Bio-Fuel Production Technologies from Ligno-cellulosic Biomass and Asian Biomass Strategy

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Abstract

Biomass is a renewable and carbon neutral resource, because it can fix carbon dioxide from the atmosphere by photosynthesis. Recently, it is getting more attractive as alternative fuel resources from the viewpoint of global warming mitigation and fossil resource saving. However, in Japan, biomass resources are very limited and dispersive energy in terms of their sustainable production and utilization. Therefore, more intensive and concentrating research and development are required to convert biomass into energy at the higher efficiency.

Biomass Technology Research Center (BTRC) of AIST has been conducting the technical developments and organizing the social system for biomass utilization to establish a sustainable society not only in Japan but also in the world in terms of the three important targets, which are described as follows; 1) Ethanol production from woody biomass; 2) Biomass to Liquids(BTL) process, and 3) Study on Biomass Total System.

Research activities of BTRC are reviewed in terms of the priority projects on ethanol fermentation from woody biomass through mechanochemical and/or hydrothermal refining pretreatments, BTL(biomass to liquids) by clean gasification, F-T synthesis and catalytic upgrading reactions, and the evaluation of total biomass system by simulation. Especially, feasible utilization technologies of woody biomass resources are most important projects from the viewpoints of CO_2 reduction, because their amounts are abundant in Japan and Asian countries, and the woody biomass resources not only contribute to the substitution of fossil fuels such as coal and crude oil, but also considerably reduce the CO_2 emission due to their carbon neutrality and deliberate plantation for their sustainable utilization.

1. Introduction

Biomass is a renewable and carbon neutral resource, because it can fix carbon dioxide from the atmosphere by photosynthesis. Recently, it is getting more attractive as alternative fuel resources from the viewpoint of global warming mitigation and fossil resource saving. However, in Japan, biomass resources are very limited and dispersive energy in terms of their sustainable production and utilization. Therefore, more intensive and concentrating research and development are required to convert biomass into energy at the higher efficiency. Biomass Technology Research Center (BTRC) has been conducting the technical developments and organizing the

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social system for biomass utilization to establish a sustainable society not only in Japan but also in the world in terms of the three important targets, which are described as follows; 1) Ethanol production from woody biomass by non-acidic pretreatment, 2) Biomass to transportable liquid fuels via gasification(R&D on BTL process), and 3) Study on biomass total system and Asian biomass strategy for sustainable development.

2. Ethanol Production from Woody Biomass

Major components of wood are cellulose, hemicellulose and lignin. In a production process of a liquid fuel such as ethanol from woody biomass, monosaccharides obtained from cellulose and hemicellulose by hydrolysis (saccharification) are ferment to ethanol. The aim is to establish ethanol production technology with enzymatic saccharification in which low environmental load and high yield are expected. In order to enzymatically saccharify wood, the pre-treatment of lignocellulosic biomass, especially woody feedstocks is very important.

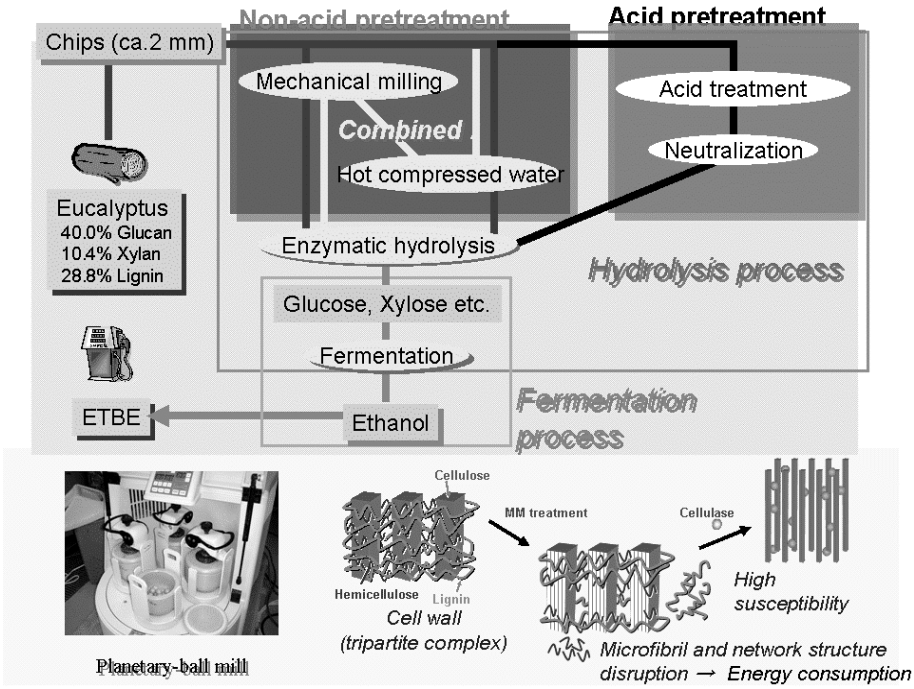

Figure 1. Scheme of non-acidic MC-HCW treatment of wood.

