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Potential Use of Algae-A Review

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ABSTRACT
Algae are an extremely diverse group of organisms that make up the lower phylogenetic echelons of the plant kingdom. Most of the algae are photosynthetic (like higher plants) or are closely related to organisms that are. Algae perform roughly 50% of the photosynthesis on this planet and thus are instru-mental in supporting the biosphere. The first use of microalgae by humans dates back 2000 years to the Chinese, who used Nostoc to survive during famine. However, microalgal biotechnology only really began to develop in the middle of the last century. Nowadays, there are numerous commercial applications of microalgae. For example, (1) microalgae can be used to enhance the nutritional value of food and animal feed owing to their chemical composition, (2) they play a crucial role in aquaculture and (3) they can be incorporated into cosmetics. Moreover, they are cultivated as a source of highly valuable molecules. For example, polyunsaturated fatty acid oils are added to infant formulas and nutritional supplements and pigments are important as natural dyes. Stable isotope biochemicals help in structural determination and metabolic studies. Future research should focus on the improvement of production systems and the genetic modification of strains. Microalgal products would in that way become even more diversified and economically competitive. In this article some commercially available products derived from algae and a few product areas in which algae may make a significant contribution in the near future has been described.
Keywords: microalgae, applications, nutrition, carotenoids, phycobiliproteins, polyunsaturated fatty acids

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INTRODUCTION

The word algae represent a large group of different organisms from different phylogenetic groups, representing many taxonomic divisions (Falkowski and Katz 2004). In general algae can be referred to as plant-like organisms that are usually photosynthetic and aquatic, but do not have true roots, stems, leaves, vascular tissue and have simple reproductive structures. They are distributed worldwide in the sea, in freshwater and in moist situations on land. Most are microscopic, but some are quite large, e.g. some marine seaweeds that can exceed 50 m in length. The algae, like other plants containing chlorophyll, are able to convert inorganic compounds into organic matter by

means of light energy through the process of photosynthesis. Recently they are classified in the kingdom of protiste, which comprise a variety of unicellular and some simple multinuclear and multicellular eukaryotic organisms that have cells with a membrane-bound nucleus. Almost all the algae are eukaryotes and conduct photosynthesis within membrane bound structure called chloroplasts, which contain DNA (Becker 1994).
The exact nature of the chloroplasts is different among the different lines of algae. Cyanobacteria are organisms traditionally included among the algae, but they have a prokaryotic cell structure typical of bacteria and conduct photosynthesis directly within the cytoplasm, rather than in specialized organelles (Falkowski *et al.,* 2004)

Algae have been studied intensively for over sixty years, during which time some progress has been made in gathering and co-ordinating information about the 17, 000 species that have been described. Algae as a feedstock have been used for many products and applications, and new ones are constantly being discovered (Briggs 2004). With the recent surge in interest to use algae as a feedstock for biofuels, there is growing interest in utilizing the Algal Biomass in an optimal manner – not just to produce fuel but also valorising the co-products of the process. Such an optimal utilization could make algae based biofuels more economically viable (Hu Q *et al., 2008*)

Valorisation of co-products is an attractive option, given the fact that the world has the experience of using algae for a wide array of products. In addition to oil and Biodiesel the starch component of the biomass makes a suitable feedstock for the production of ethanol. (Chisti Y, 2007). The residue that is left over could then be used for conventional animal, fish or poultry feed, or for other nutraceuticals. There are emerging technologies using which the residue could be used to make products such as bioplastics. During the past thirty years a few species have been used as research tools by plant physiologists in the study of the mechanism of photosynthesis. One such investigation by Roessler and Ohlrogge 1993 showed that the composition of an alga such as Chlorella pyrenoidosa could be controlled. This finding gave added interest to the idea that unicellular algae might be grown on a large scale as a source of food. The possibility of growing a high-protein plant food in large quantities is of paramount importance in connection with long-range planning for the feeding of an ever expanding world population. In certain quarters of the world today large numbers of people do not have access to sufficient protein, with the result that they exist in a state of malnutrition, even if they have adequate quantities of carbohydrates. There is little hope for relief by the traditional method of raising animals for food, because of the large areas of land required to grow grass and other crops to support them. Furthermore, the local production of fish is not always feasible. In this sort of situation, algal culture may fill a very real need (Mc Garry and Tongkasame 1971).

