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CONVERSION OF ALGAE BIOMASS INTO BIOFUEL BY NANO-CATALYSIS

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***Abstract*—Energy crisis is a familiar yet an uneasy word that people hear in their everyday life. In most countries non-renewable, carbon emitting fossil fuels are used to push their day-to-day mundane lifestyle which ultimately results in Global Warming. This article proposes the synthesis of third generation of biofuel, algae based biofuel, through Nano-catalysis. The third generation of biofuel is based on simple microscopic organisms (algae) that live in water and grow hydroponically. The main advantages of this project are higher energy per-acre than other bio-fuels, inherently renewable, non-consumption of feedstock, non-toxic, biodegradable and non-emission of sulphur. Public concerns over the impacts of nanotechnologies on security, health and the environment are also mentioned and discussed. But, a cautionary optimistic view is presented on the huge benefits of a careful penetration of nanotechnologies in the realm of biofuels and fuel additives, especially those dealing with human health.**

***Keywords*—algae, biofuel, nanotechnology, renewable**

I. INTRODUCTION

Nowadays, globally increasing energy demands and growing environmental concerns have highlighted urgent issues and big challenges in exploring alternative energy sources and eliminating the emissions of carbon dioxide and toxic pollutants in our environment. Mitigating these important factors is critical for the survival of the planet. The enormous global daily consumption of fossil fuels is of the order of 80 million barrels/day (equivalent to 12.7 million m^3/day) [1].
The use of alternative fuels has increased recently in order to overcome the high consumption rate of fossil fuels. Biodiesel is as clean fuel produced from renewable resources. Biodiesel is the major substitute for fossil diesel. The advantages of biodiesel (fatty acid methyl esters, FAMEs) include renewability, biodegradability, non-toxicity, low emission profiles, high flashpoint, and excellent lubrication of the system [2]. In addition, as an alternative fuel, biodiesel is virtually compatible with commercial diesel engines and practically there are no modifications required for the engine [3]. The viscosity of vegetable oils is 10–20 times higher than petroleum fuel. Therefore, using vegetable oils directly as a fuel can cause engine problems like injector fouling and particle agglomeration [4, 5]. These effects can be reduced or eliminated through Trans esterification of the vegetable oils to form alkyl esters [5]. This process decreases the viscosity of vegetable oils but maintains their properties similar to the diesel fuel. Biodiesel synthesis is chemically described as the Trans esterification of triglycerides (oil sources) into alkyl esters using an alcohol [5]. The resulting alkyl esters (i.e., fatty acid alkyl esters) with various alkyl groups have been utilized as biodiesel in industry [6].
Nanotechnology is generating a lot of attention these days and therefore building great expectations not only in the academic community but also among investors, the governments, and industry. Its unique capability to fabricate new structures at atomic scale has already produced novel materials and devices

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with great potential applications in a wide number of fields. Among them, significant breakthroughs are especially required in the energy sector that will allow us to maintain our increasing appetite for energy, which increases both with the number of people that join the developed economies and with our demand per capita. This needs to be done in a way that includes the environment in the wealth production equation as we gather more evidences of the human impact on the climate, biodiversity and quality of the air, water and soil [7].

A. Various generations of biofuels

A biofuel is a fuel that is produced through contemporary biological processes, such as agriculture and anaerobic digestion, rather than a fuel produced by geological processes such as those involved in the formation of fossil fuels, such as coal and petroleum, from prehistoric biological matter. Biofuels can be derived directly from plants, or indirectly from agricultural, commercial, domestic, and/or industrial wastes. [8] Renewable biofuels generally involve contemporary carbon fixation, such as those that occur in plants or microalgae through the process of photosynthesis. Other renewable biofuels are made through the use or conversion of biomass (referring to recently living organisms, most often referring to plants or plant-derived materials). This biomass can be converted to convenient energy containing substances in three different ways: thermal conversion, chemical conversion, and biochemical conversion. This biomass conversion can result in fuel in solid, liquid, or gas form. This new biomass can also be used directly for biofuels.

