Renewable and Sustainable Energy Reviews (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Algal bioethanol production technology: A trend towards sustainable development

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ARTICLE INFO

Keywords:
Bioethanol
Biofuel
Algae
Cultivation
Bioreactors
Sustainability

ABSTRACT

Fuel security, economics and climate change issues are creating a requirement for alternative renewable fuels. Bioethanol produced by algal biomass is becoming increasingly popular all over the world due to the sustainability of feed stock and environmentally friendly nature. This review paper describes the bioethanol production technology from algae using various cultivation, harvesting, extraction and commercialization techniques and its environmental perspectives. The economic sustainability of algae-derived bioethanol biofuel depends on the cost of production that could be minimized by producing valuable secondary by-products, which is the aim of current algal biofuel research. Future technologies with sufficient potential for maximum extraction capacity and minimal downstream processing using low cost feedstock will address the cost-effectiveness of renewable bioethanol biofuel.

1. Introduction

Sustainable energy is a big challenge for the growing population of the world. The world's population will continue to grow for at least several decades. Demand for energy will probably increase even more rapidly and the proportion of fossil fuels will increase as rapidly to meet the demand for motor vehicles as fuels and industries. Fossil fuel resources are exhausting from day to day, which has ultimately increased the price of petroleum fuels [1]. Moreover, many environmental issues like global warming have emerged with the incredible use of fuel reserves. Elated energy demands and global climate change interests have brought biofuels in burst. To meet current and future energy needs, environmental-friendly energy sources that are capable of being irreproachable, efficient, substituting, inexhaustible, cost-effective and low-emitting greenhouse gases are the need for time [2,3].

Exploitation of renewable energy sources is an appropriate first consideration in sustainable development. Liquid fuels such as bioethanol, biodiesel and pyrolysis oils, gases such as biogas (methane) and solids such as charcoal and fuel wood pellets produced mainly from biomass are called biofuels [4]. A number of fuels such as methanol, ethanol, biodiesel, Fischer-Tropschdiesel, methane and hydrogen can be made from biomass [5]. Biofuels derived from biomass bring many local environmental benefits [6]. Biofuels are essential because they renew petroleum fuels [7]. Many developed and developing countries find biofuels important to reducing dependence on foreign oil, reducing GHG emissions and achieving rural development goals [8]. Increased energy security, exchange rate savings, reduced environmental impact and socio-economic problems are the main achievements of biofuels [9,10]. Many conventional biofuels are encumbered with higher production costs and therefore, uncompetitive retail prices [5,11]. However, political support through mergers and tax credit policies has allowed some types to penetrate the market for consumer fuels, with sugar ethanol in Brazil being an excellent example [12].

The production of bioethanol in the world has increased rapidly in the few years. In fact, production rose from 1 billion liters in 1975 to 86 billion liters in 2010, and production is expected to exceed 160 billion liters by 2020 [13]. However, the depletion of water sources and the use of arable land have put the viability of bioethanol under the scanner. The extreme use of arable land to produce biomass for bioethanol production may lead to a deficiency in basic food crops

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http://dx.doi.org/10.1016/j.rser.2016.12.126
Received 25 November 2015; Received in revised form 13 December 2016; Accepted 26 December 2016

