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Algal Biomass as Feedstock for Biomethane Production: an Introduction

Editorial

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More than half of the world's population live in rural areas, out of which around 90% (over 2 billion) is from developing countries [1]. Energy and clean water are the two major concerns in the daily life of rural people. Furthermore, rapidly increasing energy demand and growing concern about environmental deterioration demands encouragement of the use of renewable energy resources as alternate fuels [2].

The current renewable energy resources such as solar, wind, hydro, geothermal and biomass represent up to 14% of primary-energy consumption in the world (Figure 1). Out of this, biomass (including terrestrial and aquatic) based energy contributes approximately 53% of the renewable energy consumption [3]. However, the biomass based fuel may compete with the food and fodder crops. Unlike current international approaches, Indian approach to biomass based fuels production is based solely on non-food feedstock to be raised on degraded or wastelands that are not suited to agriculture, thus avoiding a possible conflict of fuel vs. food security [4]. Growing biodiesel crop *Jatropha curcas* on marginal land as a protective barriers without competing with natural resources can utilize large percentage of wastelands in India (14.75%).

Various routes for energy production from biomass include production of biodiesel, ethanol, hydrogen, methane or direct burning based on the characteristics of the biomass [5,6]. However, minimal processing requirement prior to anaerobic digestion makes biomethane production an attractive option [7]. Biomethane produced from anaerobic fermentation of biomass is a versatile and

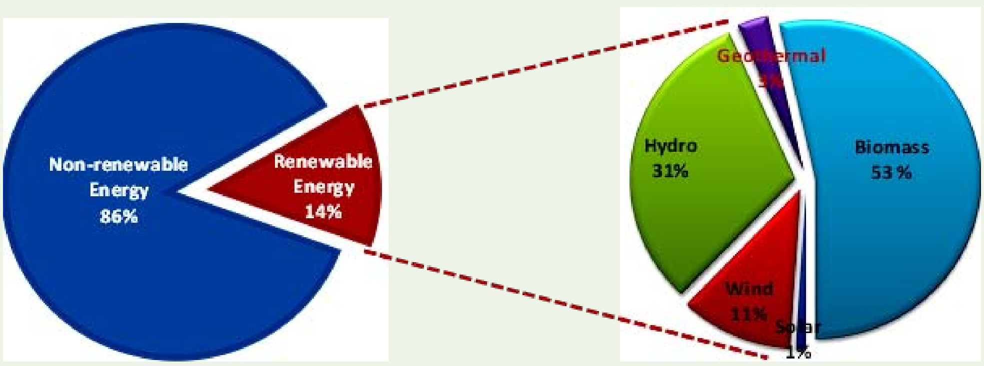

Figure 1: Scenario of primary-energy consumption in the world.

environment friendly fuel as it releases fewer amounts of greenhouse gases. The traditional substrates for anaerobic digestion include agro-residues such as sugarcane, rice and wheat straw, industrial effluents, cattle dung and other biodegradable wastes including municipal waste [8]. Among the above substrates, cattle dung is the most common feedstock for anaerobic digestion. Biomethane production form cattle dung is a well-developed and adopted technology in India and other developing countries [9]. In fact, Indian government had taken appreciable steps for the adaptation of biogas technology [10]. Despite of having high potential for biomethane production these conventional feedstock face challenges of low methane yields and larger-scale production due to price/land competitiveness. There is a need to look for alternative feedstock for future generation biofuels. Algae prove to be an attractive bio-energy feedstock due to their high areal productivity, high energy content and limited competition with food crops for arable land [11]. Moreover, algal biomass production can utilize nutrients from waste streams including rural sector grey water [2] and livestock effluent [9]. Hence, algae can serve dual roles: wastewater treatment agent and bioenergy feedstock. As an environment friendly biofuel feedstock, algae have attracted increasing interest for commercial production and many fuel companies including Indian Oil Corporation Ltd, ONGC are investing in research of algal biofuels.

