THE SUPERIORITY OF MICRO-ALGAE AS A POTENTIAL FEEDSTOCK FOR ALTERNATIVE ENERGY

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ABSTRACT

Micro-algae are plant like organisms belong to Thallophytic group, they have no true roots, stems, and leaves. They can easy to grow in fresh, saline, and brackish water. Like plants, micro-algae can conduct photosynthetic process to manufacture carbohydrates for their own food. Algal cell generally contains high concentration of proteins, carbohydrates, and lipids. Micro-algae grow very rapidly, and their biomass is commonly double within 24 hours. The algal are the highest potential energy yield agricultural oil crop. In accordance with capability of their lives, micro-algae have potential as feedstuff for alternative energy. Other capabilities of algal are as carbon dioxide reduction, animal feed, livestock feed, fertilizer, supplement for human health, etc.

Key word: micro-algae, bio-fuel, bio-diesel, alternative energy

I. INTRODUCTION

Micro-algae are a large and diverse group of photosynthetic, eukaryotic, plant-like organisms that use chlorophyll in capturing light energy, but they are lack of characteristic plant structures such as leaves, roots, flowers, vascular tissue, and seeds.(1) Therefore, the microorganisms belong to thallophytic, because that organism having no true roots, stems, and leaves. Like other common plants, micro-algae require primarily three components to grow, they are sunlight, CO_2 and water. They use the sunlight for the process of photosynthesis. During photosynthesis process, micro-algae use carbon dioxide, water and light to manufacture carbohydrates as their food, consequently CO_2 reduction from the atmosphere occurs.(14)

In the absence of light, micro-algae metabolize organic matter in the same manner as do non-photosynthetic organisms. Thus algae may satisfy their metabolic demands by utilizing chemical energy from the degradation of stored starches or oils, or from the consumption of algal protoplasm itself. In the absence of photosynthesis, the metabolic process consumes oxygen, so during the hours of darkness, an aquatic system with a heavy growth of micro-algae may become depleted in oxygen.(2)

The cell of micro-algae primary comprise of proteins, carbohydrates, fats and nucleic acids, they can be used on several activities. They form an important food source for many animals such as little shrimps and huge whales. Therefore, they are at the bottom of the food chain with many living things depending upon them. Algal biomass has potential on- and off-farm uses. It has considered to be a high-grade protein source in animal feed. It can also be used as livestock feed, such as chicken feed. Algae biomass with a balanced N / P ratio is a potentially valuable organic fertilizer. Some micro-algae have also been applied as a caroteneoid and vitamin supplement for poultry, and others product as supplement for human health. They produce more oxygen than all the plants in the world. By oxygen addition, they can remediate an aquatic contamination. (14)

More over, according to the recent research micro-algae can be used to produce alternative energy, for algae biomass contains high fats that are potential for bio-diesel production. The algae biomass that remained after squeering to produce algae oil can be processed to produce ethanol. The solid wastes left over ethanol process can be used as feedstock for biogas production. H_2 can be produced during photosynthesis. (14, 22)

II. CULTIVATION AND BIOMASS PRODUCTION

Micro-algae are common in aquatic environments. They can growth in fresh, saline and brackish water. Most unicellular and colonial micro-algae float near the surface of water. Under appropriate condition, micro-algae grow very rapidly. Their biomasses are commonly double within 24 hours. Biomass doubling times during exponential growth are as short as 3.5 hours. [(19)]

Micro-algae can be grown in "open pond" system such as tanks, ponds, raceway type ponds, and lakes. Micro-algae are much more vulnerable to being invaded by other algal species and bacteria in "open pond" system. Only a relatively small number of species have been successfully cultivated for a given purpose in an outdoor system. In open system, one does not have control over water temperature and little control over lighting conditions. In temperature climates, the growing system is limited to the warmer months. Some of the benefits of this type of system are that it is one of the cheaper methods. Development of the open pond system is to close it off, by covering the pond or pool with a greenhouse. While this usually results in smaller system for economic reasons, it resolved a number of the challenges associated with open system. In addition micro-algae can be grown in photo-bioreactor. This reactor is a tool of close pond system for micro-algae cultivation. [(1)]

