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Review

Current status and strategies for second generation biofuel production using microbial systems

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ABSTRACT

Economic growth and industrial energy demand necessitate sustainable energy resources. The food vs. fuel issue means that first generation biofuels appear unsustainable. Therefore, biofuel production using lignocellulosic biomass clearly needs to be explored and promoted. However, due to technological barriers, the production of biofuel from lignocellulose (second generation biofuel) is currently not cost effective. Although microbial fermentation is an ecofriendly way to convert lignocellulose into biofuel, it will take time to become a commercial reality. Biofuels of different generations can contribute synergistically to fulfill energy demand. More research and government participation is needed to make the biofuel production process more feasible. This review focuses on the pretreatment of biomass, the production of biofuel (biodiesel, bioalcohol, and biogas) using microbial systems, and the various efforts that have been implemented to improve biofuel production.

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1. Introduction

The world energy demand is continuously increasing, which forces overexploitation of fossil fuel reserves [1,2]. The burning of fossil fuels contributes to increases in atmospheric CO_2 level, and poses a threat to the environment, as it is directly related to global warming [3]. To meet the ever increasing demand for energy and to counter greenhouse effects, alternate sources of clean and renewable energy need to be found [4]. Biofuel (biodiesel, bioalcohol and biogas) can be a suitable alternative to fossil fuel, as it is derived from biological processes (Fig. 1). Biofuel can be produced from different kinds of feedstocks, such as food crops, agriculture waste, municipal waste, industrial waste, waste cooking oils, and animal fats, by using different thermochemical or biochemical processes [5–8]. Thermochemical methods subject biomass to pyrolysis or gasification, while biochemical processes convert the biomass first into sugar, and then the sugar is applied to microbial fermentation [9–11]. Biofuel can be divided into different generational groups, based on the raw material used. First generation biofuel is produced using sugars, edible oil, and starch; second generation biofuel is produced from non-edible biomass; third generation is produced using algae (algal biofuel); while fourth generation biofuel is produced by capturing CO_2 or other advanced technologies [3,12]. The majority of biofuel currently produced is first generation. It is directly produced from food crops, e.g. the United States and Brazil use corn and sugarcane, while European countries use wheat and barley for ethanol production [13,14].

Recently, significant concern has been raised about first generation biofuel production due to the food vs. fuel issue, and has encouraged researchers to explore other avenues for biofuel production [15]. Second generation biofuel produced using biomass has a number of advantages compared to the first generation. Lignocellulose is the most abundantly available and unutilized biological material on earth, and can be a promising raw material for fuel production [16–18]. The biomass can be produced using less farmland, since the whole plant can be utilized as raw material, while first generation uses only seeds. Further different types of crops can be grown together, which requires less fertilizer, and makes the raw material more economic [19,20]. The use of lignocellulose as a raw material also has shortcomings, as it is mostly composed of carbohydrate, with little protein or other nutrients [21]. Third and fourth generation biofuels are more advantageous, but production of these remains at an early developmental stage.

Lignocellulosic biomass (cereal straw, sugarcane bagasse, agriculture residue) is composed of lignin, hemicellulose, and cellulose, and can be used as raw material for biofuel production [22]. However, this type of biomass is recalcitrant in nature, and microbes are not able to utilize it. Therefore pretreatment methods that may be physical, chemical, or biological are required to hydrolyze it to release free sugars (Fig. 1) [23]. Pretreatment releases sugars, but also leads to the production of other toxic byproducts (furan aldehyde, organic acid, and phenolic compounds) that affect microbial growth and fermentation [24]. Detoxification methods can be applied to remove toxic compounds from hydrolysate, but this adds to cost [25]. Various microbes have been reported to be useful for the production of biodiesel (*Cryptococcus* spp., *Rhodococcus* spp., and *Rhodosporidium* spp.), bioalcohol (*Candida* spp., *Saccharomyces* spp., and *Kluyveromyces* spp.) and biogas (*Clostridium* spp., and *Thermoanaerobacterium* spp.) [1,26–29]. Furthermore, different strategies can be used to increase the efficiency of biofuel production, such as metabolic engineering to increase substrate

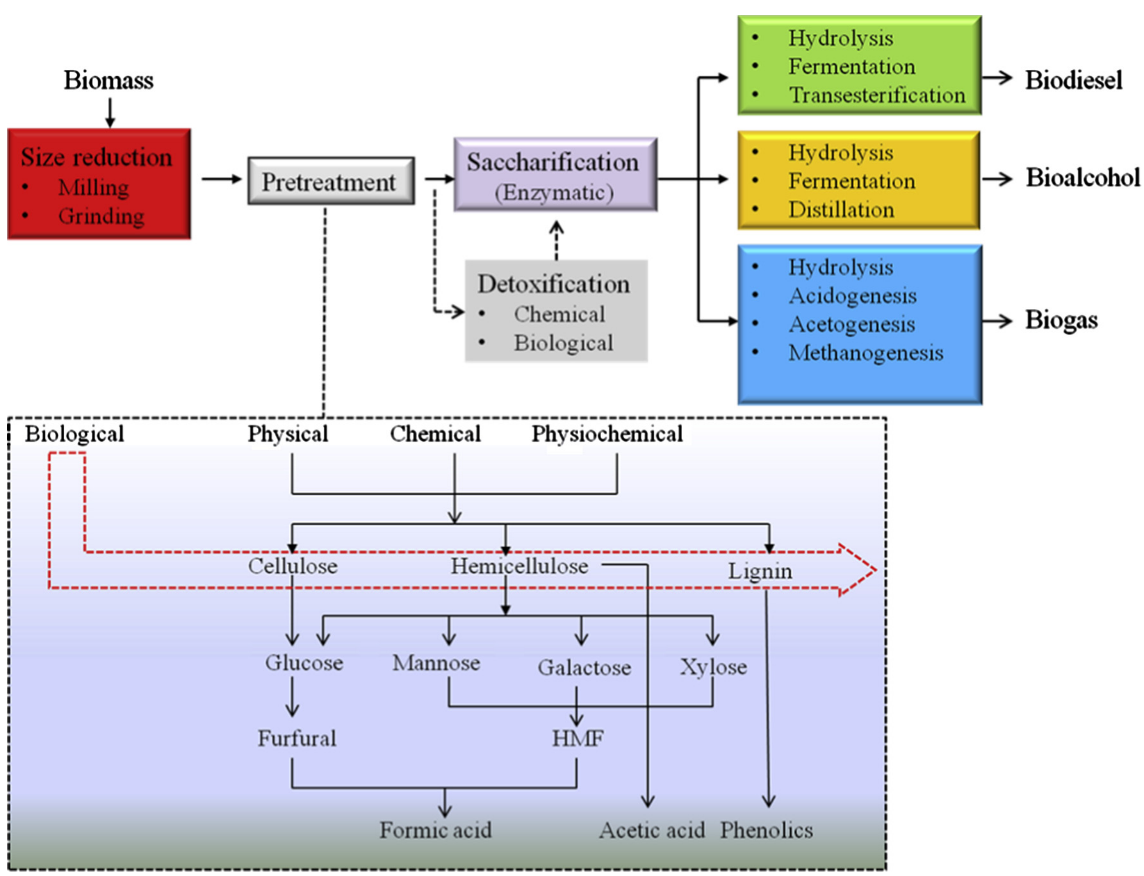

Fig. 1. Schematic presentation of second generation biofuel (biodiesel, bioalcohol and biogas) production using microbial fermentation.