubes bring light from the roof to the surface, solar collectors send light through fiber optic inside the culture, as well as artificial lighting with LEDs. (Algae to Omega , 2013)

LGem is growing nannochloropsis for omega3 oils in Den Haag, the Netherlands. Inside large high-tech warm greenhouses, widely used for growing crops, sunlight illuminates the algae cultures during sunny days and can be supplemented with artificial lighting during cloudy days and in the off season with shorter days. (LGem, 2012)

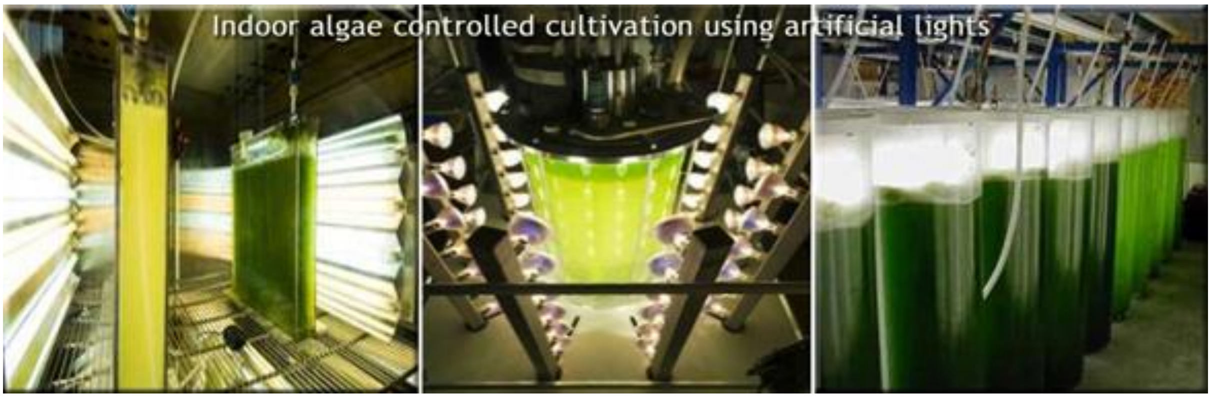
Urban and community gardens are a rapidly emerging movement for local food production in urban and suburban communities in empty lots, even on rooftops. Because algae is so productive in a small area, algae growing systems are ideal for urban gardens and containerized systems for growing food. (Urbanfarmers, 2012)

Shipping containers have been redesigned for modular housing, offices and health clinics. Now they are being transformed into container gardens with controlled environmental systems. With a 20 foot shipping container and a greenhouse on the roof or sides, a tiny urban farm would help supply a small community. This urban agriculture system can be placed anywhere to create local, sustainable, fresh food that also tastes better. Containers are inexpensive and durable, easy to insulate, and stackable, easy to transport and set up. (Urbanfarmers, 2012)

Rostlaube fish and vegetable farm by UrbanFarmers AG combines aquaponics with hydroponics. A mutual support system uses microbe-powered biological filters to convert fish wastes into fertilizers that plants need to grow in a hydroponic greenhouse. The greenhouse warmth encourages vegetable growth and keeps the fish comfortable below. The lower level has a fish tank with two filter systems, recycling all water, with water added only to make up for evaporation. (Urbanfarmers, 2012)

The ArkFab is a vertical farm for mushroom cultivation. A repurposed shipping container estimated lifetime of 10 years and allows stacking to use up valuable real-estate. Containers around the globe, so containerized urban agriculture systems can be transported to post-disaster recovery areas. (AlgaeIndustry Magazine, 2013)

PodPonics Urban Agriculture converts used shipping containers into controlled-environment growth pods with LED lights. PodPonics crops use 90% less water than traditional green houses, with no pesticides, less fertilizer, and go from harvest to plate very rapidly. (PodPonics, 2012)



For modular growing systems, a variety of algae controlled cultivation systems are being developed for food and higher value products by PodPonics.

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