Biological Treatment of Lignocellulosic Biomass to Bioethanol

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Abstract
This study highlights the biological treatment of lignocellulosic biomass to bioethanol using three major conversion techniques such as pretreatment, hydrolysis and fermentation. Energy from lignocellulosic biomass, especially bioethanol may contribute to a healthy atmosphere and economic development. Bioconversion of sustainable feedstock to bioethanol can enhance the energy dependence of our future generation. Different microbial treatments are summarised here with the recent trend and future aspect. This review article may pave to resolve the challenges on biological processing a reality for the large scale bioethanol production.

Keywords: Lignocellulosic biomass; Biological processing; Bioethanol

Introduction
Due to the depletion of reserve petroleum oil, its rising price, uncertainty in availability and environmental pollution has drawn attention worldwide towards the production of bioethanol as an alternative energy source of transportation fuel [1]. Therefore, in recent years efforts have been put in place to produce bioethanol from lignocellulosic biomass rather than from energy crops because of the consumption of land, water for their growth and rise in cost [1,2]. Lignocellulosic biomass consists of cellulose (major component), hemicellulose (complex carbohydrates) and lignin polymer [3,4]. The complex polymer of lignocellulosic biomass can be degrading by different microorganisms due to their potential synergic action of enzymes [5]. It is evident from the literature that biological pretreatment is advantageous over chemical, physicochemical, ammonia and steam explosion pretreatment methods because of the requirement of mild reaction conditions, low energy and formation of minimal toxic by-product [6,7]. The conversion of lignocellulosic biomass to bioethanol is mainly divided into three major steps such as pretreatment, hydrolysis and fermentation. The conversion techniques follow several biological methods based on different enzymes production for hemicellulose, cellulose and lignin degradation.

Microbial delignification
Biological pretreatment or so called delignification involves fungi such as white, brown and soft-rot fungi that are used to degrade or decompose complex lignin and solubilize hemicellulose without losing structural sugars [7]. White rot fungi are the most potential strains for the degradation of complex lignin polymer [8]. Most of the mixed cultures of white rot fungi were reported for biodegradation in producing high activity enzymes (ligninase, laccase, manganese peroxidise & lignin peroxidase) due to their synergistic actions [9,10]. Mixed fungal cultures could lead to a higher enzyme production through synergistic interactions, but the final results seem to depend on several factors such as particular species combination or mode of interaction among species, micro-environmental or nutritional conditions in the substrate under colonization [11]. Some of the widely studied white-rot fungi are P. chrysosporium, Pleurotus ostreatus Pycnoporus cinnarbarinus, Trametes pubescens, Cyathus stercolerus and Ceriporiopsis subvermispora which showed high delignification efficiency [6,7-12]. Several newly isolated microorganisms were also explored to enhance the delignification process [13-17]. Recent review explore on potential delignification of lignocellulosic biomass using genetically engineered fungi [3,4,18]. Some bacteria have also been characterized from Azospirillum lipoferum and Bacillus subtilis for delignification [19].

Biodegradation of cellulose and hemicellulose
This treatment of biomass is carried out to break the carbohydrate polymers to free sugar monomers. This method is known as hydrolysis or saccharification which includes an enzymatic method (fungal and bacterial or commercial enzyme),
steam explosion, dilute and concentrated acid methods for lignocellulosic biomass have been reported [20,21]. Among this, enzymatic hydrolysis is one of the most suitable options for the conversion of polysaccharide to monosaccharide by avoiding toxic by-product formation. A variety of microorganisms including fungi and bacteria was reported to degrade cellulotic and hemicellulosic biomass to monomer glucose. Due to the complex structure of pentose or hemicellulose, several different enzymes are needed for their enzymatic degradation. The cellulose enzymes employed for the hydrolysis of cellulose to glucose are mainly categorized into three groups: endo-glucanases, exoglucanases, and beta-glucosidases [1]. Hemicellulase and xylanase enzymes are used for the hydrolysis of hemicelluloses [21,22]. The microbial strains of Trichoderma, Aspergillus, Penicillum Altrernaria, Cellulomomas, Streptomycyes, Bacteriodes and Bacillus are reported to produce efficient enzymes such as xylanase, hemicellulase, lignocellulolytic activity (synergistic effects of celluloslytic and lignolytic) and hemicellulolytic activity for potential hydrolysis to improve ethanol production [23,24]. Researcher are developed some mutant or genetically modified fungal and bacterial strains for cellulose and hemicellulose degradation [24-26].

**Microbial fermentation**

Fermentation is the final step of the conversion of lignocellulosic biomass to produce bioethanol. Evaluation of bioethanol production by fermentation is of utmost importance to quantify the performance of the final process [1]. A variety of microorganisms (yeast, fungi and bacteria), and suitable technology implied for efficiency carbohydrates fermentation. Some of the microbes have ability to ferment both glucose and xylose [26-28]. A number of genetically engineered yeast and bacterial strains were reported for the production of bioethanol from different sugars using potential Saccharomyces, Pichia stipitis, Candida shehatae, Klebsiella oxytoca and Zymomonas mobilis strains [22,24,29]. Recently co-culturing and sequential use of yeast strains have been explored as promisingly, for the high-level bioethanol production [7,30,31]. Ethanologenic E. coli enhanced the yield of ethanol production using micro aeration process [7]. Genetically engineered Escherichia coli KO11 was reported as to produce efficient ethanol from both pentose and hexose sugars [32]. Protoplasts fusant strains were also reported as glucose and xylose-fermenting yeast [7,33].

**Future Work**

Efforts may be given to improve bioethanol production by developing genetically modified microorganisms and advance technology. Details cost analysis and economical feasibility of different bioconversion processes need to be studied at pilot scale for further large scale production of bioethanol from lignocellulosic biomass.

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