The number of products that can be made from algae is virtually unlimited, due to the large variety of species (possibly in the millions) whose composition can be influenced by changing the cultivation conditions. With only a few commercial algae-based products available, this resource is largely untapped. This paper attempts to bring out all the possible applications of algae and its market potential (Norton *et al*,. 1996).

Algae as food source:
Except for the leafy vegetables that are eaten because of their flavour or vitamin content, man's vegetable foods are derived fruity a portion of the plant, such as its fruit, seeds, or roots. These parts contain the largest concentrations of protein, which is essential for the reproduction of the plant, and of fats and carbohydrates, which are forms of food stored for the use of the next generation. The sum total of these nutritive parts of the plant, however, is usually half or less of the total dry weight.

(Chini *et al*,. 1999). Most of the plant structure serves mechanical purposes; roots to anchor it and to draw food and water from the soil, leaves to expose large areas of cells to sunlight, and stems to support the leaves and fruits in the light and air. The primitive character of their cellular organization gives microscopic algae a number of advantages over higher plants as a source of food. In the first place, essentially the entire plant is nutritious, for little of it is devoted to indigestible structures. A second advantage concerns the kind of food produced. Dried algal cells grown under favourable conditions contain over 50 per cent protein, or more than is found in the edible parts of any of the higher plants (Kroes *et al*,. 2003). Furthermore, this protein should be suitable for human nutrition, for it contains the ten amino acids now considered essential and has a low molecular weight, which means that it can be digested readily (Radmer 1996).

Algae as energy source:

Besides adding to the food supply, algae may become a source of energy. During the growth of algae (and other plants) solar energy is transformed into latent chemical energy, which, can be released later by burning the plant material. The growing of algae on a large scale uses up energy for pumping, centrifuging, and drying. The over-all process, however, has a positive energy balance. That is, the harvested algal cells contain more stored solar energy (expressed as heat of combustion) than the non solar energy that is used up in growing and harvesting them. Therefore, an algal culture unit when combined with a steam generating plant in which the algae were burned would become an energy converter, capable of converting solar energy into high-temperature heat which in turn could be converted into electric power. In this case the source of carbon dioxide would not be a problem, since the combined plant would be a closed system for carbon, except for some losses in operation. Such a solar energy converter would not be economically feasible today; but it may become of practical importance at some future date (Sheehan *et al*,. 1998). The way that all forms of energy that man uses are derived ultimately from the sun has been described by a number of writers in recent years (Yamaguchi 1997). Our coal and oil supplies of course represent storage of solar energy from photosynthesis during an earlier stage of the earth's history. An algal energy converter might be used to take their place after they have been exhausted (Hu Q. *et al* ,. 2008) Sufficient data are not yet available to make an estimate of the power output of such a plant in terms of growth area and capital investment. Therefore, it is not possible to give a definite answer to the question of how large an area would be required to grow enough algae to meet all the food and energy needs of the expected world population of 7 billions in the year 2050, when the estimated per capita energy requirement will be 150 million calories a day (Mercer *et al*,. 2007)

Algae as an industrial raw material:

Although these preliminary investigations have not revealed any startling applications of microscopic algae as an industrial raw material further search is warranted. An especially interesting possibility is the use of algae as a source of sterol to be used as a starting material in the synthesis of cortisone. Although Chlorella pyrenoidosa does not contain a suitable sterol, Scenedesmus obtiquus does contain a small amount (Chen *et al*,. 2009). Chlorella was not found to contain any components of interest to the pharmaceutical industry, and the percentage of glutamic acid is too low to make it a satisfactory source of this amino acid. The chlorophyll content is much higher than that of the plant sources now being used for this material, and Chlorella presumably could be used as a raw material for this compound; but this does not seem to be a sufficiently large use to justify production for this purpose alone. The proteins were reported to be difficult to extract from Chlorella and were found to be of such low molecular weight that they were not suitable for use as a substitute for casein in making either adhesives or artificial wool. In a different process for making adhesives, however, low molecular weight may be an advantage. The fat fraction contains a large percentage of unsaturated acids, and its suitability as a drying oil for paints and varnishes (Liu and Zhao 2007) is under investigation.

