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Biofuels from algae for sustainable development

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ABSTRACT

Microalgae are photosynthetic microorganisms that can produce lipids, proteins and carbohydrates in large amounts over short periods of time. These products can be processed into both biofuels and useful chemicals. Two algae samples (*Cladophora fracta* and *Chlorella protothecoid*) were studied for biofuel production. Microalgae appear to be the only source of renewable biodiesel that is capable of meeting the global demand for transport fuels. Microalgae can be converted to biodiesel, bioethanol, bio-oil, biohydrogen and biomethane via thermochemical and biochemical methods. Industrial reactors for algal culture are open ponds, photobioreactors and closed systems. Algae can be grown almost anywhere, even on sewage or salt water, and does not require fertile land or food crops, and processing requires less energy than the algae provides. Microalgae have much faster growth-rates than terrestrial crops. the per unit area yield of oil from algae is estimated to be from 20,000 to 80,000 liters per acre, per year; this is 7–31 times greater than the next best crop, palm oil. Algal oil can be used to make biodiesel for cars, trucks, and airplanes. The lipid and fatty acid contents of microalgae vary in accordance with culture conditions. The effect of temperature on the yield of hydrogen from two algae (*C. fracta* and *C.* protothecoid) by pyrolysis and steam gasification were investigated in this study. In each run, the main components of the gas phase were CO_2, CO, H_2, and CH_4.The yields of hydrogen by pyrolysis and steam gasification processes of the samples increased with temperature. The yields of gaseous products from the samples of *C. fracta* and *C. protothecoides* increased from 8.2% to 39.2% and 9.5% to 40.6% by volume, respectively, while the final pyrolysis temperature was increased from 575 to 925 K. The percent of hydrogen in gaseous products from the samples of *C. fracta* and *C.* protothecoides increased from 25.8% to 44.4% and 27.6% to 48.7% by volume, respectively, while the final pyrolysis temperature was increased from 650 to 925 K. The percent of hydrogen in gaseous products from the samples of *C. fracta* and *C. protothecoides* increased from 26.3% to 54.7% and 28.1% to 57.6% by volume, respectively, while the final gasification temperature was increased from 825 to 1225 K. In general, algae gaseous products are higher quality than gaseous products from mosses.

1. Introduction

For some time now we have been living with environmental dilemmas which challenge human creativity and capacity to venture sustainable solutions to protect the life on our planet and our existence upon it. Among these are the needs to protect fresh water and agricultural lands for food production, to combat the greenhouse effect and to produce energy from non fossil sources [1–8].

In a period when fossil hydrocarbons are likely to become scarce and costly, methods to convert biomass to competitive liquid biofuels are increasingly attractive. In recent years considerable attention has been focused on lowering biofuel costs, GHG emissions, and land and water resource needs, and on improving compatibility with fuel distribution systems and vehicle engines. Policy priorities should be aligned with these research and development objectives as well as with other policies addressing climate, agriculture, forestlands and international trade [9–22].

Competitive liquid biofuels from various biomass materials by chemically and biochemically have been found promising methods for near future. Liquid biofuels may offer a promising alternative to petroleum based transportation fuels. There are two global liquid transportation biofuels: bioethanol and biodiesel, respectively. Among emerging feedstocks, jatropha currently can be converted to biodiesel with commercial processes, while processes capable of converting algae, crop wastes, perennial grasses, wood and wood wastes are still at pre-commercial stages [23–26,15,27,13].

Algae use enormous amount of CO_2 removing from power plant emissions. Allied to this is the enormous capacity of the algae to convert CO_2 into biomass, liberating via photosynthesis more oxygen for the atmosphere than forests. An additional advantage of algae is depolluted the waters by absorbing the urea expelled by these animals and at the same time increases the CO_2 conversion

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into biomass. The algae can then be converted into various kinds of biofuel using liquefaction, pyrolysis, gasification, extraction and transesterification, fermentation, and aneorobic digestion [28–35].

Produce biofuels such as biodiesel via transesterification of algal oil, and alcohol from microalgae biomass via hydrolysis and fermentation are promise well the future. Biomass conversion processes fall into three major categories: chemical, biological, and thermochemical [36–39]. The most efficient processes may be those that combine two or more processes and use the entire plant. Transesterification to produce biodiesel is more energy-efficient than fermentation to produce ethanol [40–42].

Bioethanol production from microalgae begins with the collection and drying of algae that have been cultivated in a suitable for water environment. In the next step of the process, the algal mass is ground and hydrolyzed and then the hydrolyzed mass is fermented and finally distilled [33].

