

Biotechnology and Algae

The term “algae” encompasses a variety of organisms found throughout the world in or near bodies of water. Algae species are estimated to number in the tens of thousands. Though most algae are photosynthetic or autotrophic, some are heterotrophic, deriving energy from the uptake of organic carbon such as cellulosic material.

Because algae are naturally able to replicate rapidly and produce oils, proteins, alcohols, and biomass, they have attracted the attention of researchers and industrial producers seeking alternatives to oil.

Algae thrive on organic carbon or CO₂ and nutrients such as nitrogen and phosphorus. Growth conditions and the availability of sunlight, carbon and nutrients affect the metabolism of algae and whether they produce lipids or carbohydrates. However, manipulation of nutrients has not proved successful in increasing algal productivity. Researchers, for instance, have found that when algae naturally produce hydrocarbons – molecules that can most readily substitute for today’s petroleum uses – growth and reproduction are limited.

Biotechnology research goals therefore include finding ways to increase the reproductive rate, improve metabolism of inputs, and enhance the production of desired oils, fuel-grade alcohols, or proteins in useful species. Researchers have found that many algae species are adaptable to genetic engineering, expressing complex proteins and accumulating recombinant proteins to very high levels.

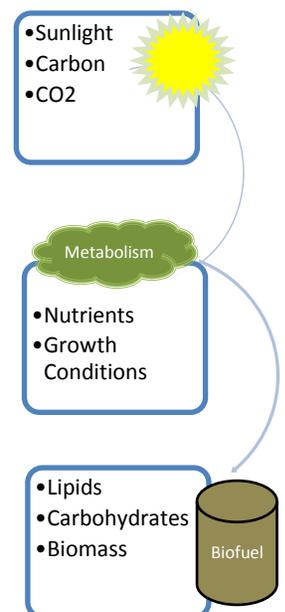
Current Research

Biotechnology is already employed in sequencing and annotating the genomes of algal species. Genomic data aids researchers in understanding the metabolic processes through which algae convert carbon and nutrients into lipids or carbohydrates. Greater understanding of algal metabolism and reactions to growth conditions will inform further research. Genetic engineering techniques currently used in plant and microbial biotechnology, including synthetic biology and metabolic engineering, are then employed to enable algae to more predictably produce desired lipids for biofuels, alcohols, proteins, enzymes and other molecules, or carbohydrate-rich biomass for bioprocessing.

Biotechnology research is important not only in the initial stages of developing algal biofuels, but also in optimizing algal strains for the mechanical engineering and processing needs of biofuel production. Algal strains used in industrial processes must fit harvest and molecule recovery requirements – such as high heat and pressure used in mechanical separation – which are probably not naturally occurring traits.

The Challenge of Replacing Petroleum: Goals for an Algae Biofuel Solution

- Convert sunlight energy directly to fuel
- Highly scalable process to meet growing consumer demand
- Low cost to compete with other energy choices
- Carbon neutral
- Contributes to overall food production



Commercial Development

Biofuel companies are currently seeking to scale commercial production of algae and are pursuing several engineering approaches – using closed systems and open pond systems – to the design of an economical system for growing algae.

In closed systems, engineers can precisely regulate algae growth conditions. Closed systems include both photobioreactors for photosynthetic algae strains and traditional bioreactors (enclosed tanks such as those used in fermentation and other microbial growth) for algae strains that feed on sugars.



Open pond systems have been used in many settings, but can be sensitive to various environmental factors, such as invasion by other algae strains or variations in nutrient availability, heat and light. Since microalgae may be dispersed by wind or by fauna, open pond systems can introduce algal strains to the surrounding environment. The probability of dispersion by these methods is equivalent for natural and biotech strains. The potential environmental impact on surrounding environments – including crops – is also equivalent for natural and biotech algal strains. Pond systems covered by thin plastic films and combination closed/open systems are being developed to control these factors. An essential factor for commercialization is the development of an economical harvesting system and the recycling of residual biomass after the biofuel is extracted.



Regulatory Structure

All biotechnology products in the United States undergo rigorous regulatory oversight and approval processes. Under the Coordinated Framework for Regulation of Biotechnology, federal agencies have a broad mandate to assess the potential health and environmental impacts of organisms whose genetic material has been intentionally changed in a way that does not occur naturally. Over the biotech industry's 35-year existence, oversight and regulatory evolution have kept pace with scientific advancements, such as synthetic biology and metabolic engineering techniques. This framework will be able to incorporate algal biotechnology products and address any specific issues associated with individual algae technology platforms.



The National Institutes of Health administers biosafety guidelines for laboratory research using recombinant DNA. The Environmental Protection Agency regulates the use of new intergeneric microorganisms in industrial processes, such as biofuel or biochemical production, under the Toxic Substances Control Act. New biotech products are also subject to environmental assessments under the National Environmental Policy Act and Endangered Species Act before commercial use.



Under the Plant Protection Act, the USDA oversees the interstate movement, importation and introduction into the environment of any organism that may impact U.S. crops. Any biotech organism that incorporates genetic material from a known plant pest or noxious weed or from another organism that has not been classified is considered a potential plant pest.



The Food and Drug Administration similarly regulates biotech products under the Federal Food, Drug and Cosmetic Act if they are expected to become a component or otherwise affect the characteristics of food, biopharmaceuticals or devices. Biotech agricultural products – such as corn and soybeans – have been used as animal feed, but are not considered to affect the characteristics of food from those animals.