"First-generation" or conventional biofuels are made from sugar, starch, or vegetable oil. They are primarily derived from feedstock like corn, sugarcane and soya beans [9]. A bone of contention in the development of the biofuels industry is the present competition for feedstock between the food and fuel industries. This is commonly termed as Food vs. Fuel controversy [10]. Due to this setback, the usage of feedstock for the synthesis of biofuel came to a freeze.

The second generation of biofuels use lignocellulose raw material such as forest residues (sometimes referred to as brown waste and black liquor from Kraft process or sulfite process pulp mills) [10]. But the energy produced per acre was relatively lesser than the predecessor. The first and second generation fuels based on terrestrial plants are controversial because they require cultivation resources that could otherwise be used for growing food.

Third generation biofuels (biofuel from algae) use non-edible raw materials sources that can be used for biodiesel and bioethanol [10].

II. ALGAE BASED BIOFUEL

Biofuels derived from algae offer a great potential in view of the possible high yields and smaller area requirements. In addition, algae can play a role in carbon mitigation, as one way of growing algae is to feed them carbon-dioxide (CO_2), besides water and sunlight. Algae can be fed other substrates as well, because to grow, cost-effectively, on carbon dioxide there would be a need of concentrated sources of the gas, such as found in combustion off-gases from fossil fuelled power plants. Oil can form up to 50% of the algae mass, in contrast with the best oil-bearing plants – oil palm trees – where less than 20% of the biomass is made out of foil [11]. Algae carbohydrates can also be made into ethanol or gasified into bio-gas, or methane or hydrogen [12].

These micro-algae do not need soil and land, and because many of them thrive in water that is salty, brackish or just plain dirty – wastewater or agricultural run-off, for example – they need not compete for scarce fresh water resources either. Also important, they are far more productive than terrestrial fuel crops. A typical algae biofuel farm is shown in fig. 1.

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Fig. 1: Algae biofuel farm

Given plenty of sunlight, these organisms can photosynthesize enough organic matter, from carbon dioxide (CO_2) and organic nutrients present in the water they are suspended in, to double their mass several times a day. Depending on the species, up to half their mass is made up of lipids – natural oils. These can be extracted and used as straight algal 'crude', or refined to higher-grade hydrocarbon products ranging from biodiesel to bio jet fuel for aircraft. Strains of algae that produce more carbohydrate than oil can be fermented to make bioethanol and biobutanol.

Algae biofuels contain no sulphur, are non-toxic and are biodegradable. A number of strains produce fuel with energy densities comparable to those of conventional (fossil) fuels. They are made from a renewable resource that is carbon neutral: the emissions that result from burning the fuel are balanced by the absorption of CO_2 by the growing organisms.

III. PHOTO-BIOREACTOR

Even closed ponds may not be ideal, however, because the growth of a top scum layer tends to block the passage of light to algae lower down in the pond. This has prompted a number of pioneers to abandon ponds altogether, instead adopting fabricated enclosures termed photo-bioreactors (PBRs) that are more three-dimensional. A variety of designs have evolved, all aimed at maximizing photosynthesis by slowly circulating the algae, along with nutrients and CO_2, in closed transparent structures that are exposed to light.

A photobioreactor is a bioreactor that utilizes a light source to cultivate phototrophic microorganisms. These organisms use photosynthesis to generate biomass from light and carbon dioxide and include plants, mosses, macroalgae, microalgae, cyanobacteria and purple bacteria [13]. A typical photobioreactor is shown in fig. 2.

Fig. 2: Vertical photobioreactor

Within the artificial environment of a photo bioreactor, specific conditions are carefully controlled for respective species. Thus, a photobioreactor allows much higher growth rates and purity levels than anywhere in nature or habitats similar to nature. Hypothetically, phototropic biomass could be derived from nutrient-rich

wastewater and flue gas carbon dioxide in a photobioreactor.