Algae can be processed through a variety of routes for biofuel production (Figure 2). Various research groups/consortiums across the world are focusing on various options. Apart from R&D, algal based technologies for biodiesel (http://solazyme.com/) production has also been scaled up and commercialized. Although, algal biodiesel have higher calorific value (up to 30 MJ kg^{-1}), lower viscosity and density than lignocellulosic biomass based biodiesel, the significantly lower biodiesel yield makes it unviable [12]. In fact there is a negative energy balance for algal biodiesel production with the current process technology including energy intensive harvesting, drying and pretreatment [13]. Another major drawback is that the mass scale algae cultivation requires huge amount of expensive nutrients [13]. Hence, in order to make the algal biofuel economically viable, the energy imbalance in the process has to be improved.

One of the possible way to improve algal biofuel viability is the anaerobic digestion of algal biomass for energy production [14]. Anaerobic digestion of algae has several advantages: high energy yield, no biomass drying required, CO_2 from biogas can be recycled to cultivation for promoting algal growth and resulting in biogas upgrading, recycling of algal digestate as nutrient source for algae cultivation and possibility to produce heat and electricity from biogas through co-generation [12]. For biomethane production from algae, two alternative approaches (Biorefinery approach or whole cell digestion) are possible (Figure 3).

In the biorefinery approach, first the lipid are extracted from the algae for biodiesel and the residual biomass is anaerobically

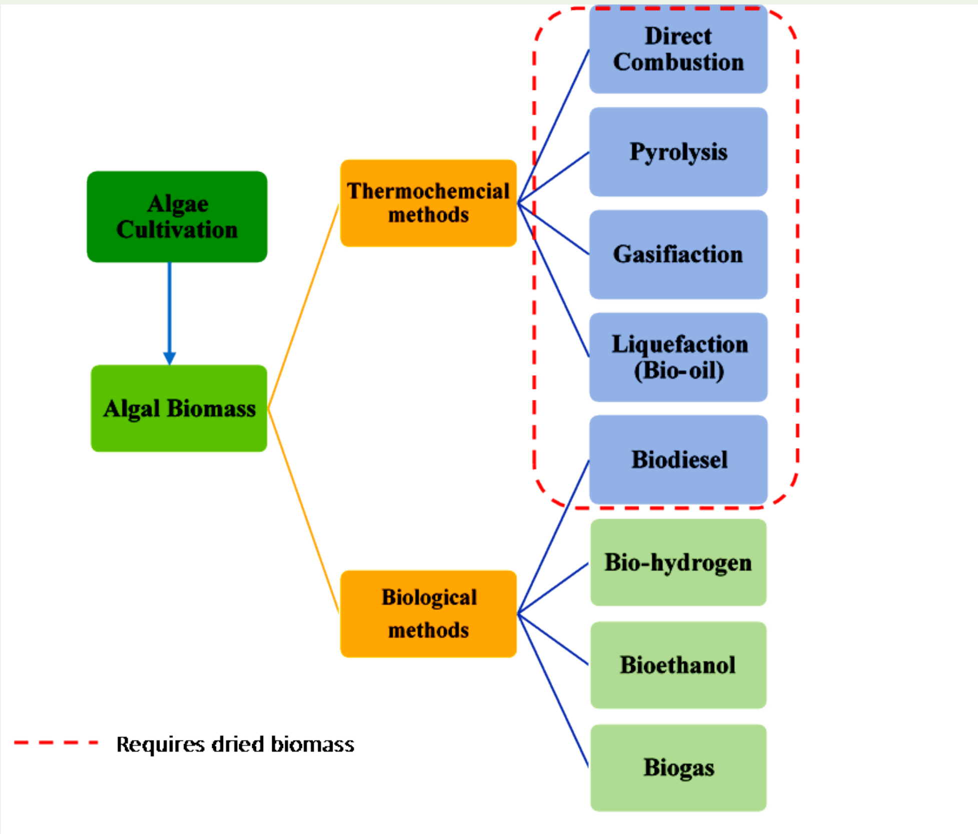

Figure 2: Various possible routes for algal biofuel production.