We combine a mechanochemical treatment(MC treatment) with a hydrothermal treatment by hot compressed water(HCW) and separate wood components for saccharification. The combined effect is described in Figure 1, indicating that the non-acidic MC-HCW pretreatment can effectively break down the strong cellulosic structure into microfibril level to be accessed by nano-level enzyme for the saccharification.

Mechanochemical treatment induces a chemical reaction by mechanical mill and hot compressed water hydrothermal treatment degrades wood components by hot water at more than 100°C. We will develop the economic and high performance techniques for activation of wood components. Monosaccharides obtained with enzymatic saccharification consist of glucose from cellulose, and xylose and other sugarsÅ@from hemicellulose. The microorganisms conventionally used for ethanol fermentation, however, cannot ferment xylose into ethanol.

The developments of thermophilic ethanol-fermenting bacteria which are suitable for simultaneous saccharification and fermentation of pretreated wood materials and also able to ferment both glucose and xylose, are implemented in the center, in order to establish high efficient ethanol production system from woody biomass. The research and development of AIST-original fermentation reactor system with adsorbents which can collect ethanol continuously are also under way. This type of bioetnaol production scheme is described in Figure 2

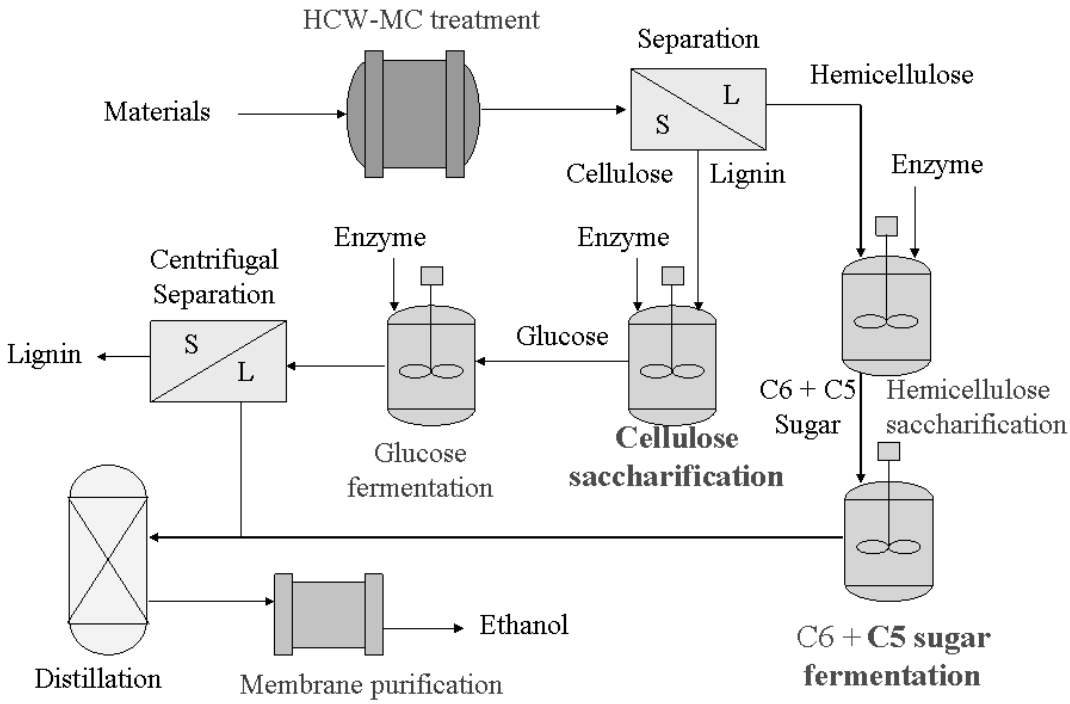

Figure 2. Total bioethanol production scheme from woody biomass
by Non-acidic HCW(hot compressed water) and MC(mechano-chemical) prepreatment.

3. Biomass to Liquids (BTL)

In order to transport overseas biomass to Japan, it is important to convert bulky biomass into liquid fuels such as gasoline and diesel. These fuels have characteristics of non-fossile resources and non-sulfur content. BTL process consists of gasification to synthesis gas (CO/H_2), gas cleaning by tar cracking and tar/ash removing, Fischer-Tropsch (FT) synthesis from CO/H_2 and hydrocracking/isomerization of wax products to increase diesel fraction. In gasification of woody biomass, a bench plant of fixed-bed gasifier(see Figure 3) was found to be effective for BTL application in combination with gas cleaning, storage, and Fischer-Tropsch(F-T) slurry-phase catalytic reactor. For hot gas cleaning, dry process by use of active carbon materials has been also developed. The produced char during the gasification of woody biomass was found to be good adsorbent for sulfur compounds such as H2S and COS. In the FT reaction, ruthenium-based catalyst was found to be active and hydrocarbon products were detected (Figure 4).