One hectare algae farm on wasteland can produce over 10–100 times of oil as compared to any other known source of oil-crops. While a crop cycle may take from three months to three years for production, algae can start producing oil within 3–5 days and thereafter oil can be harvested on daily basis. Algae can be grown using sea water and non-potable water on wastelands where nothing else grows. It is firmly reinforced that algae' farming for biofuels is expected to provide a conclusive solution to food vs. fuel debate [43]. The carbon dioxide fixation and the main steps of algal biomass technologies are illustrated in Fig. 1.

Microalgae are photosynthetic microorganisms with simple growing requirements (light, sugars, CO_2, N, P, and K) that can produce lipids, proteins and carbohydrates in large amounts over short periods of time. These products can be processed into both biofuels and useful chemicals [44]. The microalgae species most used for biodiesel production are presented and their main advantages described in comparison with other available biodiesel feedstocks [45,46].

This paper presents a brief review on algal production technology and the main processes such as thermochemical, chemical and biochemical conversion of microalgae becoming energy. Energy conversion using thermochemical, chemical and biochemical conversion processes will produce biodiesel, bio-oil, ethanol, hydrogen rich gas mixture, and methane, respectively.

2. Biofuels

The term biofuel is referred to as solid, liquid, or gaseous fuels that are predominantly produced from biorenewable feedstocks [24]. There are two global biorenewable liquid transportation fuels: bioethanol and biodiesel. Bioethanol is good alternate fuel that is produced almost entirely from food crops [47–49]. Biodiesel has become more attractive recently because of its environmental benefits [50]. Biofuels can be classified based on their production technologies: first generation biofuels (FGBs); second generation biofuels (SGBs); third generation biofuels (TGBs); and fourth generation biofuels. "Advanced biofuels" include bioethanol made from cellulosic material, hemicelluloses, sugar, starch, and waste, as well as biomass-based biodiesel, biogas, biohydrogen, and other fuels made from cellulosic biomass or other nonfood crops [50,51].

Second and third generation biofuels are also called advanced biofuels. Second generation biofuels made from non food crops, wheat straw, corn, wood, energy crop using advanced technology. Algae fuel, also called oilgae or third generation biofuel, is a biofuel from algae. Algae are low-input, high-yield feedstocks to produce biofuels. Definition of a fourth generation biofuel is crops that are genetically engineered to consume more CO_2 from the atmosphere than they will produce during combustion later as a fuel. Some fourth generation technology pathways include: pyrolysis, gasification, upgrading, solar-to-fuel, and genetic manipulation of organisms to secrete hydrocarbons. On the other hand, an appearing fourth generation is based in the conversion of vegoil and biodiesel into biogasoline using most advanced technology.

Biofuels provide the prospect of new economic opportunities for people in rural areas in oil importer and developing countries. Renewable energy sources that use indigenous resources have the potential to provide energy services with zero or almost zero emissions of both air pollutants and greenhouse gases [52–56]. Biofuels are expected to reduce dependence on imported petroleum with associated political and economic vulnerability, reduce greenhouse

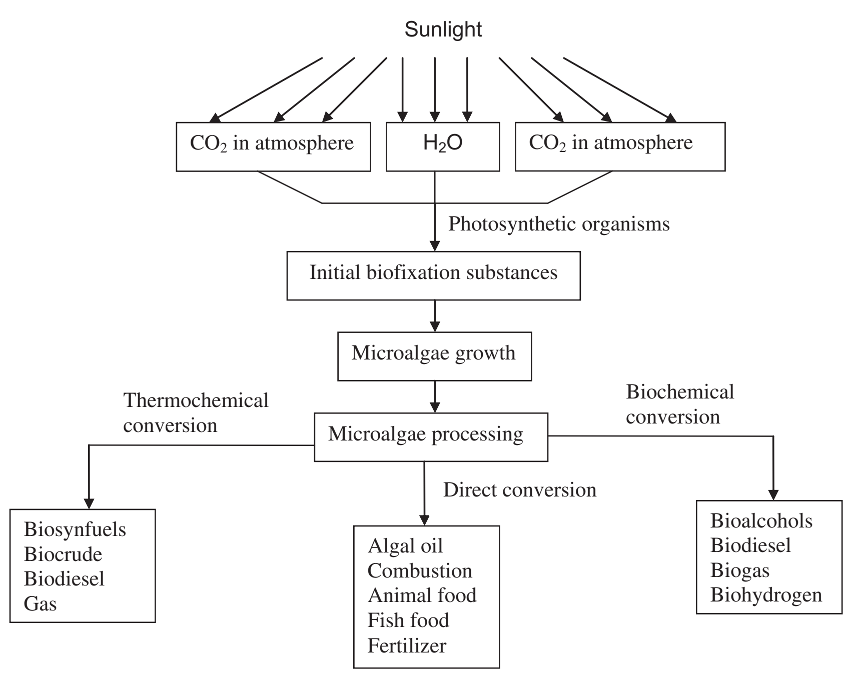

Fig. 1. Carbon dioxide fixation and main steps of algal biomass technologies.