Other by- products from Algae:

Stabilizing agent:
Chondrus crispus, common name: Irish moss is also used as "carrageen". It is an excellent stabiliser in milk products as it reacts with the milk protein casein. Other products produced include alginates used in pet foods, toothpaste, ice-creams, lotions absorbable through the skin (Grima *et al*,. 1994)

Hydrogen:
There are three methods by which Hydrogen can be produced from algae--
1. Biochemical Processes - Under specific conditions, algae produce hydrogen, via biological and photobiological processes. Under these conditions, enzymes in the cell act as catalysts to split the water molecules.
2.Gasification – During gasification, biomass is converted into a gaseous mixture comprising primarily of hydrogen and carbon monoxide, by applying heat under pressure in the presence of steam and a controlled amount of oxygen. The carbon monoxide is then reacted with water to form carbon dioxide and more hydrogen.

3.Through Steam Reformation of Methane – Fermentation of Algal Biomass produces methane. The traditional steam reformation (SMR) techniques can be used to derive hydrogen from methane. At high temperatures (700 – 1100 °C) and in the presence of a metal-based catalyst (nickel), steam reacts with methane to yield carbon monoxide and hydrogen $CH_4 + H_2O \rightarrow CO + 3\ H_2$ (Kroes 2003)

Methane:

Methane is important for electrical generation by burning it as a fuel in a gas turbine or steam boiler. Compared to other hydrocarbon fuels, burning methane produces less carbon dioxide for each unit of heat released. Methane in the form of compressed natural gas is used as a vehicle fuel, and is claimed to be more environmentally friendly than fossil fuels such as gasoline/petrol and diesel. Theoretically, methane can be produced from any of the three constituents of algae – carbohydrates, proteins and fats. Closed algal bioreactors offer a promising alternative route for biomass feedstock production for bio-methane. Using these systems, micro-algae can be grown in large amounts (150-300 tons per ha per year) using closed Bioreactor systems (lower yields are obtained with open pond systems). This quantity of biomass can theoretically yield 200,000-400,000 m of methane per ha per year (Spolaore *et al*,. 2006)

Ethanol :

Algae have a tendency to have a much different makeup than does most feed stocks used in ethanol, such as corn and sugar cane. Ethanol from algae is possible by converting the starch (the storage component) and Cellulose (the cell wall component). Put simply, lipids in algae oil can be made into biodiesel, while the carbohydrates can be converted to ethanol. Algae are the optimal source for second generation bioethanol due to the fact that they are high in carbohydrates/polysaccharides and thin cellulose walls. The real problem is that there are so many more valuable products to produce from it, such as carrageenan, agar, and dozens of valuable compounds. In comparison, alcohol is a low-priced product. Some prominent strains of algae that have a high carbohydrate content and hence are promising candidates for ethanol production: *Sargassum, Glacilaria, Prymnesium parvum, Euglena gracilis* (Apt and Behrens 1999).

Algae in Nutraceuticals :

Astaxanthin:

Astaxanthin is a naturally occurring high-value ketocarotenoid pigment with excellent antioxidant effects. Astaxanthin is present in many types of seafood, including salmon, trout, red sea bream, shrimp and lobster, as well as in birds such as flamingo and quail. As of today, astaxanthin is commercially produced from the microalga: *Hematococcus pluvialis*. Commercial production of astaxanthin is being carried out in USA, India, Japan and Israel Research shows that due to astaxanthin's potent antioxidant activity, it may be beneficial in cardiovascular, immune, inflammatory and neurodegenerative diseases Although natural sources have long been exploited for astaxanthin production (Radmer 1996)

Beta-carotene:

Beta-carotene belongs to the group of pigments called carotenoids. Carotenoids are a class of natural fat-soluble pigments found principally in plants, algae, and photosynthetic bacteria, where they play a critical role in the photosynthetic process. *Dunaliella salina*, a marine microalga is a rich source of beta-carotene, alpha-carotene, cryptoxanthin, zeaxanthin, lutein and lycopene. Other algae strains used for beta carotene production include *Spirulina platensis, Chlorella, Caulerpa taxifolia* Beta-carotene was the first carotenoid from algae to be commercialized. Beta-carotene is the precursor for Vitamin A biosynthesis in the body. Like all other carotenoids, beta-carotene is an antioxidant. It protects the body from damaging molecules called free radicals. Research has proven that consumption of the *Dunaliella salina* algae is effective in prevention of some forms of cancer (Radmer 1996)