Biomass of micro-algal is cells collection of micro-algae. Producing micro-algal biomass has to pass through photosynthetic process. The photosynthetic process requires carbon dioxide, water, light and inorganic salt. The process works in the cells containing chlorophyll. They use the sunlight for the process of photosynthesis. Photosynthesis is an important biochemical process in which micro-algal convert the energy of sunlight to chemical energy. This chemical energy is used to drive chemical reactions such as the formation of carbohydrate or the fixation of nitrogen into amino acids, the building blocks for protein synthesis. Carbohydrate production by photosyinthesis uses carbon dioxide and water as the feed (Figure 1). The carbohydrate (sugar) yield is used as food for micro-alga. The inorganic salt will supports micro-algal growth. Normal photosynthesis in micro-algae is the output of oxygen and the uptake of carbon dioxide according to de Saussure's equation as shown in Figure 1. The effectiveness of light for normal photosynthesis falls sharply at wave lengths longer than 680 nm. (20)

All the cells of many species of micro-algae primary comprise of the following, in varying proportions: Proteins, Carbohydrates, Fats and Nucleic Acids. The primary chemical composition in cells of some micro-algae is shown in Table 1. The contents of protein are 6% - 71%, carbohydrates are 4% - 64%, and lipids are about 4% - 40%. [(14)]

$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{light}} C_6H_{12}O_6 + 6O_2$$

carbohydrate

Figure 1
Photosynthetic reaction

Algal-oil is very high in unsaturated fatty acids (UFA'S). Some UFA's found in different algal-species include: Arachidonic acid (AA); Eicospentaenoic acid (EPA); Linoleic acid (LA); Docasahexaenoic acid (DHA); Gamma-linolenic acid (GLA).

Implementation of micro-alga growth involves growth medium, and the condition of temperature must remain generally within 20-30^{o}C. The growth medium must provide the inorganic elements that constitute the algal cell. Phosphorous (P), nitrogen (N), iron (Fe) and in some cases silicon (Si) are essential elements in the growth medium. Minimal nutritional requirements can be estimated using the approximate molecular formula of the micro-algae biomass that is $CO_{0.48}H_{1.83}N_{0.11}P_{0.01}$.[(3)]. Phosphorous must be supplied in significant excess because the phosphates added, form complex substrate with metals ions, therefore, not all of the added P is bio-available. Sea water supplemented with commercial nitrate and phosphate fertilizers and few other micronutrients is commonly used for growing marine micro-algae.[(4)]

Large scale production of micro-algal biomass, generally use continuous culture during daylight. In this method of operation, fresh culture medium is fed at a constant rate and same quantity of micro-algal broth which is withdrawn continuously. Feeding ceases during the night, but the mixing of broth must continue to prevent settling of the biomass. As much as 25% of the biomass produced during daylight, may be lost during the night because of respiration. The extent of this lost depends on the lights level under which the biomass was grown, the growth temperature, and the temperature at night. (4, 5). The methods of large-scale biomass production of micro-algae are raceway ponds and tubular photo-bioreactor.

III. RACEWAY PONDS

A raceway pond is made of a close loop recirculation channel. Mixing and circulating are produced by a paddlewheel. Flow is guided around bends by baffles places in the flow channel. Raceway channels are built in concretes, or compacted earth, and may be lined with white plastic (Figures 2).The culture is fed continuously during daylight. The paddlewheel operates all the time to prevent sedimentation. Raceway is open shallow pond and simple operates, that pond is much cheaper to build and operates.

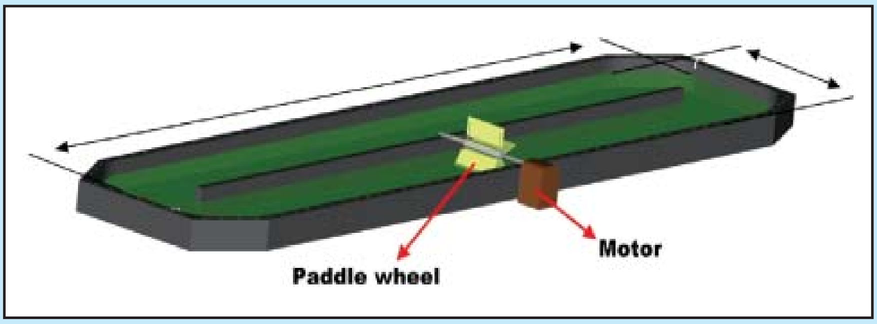

Figure 2
The view of a raceway pond

Table 1
Chemical Composition of Algae Expressed on Dry Matter Basis (%)

