Algae to Combat Food Crisis?

Microalgal cultivation captures greenhouse gas carbon dioxide and simultaneously produces biomass containing high-value consumer products. How is algaculture carried out in different kinds of environments?

Algae are receiving wide attention as a source of biomass protein for use in animal feeds and foods. High oil prices and the competing demands between food crops and other biofuel sources (which are leading to the world food crisis) have ignited interest in algaculture for making vegetable oil and other biofuels (biodiesel, bioethanol, biogasoline, biomethanol, biobutanol), using land that is not suitable for agriculture. Biodiesel produced from algae appears to be the only feasible solution today for replacing petrodiesel completely. In practice, however, biodiesel has not yet been produced on a wide scale from algae, though large-scale algae cultivation and biodiesel production appear likely in the near future.

Algae do not lend themselves readily to cultivation due to their size and the specific requirements of the environment in which they need to grow. The algal culture facility, therefore, is a vital part of an aquaculture operation. Extreme care is taken to ensure production of healthy monocultures of selected algal species. Production of algae depends on a reservoir of small master or stock cultures. It is crucial to maintain this reservoir free of contaminants and excessive bacteria.

In a few countries, cultivation of algae is carried out in large trenches, particularly in sewage oxidation ponds by using sunlight or in artificial illumination conditions used in life supportive systems for extended space exploration. Mass cultivation of algae has been started in many countries, such as Japan, Germany, Mexico, Czech Republic and India.

In India, the CSIR-National Environmental Engineering Research Institute (NEERI), Nagpur has developed a technique of cultivating algae in sewage oxidation pond systems. This practice is also in use at the CSIR-National Botanical Research Institute (NBRI), Lucknow, Hyderabad and other centres. Interestingly, experiments conducted at the CSIR-Central Food Technological Research Institute (CFTRI), Mysore have...
shown that the microalgae e.g. *Scenedesmus acutus* and *Spirulina platensis*, could be cultivated on a large scale and used as food and feed as they are rich in protein and their nutrient value is comparable to conventional foods.

**Methods of Algaculture**

Ways of culturing algae range from closely controlled methods on the laboratory bench top with a few litres of algae to less predictable methods in outdoor tanks, containing thousand litres in which production relies on natural conditions. The rate of growth and division varies with different types of algae and also depends on how well the various culture conditions necessary for growth have been met. There are three types of culture methods generally followed:

1. **Batch Culture**: A batch culture is used for small volumes of cultivation space, usually up to ten litres. It is a system where the total culture is harvested and used as a food.

2. **Semi-Continuous culture**: A semi-continuous culture is a system where part of the culture is harvested and used as food and the amount taken is replaced with fresh culture medium. After allowing 2–3 days for the remaining cells to grow and divide, the process is repeated. Semi-continuous cultures may be operated for 7 to 8 weeks.

3. **Continuous Culture**: A continuous culture is more long term, and is maintained by monitoring and keeping some factor constant. In a turbidostat continuous culture, the number of algal cells in the culture is monitored. As the cells divide and grow, an automatic system keeps the culture density at a pre-set level diluting the culture with fresh medium. In a chemostat continuous culture, a flow of fresh medium is introduced into the culture at a steady predetermined rate.

**Environments for Algaculture**

**Cultivation of Algae in Open Ponds**

Open ponds can be categorized into natural waters (lakes, lagoons, ponds) and artificial ponds or containers. The most commonly used systems include shallow big ponds, tanks, circular ponds and raceway ponds. The ponds in which the algae are cultivated are usually what are called the “raceway ponds”, as the algae, water and nutrients circulate around a racetrack in these ponds. With paddlewheels providing the flow, algae are kept suspended in the water, and are circulated back to the surface on a regular frequency. The ponds are usually kept shallow because the algae need to be exposed to sunlight, and sunlight can only penetrate the pond water to a limited depth.

The ponds are operated in a continuous manner, with carbon dioxide and nutrients being constantly fed to the ponds, while algae-containing water is removed at the other end. The biggest advantage of these open ponds is their simplicity, easy construction (especially compared to closed systems), low production and operating costs.

While this is indeed the simplest of all the growing techniques, it has some drawbacks owing to the fact that the environment in and around the pond is not completely under control. Bad weather can stunt algal growth. The water in which the algal grow also has to be kept at a certain temperature, which can be difficult to maintain. Another drawback is the uneven light intensity and distribution within the pond. Furthermore, contamination by predators and other fast growing heterotrophs restricts the commercial production of algae in open culture systems to only those organisms that can grow under extreme conditions.

**Cultivation of Algae in Closed Ponds**

As a variation of the open pond system, the idea behind the closed pond is to close it off, to cover a pond or pool with a greenhouse. While this usually results in a smaller system, it does take care of many of the problems associated with an open system particularly better control over the environment. Closed Pond systems cost more than the open ponds, and considerably less than photobioreactors for similar areas of operation. It also allows more species to be grown, allows the species that are being grown to stay dominant, and extends the growing season, both slightly higher temperatures or in unheated, and if heated it can produce year round. It is also possible to increase the amount of carbon dioxide in these closed systems, thus again increasing the rate of growth of algae. Closed ponds are used in Spirulina cultivation.

**Cultivation of Algae in Photobioreactor**

A photobioreactor is a closed equipment which provides a controlled environment and enables high productivity of algae. As it is a closed system, all growth requirements of algae are introduced into the system and controlled according to the requirements. Photobioreactors facilitate better control of culture.
environment such as carbon dioxide, water supply, optimal temperature, efficient exposure to light, culture density, pH levels, gas supply rate, mixing regime, etc.

Cultivation of Algae in Desert
Algae can be grown cheaply in saltwater ponds in the desert or even more efficiently in proprietary photobioreactors. It is conceivable that the photobioreactors could be placed in a desert environment, although one of the challenges for growing algae is to keep the water at a very consistent temperature of around 70 degrees Fahrenheit so that it will likely also influence optimal placement of the photobioreactors. Growing algae is best accomplished closer to the desert, where seasonal sunlight levels and temperatures don’t vary as much as they do further away from the equator.

Another possible strategy to maintain temperature is to put the photobioreactors near a conventional coal-burning electric plant and harvest the significant amounts of carbon dioxide generated by the plant. Attractive as this sounds, the production of biodiesel should not depend on a coal plant operating indefinitely. Algae strains suitable for desert cultivation include, Haematococcus pluvialis, Microcoleus vaginatus, Chlamydomonas perigranulata and Synechocystis.

Cultivation of Algae in Marine Environment
Salt water is more economical than fresh water for growing algae as the main nutrients needed for algal growth are already present in seawater. Macroalgae are cultivated at sea mainly by tying them to anchored floating lines. Seaweeds do not require soil, and are already provided with all the water they need, which is a major advantage over land production of biofuels since water is the most limiting factor for most agricultural expansion (especially with climate change).

Aquaculture systems based jointly on microalgae and their animal consumers, which can be considered as an indirect use of microalgae in human food, have so far been much more successful. The uptake of microalgal biomass by commercially important filter feeders is very promising from the energetic standpoint. Microalgae are indeed the biological starting point for energy flow through most aquatic ecosystems and as such are the basis of the food chain in many aquaculture operations.

Flocculation is an essential step in the concentration and harvesting of microalgae from aquatic media. Salinity of brackish water and seawater requires high flocculant dosages and renders flocculation less effective than in freshwater algal media.

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