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A review on third generation bioethanol feedstock

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ABSTRACT

The current issues of the depletion of fossil fuels reserve and environmental changes have increased the concern for the hunt of sustainable renewable energy for the future generations. Biofuels emerged as a promising viable alternative to replace the existing fossil fuels. Among these, bioethanol outstands due to its ability to substitute gasoline. However, the major challenge in bioethanol industry is the need to discover a suitable feedstock together with an environmentally friendly approach and an economically feasible process of production. The first generation and second generation bioethanol appeared unsustainable due to its impact on food security as well as inflated production process. These problems and concerns have directed the search for the third generation bioethanol (TGB) feedstock from marine algae. The integration of algae (microalgae and macroalgae) as a sustainable feedstock for bioethanol has gained worldwide attention in terms of food security and environmental impact. The research on algal utilization in bioethanol has increased in recent years and is expected to become the major drives in bioethanol industry. Therefore, the potential and prospects of the third generation bioethanol feedstock are being highlighted in this review. An insight into the current hydrolysis and fermentation technologies on algal conversion together with the economics and viability of the process are also accounted. This review can be crucial in providing ideas for the future studies that can be implemented in the commercialization of bioethanol from the third generation feedstock.

Contents

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1. Introduction

The rapid industrialization and high population growth are the two major factors which contribute to the global energy crisis. The man was so dependent on non-renewable feedstock like fossil fuels for their day to day needs. Unfortunately, the massive use of fossil fuels led to the problems such as depletion of its reserves, price fluctuation, negative environmental impacts and climatic change [1,2]. The alarming rate of dependence on fossil fuel reserves can be affirmed by the fact that majority of energy is produced from fossil fuels whereas only about 10% of it is produced from renewable energy sources [3]. Hence, the key challenge for the present world is to discover new renewable energy resources which can attenuate these problems for sustainable development of energy in the future.

Biofuels emerged as a promising solution to alleviate the energy crisis to a greater extent as there is substantial reduction of fossil fuels supply for the past several decades [4,5]. The main attraction which give biofuels superior benefits compared to fossil fuels are due to its ability to reduce the greenhouse gases (GHGs) emission, continuous supply of feedstock throughout the year, ease of cultivation, harvesting and transportation as well as the unique properties which contributes to the improvement of engine efficiency [2,6]. It is estimated that by 2050, liquid biofuels such as bioethanol is predicted to be on top of the 'biofuel ladder' due to their effectiveness in replacing gasoline for the transportation sector [7]. In other words, bioethanol can be termed as a promising fuel alternative globally because of its easily biodegradable nature which paves a way to address the current environmental issues [8]. The ease of availability of feedstock with respect to its geographical distribution plays an important role in the development and commercialization of bioethanol [9]. The biofuels industry including bioethanol is expected to open up a lot of opportunities for socio-economic development in various sectors [10].

The industrial potential of ethanol has been tested early in 1800 to be used as an engine fuel after the invention of an internal combustion engine. According to Morris [11], during the end of the 1800s, the sale of ethanol exceeded 25 million gallons per year since it was used as lamp fuel in the United States. However, the occurrence of Civil War induced the government to place a tax on ethanol in order to fund the war in which the action almost destroyed the ethanol industry [12]. The highlighted concerns over the limited use of ethanol continued until the oil crisis in the 1970s and the use of ethanol as a fuel was reborn in the late 1970s [12].

Almost 85% of the global production of biofuels is contributed by bioethanol within the period of 2000 until 2007 [13]. A wide variety of potential feedstock from all around the world can be utilized for bioethanol production [14]. But the search of a suitable feedstock for bioethanol has led to the rise of three generations so far namely first generation derived from edible crops, second generation from non-edible crops and third generation from the algal feedstock. At present, the biofuels research is focused on the third generation feedstock due to its ease of availability and immense potential for commercialization [15].

Up to now, most of the reviews published have focused mainly on the sustainability of microalgae as the feedstock for biofuel [15–20]. At some point, the uniqueness in the characteristics of macroalgae also holds an immense potential to be emphasized further. Therefore, the novelty of this review is to present the detailed utilization of both micro- and macro-algae in biofuels application particularly for the third generation bioethanol production. The importance of third generation bioethanol including its feedstock, geographical distribution, conversion technologies, economics and financial aspects together with its commercial viability are highlighted in this review. Technically, this review attempts to suggest some ways for a better commercialization of the third generation bioethanol with respect to Asian perspective. A thorough understanding of the significance of bioethanol production paves a way for its use as a versatile transportable fuel with excellent performance [21].

2. Bioethanol generations

In comparison to the fossil fuels, production of bioethanol based on biomass are more sustainable and widely distributed. Currently, there are three generations of bioethanol that have been flourished based on different feedstock. First generation bioethanol is derived from fermentation of glucose contained in starch and sugar crops [22]. USA and Brazil are the main producers of bioethanol worldwide utilizing corn and sugarcane while potato, wheat and sugar beet are the common feedstock for bioethanol in Europe [23]. However, the main drawback of first generation bioethanol is the threat of limitation in food supply which may affect the human world population as the feedstock are derived from food sources [24]. Millions of people around the world are currently suffering from hunger as well as malnutrition and moreover utilization of food resources for fuel can lead to an increase in food prices [25,26]. Ritslaid et al. [27] specified that first generation bioethanol is economically unreasonable, since the carbon contents of the plants are mostly lost during the conversion process. Considering this limitation, the researchers have come out with an idea that was more technologically efficient and versatile which is second generation bioethanol [28].

The term 'second generation bioethanol' emerged as a boon to overcome the 'food versus fuel' feud faced by the first generation bioethanol [29]. Second generation bioethanol also referred to as 'advanced biofuels' are produced by innovative processes mainly using lignocellulosic feedstock and agricultural forest residues [24,30]. The advantages of these feedstocks are the ease of availability which does not compete with food and thus eventually has a much lesser impact on the environment. However, the industrial scale-up of second generation bioethanol experienced the main hurdle due to some technological issues [31]. This refers to the high cost and medium yield of bioethanol due to its lignin composition [32]. Other main problems that are related to the second generation bioethanol production are the requirement of advanced technologies and facilities to aid the conversion process [33]. Furthermore, for the collection of feedstock such as woody biomass, logging and forest clearance are needed in which the act can destroy the nature [34]. Hence, there is a demanding challenge to develop bioethanol from marine plants as they have high potential to produce large amounts of biomass.

The emergence of third generation bioethanol provides more benefits as compared to the first and second generation. The third generation bioethanol is focused on the use of marine organisms such as algae. The public acceptance on the ability of algae to