Strain	Protein	Carbohydrates	Lipids	Nucleic acid
Scenedesmus obliquus	50-56	10-17	12-14	3-6
Scenedesmus quadricauda	47	-	1,9	-
Scenedesmus dimorphus	8-18	21-52	16-40	-
Chlamydomonas rheinhardii	48	17	21	-
Chlorella vulgaris	51-58	12-17	14-22	4-5
Chlorella pyrenoidosa	57	26	2	-
Spirogyra sp.	6-20	33-64	11-21	-
Dunaliella bioculata	49	4	8	-
Dunaliella salina	57	32	6	-
Euglena gracilis	39-61	14-18	14-20	-
Prymnesium parvum	28-45	25-33	22-38	1-2
Tetraselmis maculata	52	15	3	-
Porphyridium cruentum	28-39	40-57	9-14	-
Spirulina platensis	46-63	8-14	4--9	2-5
Spirulina maxima	60-71	13-16	6-7	3-4,5
Synechoccus sp.	63	15	11	5
Anabaena cylindrica	43-56	25-30	4-7	-

Source: Becker, (1994)

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In raceways, any cooling is achieved only by operation. Temperature fluctuates within a diurnal cycle and seasonally. Evaporative water loss can be significant. Because of significant losses to atmosphere, raceway use carbon dioxide much less efficiently than tubular photo-bioreactor. Productivity is affected by contamination with unwanted algae and microorganisms that feed on algae. The biomass concentration remains low because raceways are poorly mixed and cannot sustain an optically dark zone.[6, 7]

IV. TUBULAR PHOTO-BIOREACTOR

A photo-bioreactor is basically a bioreactor that incorporates some type of light source. Because these for the most part are closed systems when used to cultivate micro-algae, everything that the micro-algae need to grow (carbon dioxide, nutrient-rich water, and light) must be introduced into the system.[1].

A tubular photo-bioreactor consists of an array of straight transparent tubes. This tubular array, or the solar collector, is where the sunlight is captures. The diameter of solar collectors is limited because light does not penetrate too deeply in the dense culture broth that is necessary for ensuring a high biomass productivity of the photo-bioreactor. Micro-algae broth is circulated from a reservoir to the solar collector and back to the reservoir. Continuous culture operation is used.

Tubular photo-bioreactor has many advantages. It is unique, scalable, affordable and easy to install saltwater and fresh water algae growing system. The system is equipped with monitoring and control systems and includes feeding systems, pumps, sensors and series of clear. For optimal light penetration used transparent tubes have a diameter of 640 mm, 320 mm, or lest. Photo-bioreactor is mounted in horizontal or vertical arrangements in many different shapes and sizes. All these systems depend on frames or structures to support the photo-bioreactor enclosures. The benefits of photo-bioreactor are: [13]

- It offers maximum efficiency in using light and therefore greatly improves productivity. Typically the culture density of micro-algae produced is 10 to 20 times greater than bag culture and can be even greater.
- Space saving. Can be mounted indoors or outdoors.
- Low transport cost because we ship no pipes but sheets. The sheets will be converted with our patented technology to pipes on location.
- Dramatically reduces labor requirements and eliminates handling problems.
- Systems can be operated for long periods without culture crashes occurring.
- Easy patented self cleaning system can dramatically reduce fouling.
- Closed, controlled, continuous automated systems and therefore cultures may be more easily kept hygienically. Environmental parameters are simply controlled.
- Can be build at any size and short delivery time.
- Oxygen poisoning can't occur. Systems release automatically all of the oxygen.
- Reactor stimulate rapid micro-algae grow.

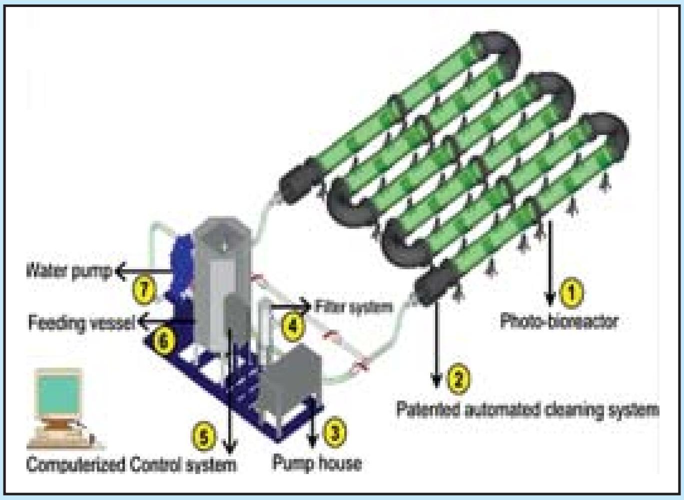

Figure 3
The view unit tubular photo-bioreactor

V. BIOMASS OF MICRO-ALGAL FOR BIO-FUEL

In recent years, our concern with energy production has focused attention on several biochemical processes in which H_2 is the one of ultimate product. Bio-hydrogen (H_2) can be produced during photo-