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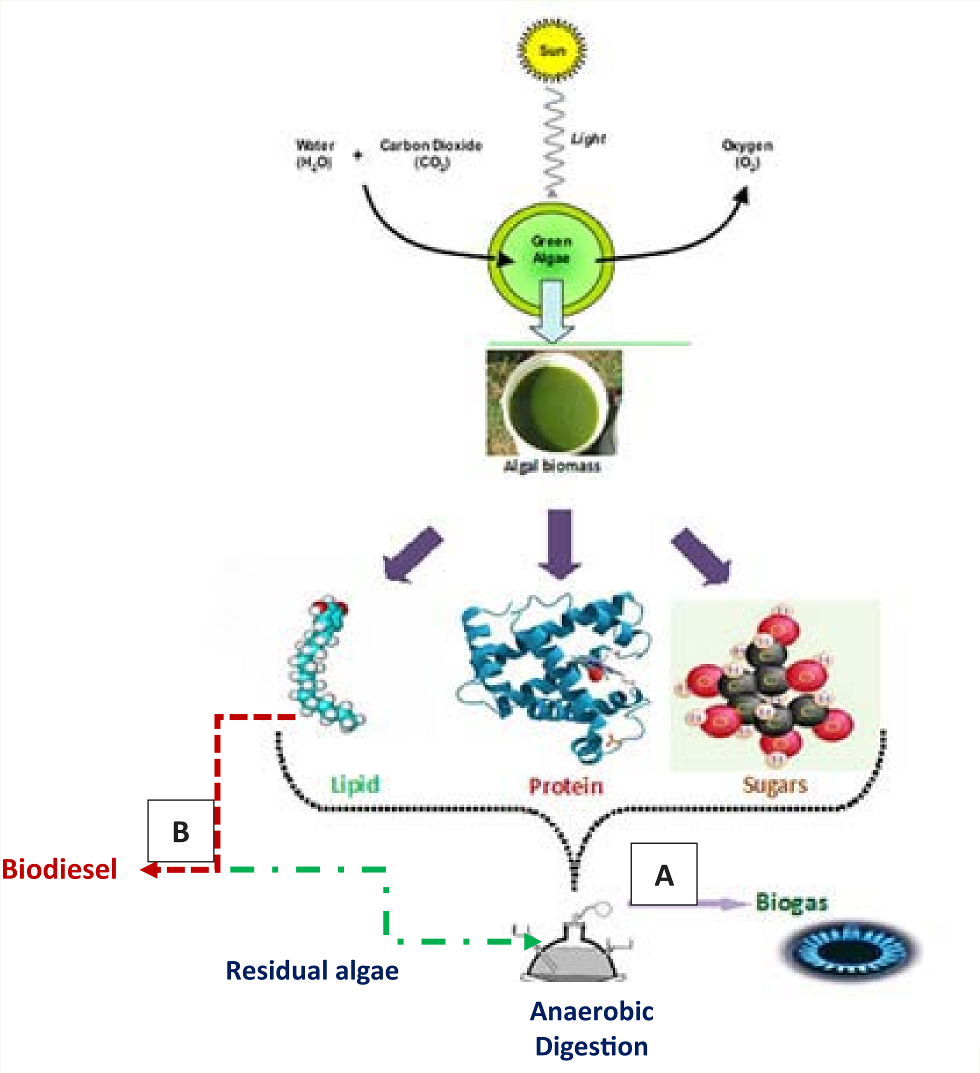

Figure 3: Photosynthesis of algae and alternative approaches for energy recovery through anaerobic digestion of (A) whole cell and (B) lipid extracted algal biomass.

digested for energy recovery [15]. Although the energy balance under biorefinery approach is relatively improved as compared with biodiesel production alone, the net energy output remains much lower than that in case of while cell anaerobic digestion [12]. The added advantage of whole cell anaerobic digestion is that the algae having very less amount of lipid and rich in protein and carbohydrates may also result in positive energy balance [12]. Moreover, the liquid digestate resulting for algal digestion is a good growth medium for further algae cultivation. This results in the development of closed loop process for algal bioenergy generation [16].

In brief, algae have several advantages as biofuel feedstock over other substrates. Further, the whole cell anaerobic digestion for biomethane production is the better approach for bioenergy extraction form algal biomass. Moreover, utilization of wastewater steams including liquid digestate for algal biomass production further strengthens the feasibility of the algal based biomethanation.

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