Green Alternative of Biomass Pretreatment for Bioethanol Production

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Introduction

In general, bioethanol production from lignocellulosic biomass requires three basic steps; pretreatment, saccharification (cellulose hydrolysis) and fermentation (Figure 1). Pretreatment is the main step which may bring domino effect to the subsequent steps for bioethanol production (Maurya et al., 2015). This initial pretreatment step is essential to open up the complex structure of lignocellulosic biomass.

Lignocellulosic biomass is composed of three primary polymers which are cellulose, hemicellulose and lignin that intricate together to form heteropolymer. Cellulose and hemicellulose are the vital parts that contributed to the fermentable sugars production prior to bioethanol fermentation. However, lignin component resided in the biomass act as a shield that protect the cellulose and hemicellulose. Lignin is also well known for its recalcitrant compounds that are resistant for biodegradation (Ceballos et al., 2015). Physicochemical pretreatment is the most common method used to pretreat lignocellulosic biomass. Nevertheless, chemical utilization in this method generates chemical waste that need to be further treated. Biological pretreatment is one of the environmental friendly approaches for effective delignification (Sindhu et al., 2016). In this mini review, type of biological pretreatment and fungal pretreatment are discussed.

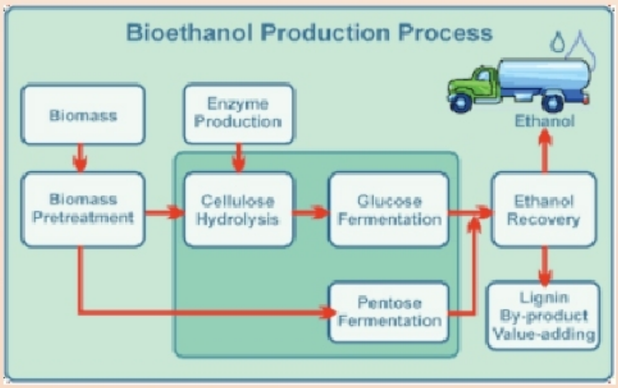

Fig. 1. Bioethanol production process from biomass
Source: https://www.gns.cri.nz

Type of Biological Pretreatment

The aim of biological pretreatment of lignocellulosic biomass is to delignify the biomass and increase the accessibility of holocellulose for further applications. Comparison of delignification method of lignocellulosic biomass is summarized in Table 1. Enzymatic pretreatment requires purification step of ligninolytic enzymes before applying to the biomass and this contribute to the high cost of this pretreatment. Although, fungal pretreatment takes a long time to delignify the biomass but the pretreatment cost is still considered low. Laccase mediated system (LMS) is similar to enzymatic pretreatment method with addition of mediator. Mediator acts as an electron transfer to oxidise non-phenolic structure in lignin (Rich et al., 2016). Integrated fungal fermentation (IFF) involves a fungus or consortium of fungi that are able to convert lignocellulosic biomass into ethanol directly. This fermentation does not require any other pretreatments or microorganisms to produce ethanol.

Table 1. Comparison of delignification method of lignocellulosic biomass

Delignification Method	Delignification	Sugar losses	Duration	Economic	Environmental Impact
Enzymatic	High	Low	2-48 h	High cost	Positive
Fungal	High	Low	6-45 days	Low cost	Positive
LMS	High	Low	2-48 h	High cost	Depends on the mediator
IFF	Medium	Some	1-12 weeks	Low cost	Positive

Source: Plácido and Capareda, 2015

Fungal Pretreatment

Fungi are the most widely used for delignification of lignocellulosic biomass in biological pretreatment (Figure 2). Fungi are categorized into three types of wood decay; soft-rot fungi, brown-rot fungi and white-rot fungi (Wan and Li, 2012; Hamed, 2013). White-rot fungi is recognized by its capability to produce ligninolytic enzymes. The enzymes are secreted out directly from the tip of the hyphae that penetrate into the substrate system. This phenomenon enhances the catalytic reactions of the enzymes and increases the nutrient accessibility from the substrate particle to the fungal cell (Mitchell et al., 2006). In contrast, the development of bacteria and yeast are only on the exposed surface of the substrate particle (Figure 3). The spaces between the bacterial cells are occupied by water which contribute to the thick paste texture of the biofilm.

Fig. 2. Wheat straw colonised with different fungi
Source: https://www.wur.nl

The environmental factors of fungal pretreatment could remarkably influence delignification of lignocellulosic biomass in the pretreatment system. Incubation temperature, biomass amount, initial pH of nutrient supplied to the system, initial moisture content and fungal inoculum are the crucial factors that are necessary in fungal pretreatment (Rouches et al., 2016). Furthermore, different biomass and fungi utilized in fungal pretreatment have different favorable conditions. Thus, an optimal environment for delignification needs to be investigated and established depending on the type of biomass.

Conclusions

Biological pretreatment particularly fungal pretreatment has a great potential to pretreat lignocellulosic biomass as it resembled the natural condition for fungal growth. This type of pretreatment may reduce the cost of bioethanol production and may even offer a chemical-free pretreatment process. Therefore, biological pretreatment process should be investigated further to examine the potential gaps of this system.

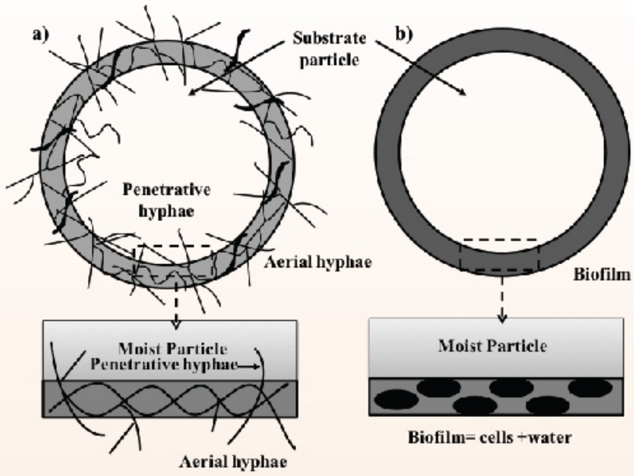

Fig. 3. Difference between (a) fungi and (b) bacteria growth pattern in biological pretreatment
(Source: Mitchell et al., 2006)

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