Coenzyme Q10:

Coenzyme Q10 (CoQ10) found in almost every cell in the body, and it is a powerful antioxidant. that is found naturally in the body and helps convert food into energy. CoQ10 is Antioxidants, such as CoQ10, can neutralize free radicals and may reduce or even help prevent some of the damage they cause. Research studies indicate that CoQ10 may help with heart-related conditions, because it can improve energy production in cells, prevent blood clot formation, and act as an antioxidant. Today, Coenzyme Q10 is mostly produced from strains of blue green algae. Algae Strains that produce Coenzyme Q10 *Porphyridium purpureum*. Applications and Health Benefits of Coenzyme Q10 are Nutritionally supports heart health and the body's defense system ,Contains 82% of the daily value of antioxidant vitamin A (beta-carotene), Promotes health and vitality, Contains a full spectrum of carotenoids (natural antioxidants) , A handful of studies have shown that coenzyme Q10 (CoQ10) may have an effect on skin and the appearance of wrinkles, most notably by reducing UV damage, stimulating healthy collagen production, and reducing substances in damaged skin that wreck havoc on its support structure (Medina *et al*,.1998)

Spirulina:

Spirulina is a human and animal food or nutritional supplement made primarily from two species of cyanobacteria: Arthrospira platensis and Arthrospira maxima. Algae Strains that produce

Spirulina are *Arthrospira platensis* and *Arthrospira maxima.*. 1 kg of Spirulina has the same nutrients found in about 1,000 kgs of assorted vegetables. Some of the key health benefits of using Spirulina are: Boosts the immune system, Improve digestion, Reduce fatigue, Build endurance, detoxifier – cleanses the body, Boosts energy levels, Controls appetite, Keeps a tab on cardiovascular function, Helps proper liver and kidney functioning, Reduces inflammation and allergies. AIDS/HIV, arthritis, athletic nutrition, enhancing natural cleansing and detoxification, supporting cardiovascular function and healthy cholesterol, strengthening the immune system, improving gastrointestinal and digestive health, reducing cancer risks with antioxidant protection, general and long term health (Herrero 2003)

Chlorella:

Chlorella is a single-cell green alga that thrives on freshwater. It is spherical in diameter and measures 3 to 8 micron. It is a plant with high Photosynthesis efficiency and has a wide range of distribution. The cells are rich in chlorophyll, protein, vitamins, minerals, dietary fiber, and nucleic acid. Algae Strains that Produce Chlorella *Chlorella pyrenoidosa.* Chlorella is considered a complete food, a superfood even, because of its important role in detoxification and its high content of protein, vitamins, and minerals including carotenoids (astaxanthin, canthaxanthin, flavoxanthin, loraxanthin, neoxanthin and violaxanthin), enzymes (pepsin) and chlorophyll. Naturally cultivated *Chlorella* is rich in protein, vitamin B12, beta carotene, and many other vitamins and minerals. It includes all eight essential amino acids, lipoic acid, and is rich in RNA & DNA. Chlorella is a rich source of magnesium due to the presence of a large amount of chlorophyll in the algae. Chlorella has more chlorophyll than any other plant in the world. Because of its high levels of chlorophyll, Chlorella has many beneficial effects on the immune system. The Chlorella Growth Factor (CGF) has intriguing regenerative effects. Chlorella stimulates peristalsis in the intestines and so it is one of the major diets followed in many weight-loss programs. Chlorella is sold as a dietary supplement and food colorant. Industrial Uses of Chlorella are: adding chlorella or CGF to foodstuffs, food manufacturers can significantly extend the shelf life of fermented food products without antiseptics. Korean manufacturers are adding chlorella to fermented food products such as kimchi, tofu, yogurt and bread as well as fermented drinks. If chlorella extract is added to the dough before yeast Fermentation the visual appearance and flavor of the loaf is enhanced. Chlorella can also be added to wine, cakes, cookies, cheese, ice cream, pasta and rice to enhance flavor and nutritive value (Nagle and Lemke 1990)

Agar:

Agar is a Polysaccharide that solidifies almost anything that is liquid. This gelatinous substance is derived from seaweeds of the Rhodophyceae class. It is therefore used as a thickener and also for its water-holding capacity. It was chiefly used as an ingredient in deserts throughout Japan, but now the most important worldwide use of agar is as a gelatin-like medium for growing organisms in scientific and medical studies (Roessler and Ohlrogge 1993)

Alginates:

Alginates are cell-wall constituents of Brown Algae (Phaeophyceae). Species of Algae Used: *Macrocystis pyrifera, Ascophyllum nodosum, Laminaria hyperborean, Laminaria japonica, Lessonia nigrescens, Lessonia flavicans, Ecklonia maxima, Durvillea Antarctica* and *Durvillea potatorum.* In the food industry, alginates have an excellent functionality as a thickening agent, gelling agent, emulsifier stabilizer, texture-improver (for noodles), to improve the quality of food.

The unique properties of alginate are utilized in foods like ice cream, jelly, lactic drinks, dressings, instant noodle, and beer.Alginate is used in textile printing, ice cream, jelly, lactic drinks, dressings, instant noodle, and beer. Alginate is used for the production of welding rod, as a binder of flux. It is also used as a binder and thickening agent for pet-food, fish feed. In pharmaceutical industry, alginic acid is compounded into tablets to accelerate disintegration of tablet for faster release of medicinal component. Alginate forms gel in the high-acidic stomach and protect stomach mucosa. In cosmetics, alginate is used in cosmetics area with several applications with its functionality of thickener and moisture retainer. Alginate helps retaining the color of lipstick on lip surface by forming gel-network (Spolaore *et al*,. 2006)

Carrageenan:

Carrageenan is extracted from species of red seaweeds. Carrageenan is a multifunctional ingredient and it behaves differently in water and in milk systems. In water it shows typical hydrocolloid properties of thickening and gelling, while in milk systems it also has the property of reacting with proteins to furnish additional stabilizing abilities. Species of strains used for making carrageenan: *Chondrus crispus*, *Gigartina skottsbergii*, *Gigartina stellata*, *Eucheuma cottonii*, *Eucheuma spinosum*, *Hypnea musciformis*, *Furcellaran species* .Based on the gelling properties and protein reactivity, the carrageen family can be distinguished commercially into three main classes:

1. Kappa carrageenan **-** Kappa carrageenan is the most commonly used type of carrageenan. Its most important properties are its high gel strength and strong interaction with milk proteins. About 70% of the world's carrageenan production is based on kappa carrageenan. It forms firm gels in the presence of potassium ions.
2. Iota carrageenan -Iota carrageenan is a type of carrageenan with a sulphate content intermediate between kappa and lambda carrageenan. Iota carrageenan forms an elastic gel with good freeze thaw and re healing properties. It forms elastic gels and thixotropic fluids in the presence of calcium ions.
3. Lambda carrageenan- Lambda carrageenan is a highly sulphated type of carrageenan mainly used for its ability to impart mouth feel and a creamy sensation to dairy products. Lambda carrageenan does not gel. Commercially it is supplied as it is extracted from the Seaweed which is as a kappa / lambda mixture. It forms viscous, non-gelling solutions (Spolaore *et al*,. 2006)

Omega-3 Fatty Acids

Omega-3 Fatty Acids have gained considerable importance due to their association with the prevention and treatment of several diseases like atherosclerosis, thrombosis, arthritis, cancers, etc. The omega-3 fatty acids include Docosahexaenoic acid (DHA) and Eicosapentaeneoic acid (EPA). The conventional source of EPA and DHA is marine fish oil, however, research studies have proved that higher amount of EPA and some DHA can be produced by the use of algae. **DHA**, produced from algae, is a vegetarian source of docosahexaenoic acid, DHA. DHA is a long-chain polyunsaturated omega-3 fatty acid and is important for brain, eye and heart health throughout the lifecycle. DHA has several applications including infant formulas, products for pregnant and nursing women, food and beverage products and dietary supplements**. EPA** is a polyunsaturated fatty acid (PUFA) that acts as a precursor for prostaglandin-3 (which inhibits platelet aggregation), thromboxane-3, and leukotriene-5 groups. Microalgae are being developed as a commercial source. EPA is not usually found in higher plants. Microalgae, and supplements derived from it, are excellent alternative sources of EPA and other fatty acids, since fish often contain toxins due to pollution. Microalgae can supply omega-3 fatty acids at high concentrations. Species of