IV. NANO-CATALYSIS

Algae development into biofuels must overcome a number of challenges before algae can become significant sources of commercial biofuels. Since algae also need water to grow, expansion of algae production may create a dilemma of water versus fuel, similar to food versus fuel dilemma discussed previously. Another challenge is the low natural carbon dioxide concentration in the atmosphere, hence the consideration of additional sources of carbon for algal growth in a commercial biofuels system. One response to these challenges may include the use of nanotechnology to turn algae into biofuels.

As way of examples, in 2009, the company QuantumSphere received a grant from the California Energy Commission to develop a nano-catalyzed algae bio gasification. Also in California, the Salton Sea receives large amounts of agricultural runoff, which sometimes create large algae blooms. These algae and similar biomass have been turned experimentally into methane, hydrogen and other gases [14].

Nano catalysis is a rapidly growing field which involves the use of nanomaterials as catalysts for a variety of homogeneous and heterogeneous catalysis applications. Heterogeneous catalysis represents one of the oldest commercial practices of nanoscience; nanoparticles of metals, semiconductors, oxides, and other compounds have been widely used for important chemical reactions[15].

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Although surface science studies have contributed significantly to our fundamental understanding of catalysis, most commercial catalysts are still produced by "mixing, shaking and baking" mixtures of multi-components; their nanoscale structures are not well controlled and the synthesis-structure-performance relationships are poorly understood. Due to their complex physico-chemical properties at the nanometer scale, even characterization of the various active sites of most commercial catalysts proves to be elusive.

Nano-catalysts are used for the trans-esterification of fatty esters from vegetable oils or animal fats into biodiesel and glycerol [16]. The nano-catalyst spheres replace the commonly used sodium methoxide.

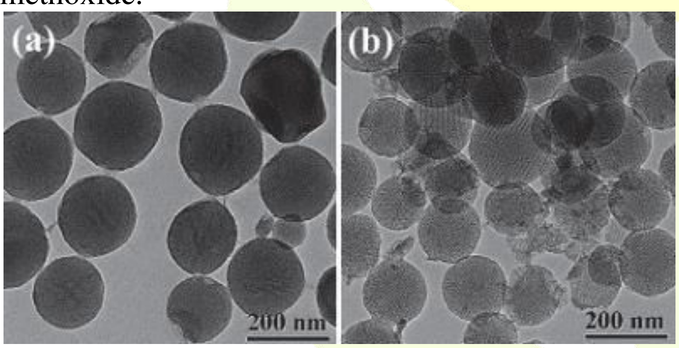

Fig. 3: Nano-particles harvesting oil from algae without harming the organism

[17]The spheres are loaded with acidic catalysts to react with the free fatty acids and basic catalysts to react with the oils as shown in fig. 3. This approach eliminates several production steps of the conventional process, including acid neutralization, water washes and separations. All those steps dissolve the sodium methoxide catalyst so it can't be used again. In contrast, the catalytic nanospheres can be recovered and recycled. The overall result is a cheaper, simpler and leaner process. In summary, the process claims to be economical, recyclable, to react at mild temperatures and pressures, with both low and high FFA (free fatty acid) feedstock, producing cleaner biodiesel and cleaner glycerol, greatly reducing water consumption and environmental contaminants, and can be used in existing facilities. Nano NiO catalyst supported on γ- Al_2O_3 microspheres of 3 mm size, KI/Al_2O_3 [18], and KOH/Al_2O_3 [19] have been developed to promote the catalysis of biomass.

V. Futurology

The research proposes the idealogy of synthesizing biofuel from algae by using nanocatalysts. Future research will focus on the fabrication of the proposed work in a medium scale, testing the output with real engine and to check the performance of the engine. Currently, the bio-fuel production from algae biomass is still at research stage. From our research, the information we collected above clearly indicates that the future of automobiles depend on bio-fuel, which is way more feasible and cheaper (on large scale production) comparing to other bio-fuel production methods.

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