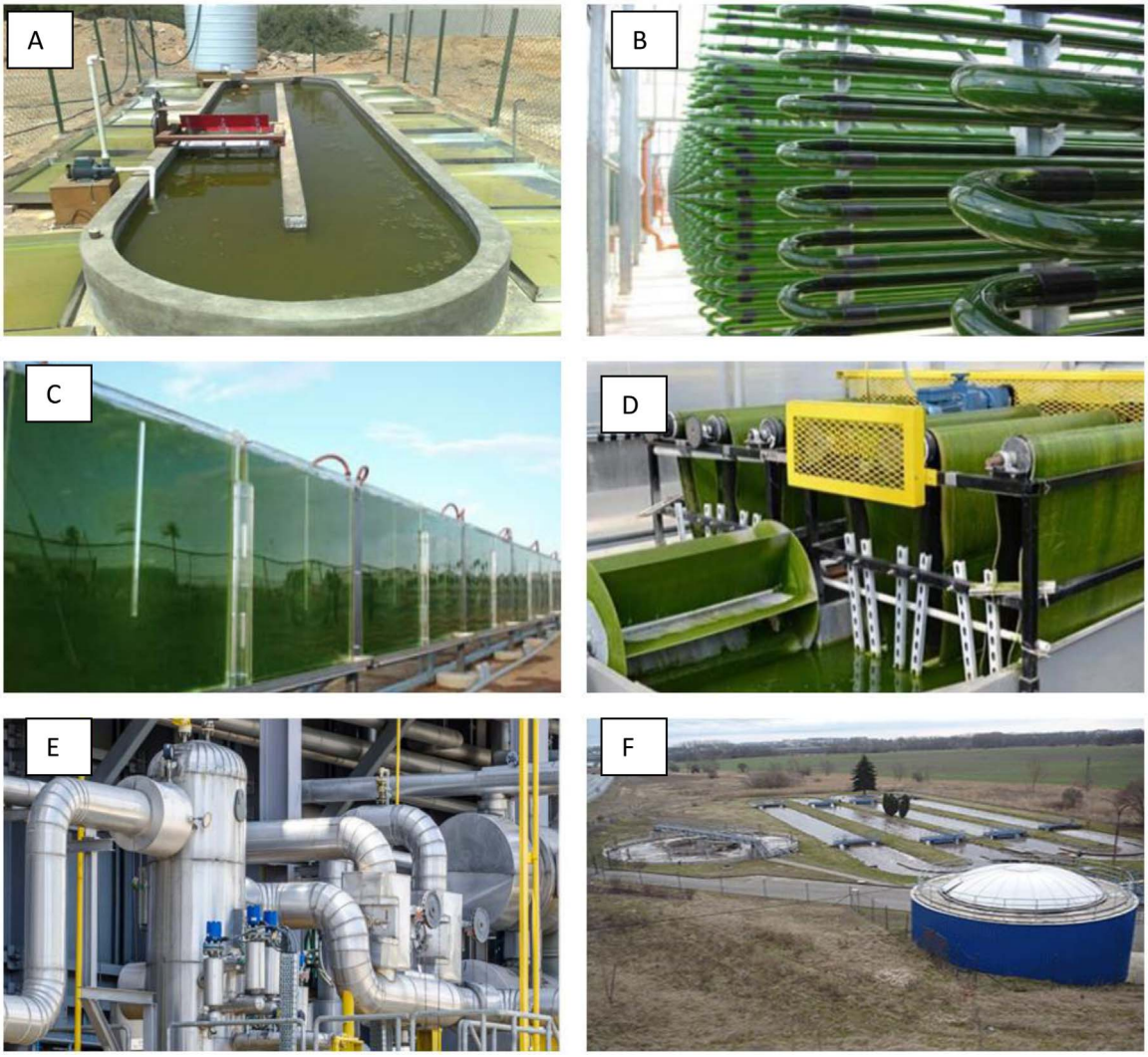

Fig. 1. Different cultivation systems for algal cultivation A) Open ponds B) Tubular PBRs C) Flat PBRs D) Biofilm based PBRs E) Fermentor cultivation F) algal biomass cultivation using waste water.

such as corn, soybeans, wheat, barley and sugar cane [14]. So there are many conflicts and debates about their sustainability [15]. To alleviate these problems, algae are gaining more attention as an alternative renewable source of biomass for the production of bioethanol [16]. The idea of using algae as a raw material for energy production dates back to the late 1950s, but now it is taken seriously [17]. Algae are huge group consisting of many thousands of different species that endure the option of wanted species according to the working environment. They are found mainly in freshwater, marine and terrestrial ecologies. Most algae species do not primarily require fresh water and can also grow under extreme conditions, such as warm or cold deserts, brackish habitats, acid waters having large quantities of heavy metals, sea deep waters and hydrothermal outlets [18–22]. Certain green algae like *Trentepohliales* are completely land-dwelling and never found in marine surroundings [23]. This implies that algae had the ability to grow in a diverse environment. Therefore, the use of algae as a renewable energy source for biofuel production will ensure self-sufficiency and energy security. This review will increase understanding on state-of-art current algal biomass technologies for bioethanol production and how these green technologies would address issues of environmental and energy sustainability in the future.

2. Feedstock for bioethanol production

Readily available and cheap raw materials are crucial to the economy of ethanol production and the viability of fermentation technology. Currently, extensive research is being carried out on the various processes that can be used to produce ethanol from heterogeneous raw materials [24,25]. Terrestrial plants are used as a plausible substitute to produce bioethanol and have gained attention all over the world. Yet owing to competition between food and fuel and land use, the use of plants for biofuel has become controversial and has raised disputes over its sustainability [26,27]. In addition, the plant-based-lignocellulosic raw material is a defiant that requires intensive labor and a high capital cost for processing [28]. Competitive supply of feedstock to a commercial plant is a difficult task, as is improving the performance of the conversion process to reduce costs [29]. Therefore, these procedures are currently not economically feasible. As a renewable alternative for the production of bioethanol, algae have reached greater consideration which is recognized as third-generation biofuels [30].

3. Algae as a feedstock for bioethanol production

Algae have received considerable attention as a source of biomass