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synthesis with bio-hydrogenase process. Photosynthetic organisms such as green algae, cyanobacteria and photosynthetic bacteria produce as a fuel process. [17]. Although photo-production of H_2 by these organisms utilize solar energy, only green algae and cyanobacteria are capable of using H_2O as the source of reductant for H_2 production. The heterocystous cyanobacterium *Anabaena variabilis* contains three hydrogenase activities, a reversible hydrogenase in the vegetative cell, an uptake hydrogenase in the heterocysts and nitrogenase. Under photosynthetic growth conditions, the H_2 evolved by the organism is catalyzed by nitrogenase. The uptake hydrogenase recycles this H_2 and thus reduces the total H_2. Although the economics of photoproduction of H_2 is not favorable at the present time, this is an area which needs to be explored by using genetics and genetics engineering techniques. [18]

The micro-algae cultures have been investigated as a source of renewable fuels for several decades. The other renewable energy is algal-methane. The concept of renewable energy algal-methane process, proposed during 1960s at the University of California Berkeley, was to grow algae in municipal wastewaters, harvest the biomass, and then convert it to methane to generate electricity. [8]. The algal cultures, were grown in high rate (shallow, channel, mixed) ponds, to produce dissolved O_2 required for bacterial oxidation of the wastes and the harvested algal biomass was converted by the process of anaerobic digestion to methane. Over the years, several Economic analyses of such processes were carried out, in particular for the production of bio-diesel from micro-algal biomass with high lipid (vegetable oil) content were made. (9,10,11). These studies used the same basic production process of high ponds, mixed with paddle wheels, and were based on favorable assumptions, in particular the achievement of very high biomass productivities and low cost harvesting, by the spontaneous flocculation of algae once removed from the ponds. The interest in bio-diesel production by micro-algae was driven by the U.S. Department of Energy. [12].

Micro-algae contain lipids and fatty acids as storage products, membrane component, metabolites and sources of energy, while the percentages vary with the type of micro-algae. Many micro-algae are exceedingly rich in oil. There are algae types that are comprised 40% of their overall mass by fatty acids.[14].

Oil content of micro-algae biomass can be extracted and converted into bio-diesel. Agricultural oil crops are widely being used to produce bio-diesel. Oil production per acre area per year can be seen in Table 2. However, the oil production of micro-algae is by factor of 8 to 25 for palm oil, and a factor of 40 to 120 for rapeseed. Micro-algae are the highest potential energy yield agricultural oil crop. Micro-algae strains with high oil or lipid content are of great interest in the search for a sustainable feedstock for the production of bio-diesel. [16]

Unlike other oil crops, micro-algae grow very rapidly and many are exceedingly rich in oil. Oil content in micro-algae can exceed 80% by weight of dry biomass. Oil levels of 20%-50% are quite common. Oil productivity depends on the algal growth rate and the oil content of biomass. Micro-algae with high oil productivities are desired for producing bio-diesel. Micro-algae produce many different kinds of lipids, hydrocarbons and other complex oils. Not all algal oils are satisfactory for making bio-diesel, but suitable oils occur commonly. Using micro-algae to produce bio-diesel will not compromise to production of food, fodder and other products derived from crops.[5, 15]

The prominent component of algal biomass is lipids, carbohydrates, protein, and nucleic acid. This biomass can be utilized for many products. The algal lipids can be used if the lipids content are removed from algal biomass. The yield of lipids is useful as feedstuff for bio-diesel production. The remainder of algal biomass contains carbohydrates component, these biomass have potential as feedstuff for ethanol fermentation. Both yeasts and bacteria have been used for the production of ethanol. *Saccharomyces cerevisiae* is the most commonly used yeast but

Table 2
Oil production per acre per year

No	Agricultural plan	Gallon of oil
1	Corn	18
2	Soybeans	48
3	Safflower	83
4	Sunflower	102
5	Rapeseed	127
6	Oil Palm	635
7	Micro-algae	5.000 – 15.000

Kluyveromyces fragilis has also been employed. The ethanol fermentation process has been done with yeast or bacteria as above under anaerobic condition. [21]

VI. CONCLUSION

Micro-algae are aquatic photosynthetic microorganisms. Algal cell commonly contains high concentration of proteins, carbohydrates, and lipids. They can grow easily in fresh, saline, and brackish water. Micro-algae grow very rapidly, their biomass commonly double within 24 hours. Micro-algae are the highest potential energy yield agricultural oil crop. In accordance with the capability of their live, micro-algae have potential as feedstuff for alternative energy. Other capabilities of micro-algae include carbon dioxide reduction, animal feed, livestock feed, fertilizer, supplement for human health, etc.

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