Crypthecodinium, Thraustochytrium, Ulkenia and Schizochytrium are rich the omega-3 fatty acid DHA, while species of Phaeodactylum, Chlorella, Monodus, and Nannochloropsis are rich in EPA (Spolaore *et al*,. 2006)

Livestock & Fish Feed:

About five decades ago, the mass production of certain protein-rich micro-algae was considered as a possibility to close the predicted so called “protein gap”. Comprehensive analyses and nutritional studies have demonstrated that these algal proteins are of high quality and comparable to conventional vegetable proteins. However, due to high production costs as well as technical difficulties to incorporate the algal material into palatable food preparations, the propagation of algal protein is still in its infancy. Micro-algae are an essential food source in the rearing of all stages of marine bivalve molluscs (clams, oysters, and scallops), the larval stages of some marine gastropods (abalone, conch), larvae of several marine fish species and penaeid shrimp, and zooplankton (Muller 2000) Microalgae are used as essential live feeds and supplements in the aquaculture of larval and juvenile animals including oyster spat, juvenile abalone, finfish larvae and rotifer. Although the mechanism has not been understood yet, algal suspension appeared to improve the balance of nutrients in a straw-based diet and thus increased the efficiency of conversion of feed to products. Nitrogen deficient straw being the main source of nutrients for ruminants in Bangladesh (Tareque and Saadullah 1988), the introduction of algal suspension in the feeding system would certainly help economic livestock production. Many livestock farmers, particularly in the urban and suburban areas, raise their animals absolutely on straw and concentrate with either very little or no green grasses. This system of feeding is often associated with infertility, night blindness or even total blindness or other symptoms of vitamin A deficiency. Algae are a very rich source of carotene and algal suspension could be a potential source of vitamin A to combat such deficiencies. Algae may be an inexpensive way to harvest proteins in developing countries where farmland is scarce (Borowitzka 1997)

Algal Bioplastics:

Biopolymers or organic plastics are a form of plastics derived from renewable biomass sources such as vegetable oil, corn starch, pea starch unlike fossil-fuel plastics derived from petroleum. Biopolymers provide the twin advantages of conservation of fossil resources and reduction in CO_2 emissions, which make them an important innovation of sustainable development. Algae serve as an excellent feedstock for plastic production owing to its many advantages such as high yield and the ability to grow in a range of environments. Algae biopolymers mainly evolved as a by product of algae biofuel production, where companies were exploring alternative sources of revenues along with those from biofuels. In addition, the use of algae opens up the possibility of utilizing carbon, neutralizing greenhouse gas emissions from factories or power plants. Algae based plastics have been a recent trend in the era of bioplastics compared to traditional methods of utilizing feedstocks of corn and potatoes as plastics. While algae-based plastics are in their infancy, once they are into commercialization they are likely to find applications in a wide range of industries. Bioplastics are plastics manufactured using biopolymers derived from two routes: Biopolymers from living organism – these are typically made from cellulose, soy protein and starch. Polymerizable Molecules – these are typically made from lactic acid and triglycerides, wherein these molecules come from renewable natural resources, and can be polymerized to be used in the manufacture of biodegradable plastics. **Algae Strains that are used in manufacturing Biopolymers** *Nostoc sp, Phormidium mucicola , Chlorella stigmaaphora, Chlorella vulgaris, Chlorella pyrenoidosa, Chlamydomonas mexicana, Ulva lactuca, Scenedesmus obliquus, Scenedesmus braziliensis, Stichiciccis bacillaris, Anabaena flos-aquae, Porphyridium aerugineum, Porhyridium cruentum.*

Role of Algae in Pollution control:

Algae are used in Wastewater Treatment facilities, reducing the need for greater amounts of toxic chemicals than are already used. Algae can be used to capture fertilizers in runoff from farms. When subsequently harvested, the enriched algae itself can be used as fertilizer. Algae Bioreactors are used by some powerplants to reduce CO_2 emissions. The CO_2 can be pumped into a pond, or some kind of tank, on which the algae feed. Alternatively, the Bioreactor can be installed directly on top of a smokestack (Oswald 1988)

Algal Oil Properties:

Micro-algae are the fastest growing photosynthesizing unicellular organisms and can complete an entire growing cycle every few days. Some algae species have high Oil content (up to 60% oil by weight) and can produce up to 15,000 gallons of oil per Acre per year under optimum conditions. One of the key reasons why algae are considered as feedstock for oil is their yields. Put simply, algae are the only biofeedstock that can theoretically replace all of our petro-fuel consumption of today and future. Owing to the fact that oil yields are much lower for other feedstocks when compared to those from algae, it will be very difficult for the first generation Biodiesel feedstock such as soy or palm to produce enough oil to replace even a small fraction of petro-oil needs without displacing large percentages of arable land towards crops for fuel production.

Table 1:Comparison of Biodiesel from Microalgal Oil and Diesel Fuel

Properties	Biodiesel from Microalgal Oil	Diesel Fuel
Density Kg l^{-1}	0.864	0.838
Viscosity Pa s	5.2×10^{-4} (40 ºC)	1.9 - 4.1 $\times10^{-4}$ (40 ºC)
Flash point ºC	65-115*	75
Solidifying point ºC	-12	-50 - 10
Cold filter plugging point ºC	-11	-3.0 (- 6.7 max)
Acid value mg KOH g^{-1}	0.374	0.5 max
Heating value MJ kg^{-1}	41	40 - 45
HC ratio	1.18	1.18

Source: Department of Biological Sciences and Biotechnology, Tsinghua University, Beijing , China (2004)

Table 2: oil content of few *microalgal* species:

Microalgal species	Oil content(% dw)
Ankistrodesmus TR-87	28-40
Botryococcus braunii	29-75
Chlorella sp.	29
Chlorella protothecoides(autotrophic/ heterothrophic)	15-55
Cyclotella DI- 35	42
Dunaliella tertiolecta	36-42

Hantzschia DI-160	66
Nannochloris	31(6-63)
Nannochloropsis	46(31-68)
Nitzschia TR-114	28-50
Phaeodactylum tricornutum	31
Scenedesmus TR-84	45
Stichococcus	33(9-59)
Tetraselmis suecica	15-32
Thalassiosira pseudonana	(21-31)
Crpthecodinium cohnii	20
Neochloris oleoabundans	35-54
Schiochytrium	50-77

CONCLUSION

There are so many potential uses of algae starting from biodiesel bioethanol to fertiliser stabiliser and food products. Algae have a great potential for meeting the world's energy need. There are so many species of algae which might offer even more possible utilisation. For that purpose there is a huge need of research in this area so that someday algae could possible becomes alternative source of energy and food. Many R&D efforts so far have advanced the technologies. However, the commercialization of algal biomass is very challenging chiefly because of the techno-economic constraints. Facility and operation are areas with potential for substantial cost reduction through technological innovation. While open pond production systems may be practical in some areas, low cost enclosed photobioreactors with high photosynthesis efficiency must be developed and evaluated. Production systems which can be operated year round with good control of competitors, grazers, and pathogens are desirable. Wastewaters rich in nutrients are the preferred culture media for algae production because they offer many economic and environmental benefits. Screening and genetic modification of algae strains will play an increasingly important role. Genetic engineering has the potential to improve the overall algal biomass yield and lipid yield. Discovery of new strains and genetically modified strains capable of secreting hydrocarbons to extracellular spaces will open some new opportunities; however, challenges with recovering the secreted liquids or volatiles remain. There is a need to develop high throughput screening and analysis methods. Current harvest and dewatering are still too energy intensive. New techniques and strategies must be devised to lower the costs. Direct conversions such as *in situ* transesterification and hydrothermal liquefaction offer the possibility to process wet algae. Fractionation of algal biomass, before or after oil extraction, deserves a closer look because it may play an important role in offsetting the costs. New techniques to disrupt algae cellular structures to improve oil extraction efficiency are needed. A bioerfining scheme is believed to maximize the economic return of downstream processing. A systems approach, which minimizes production costs, maximizes product recovery and utilization, and provides environmental benefits, must be adopted in order to reduce the overall costs of algal fuels. Stable pilot to large scale operations must be established for meaningful life cycle analysis before commercialization can take place.

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