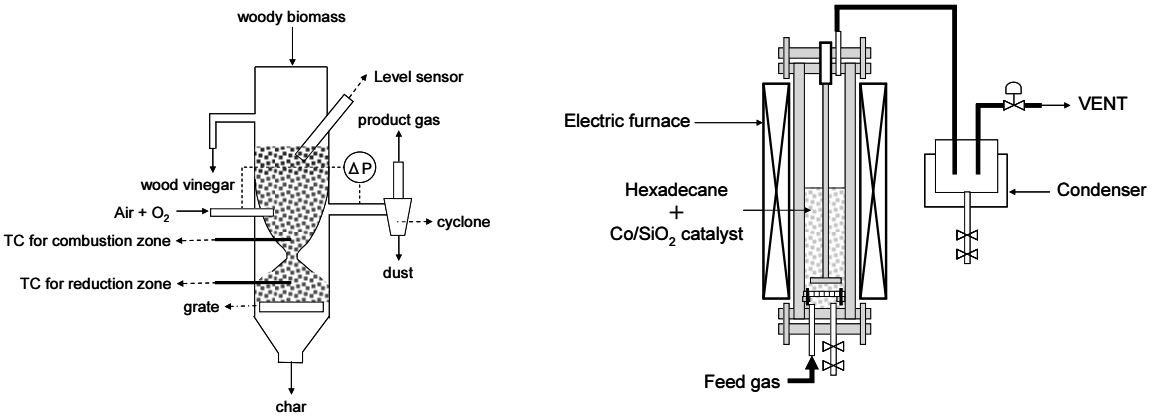

Figure 3. Fixed bed gasifier of woody biomass and Fischer-Tropsch slurry-bed reactor for BTL.

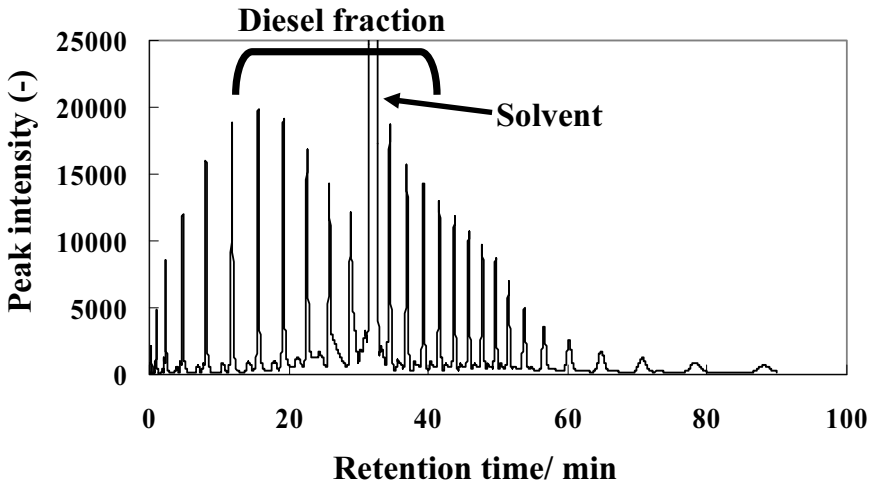

Figure 4. Compositions of BTL-FT diesel fuel.

4. Biomass Total System Analysis

Not only technology development but also system development is important to introduce and promote biomass utilization. It is need to construct the economical feasible total system.

In this study, ground database should be built, and process simulator for biomass system is developed. The optimization and economical/environmental evaluation are performed by using the simulator to propose the economically feasible total system (Figure 5). This is very important for the establishment of the total utilization system of various biomass resources in terms of the most optimized evaluation from the viewpoints of environmental and social acceptance, and most economical feasibility.

Biomass-Asia strategy is also our important target as described in Figure 6. This is essential to the worldwide utilization of various biomass resources for the sustainable development.

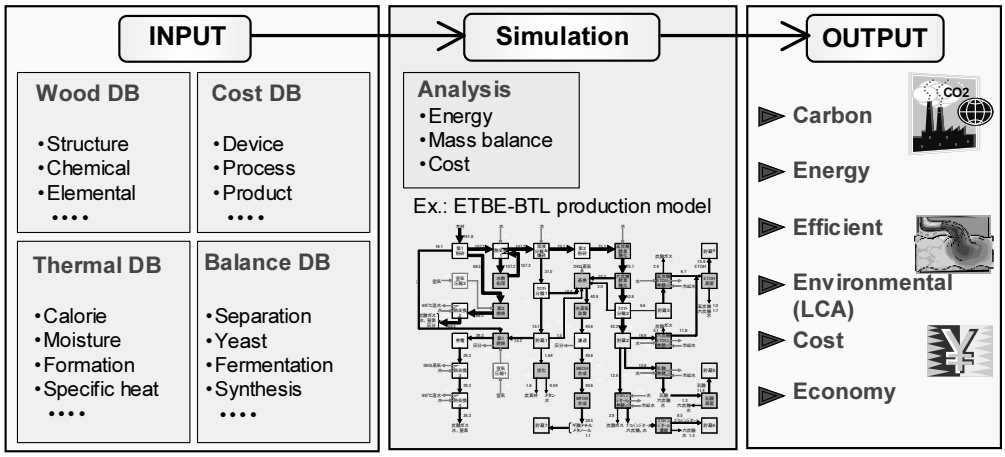

Figure 5. Biomass system simulation scheme.

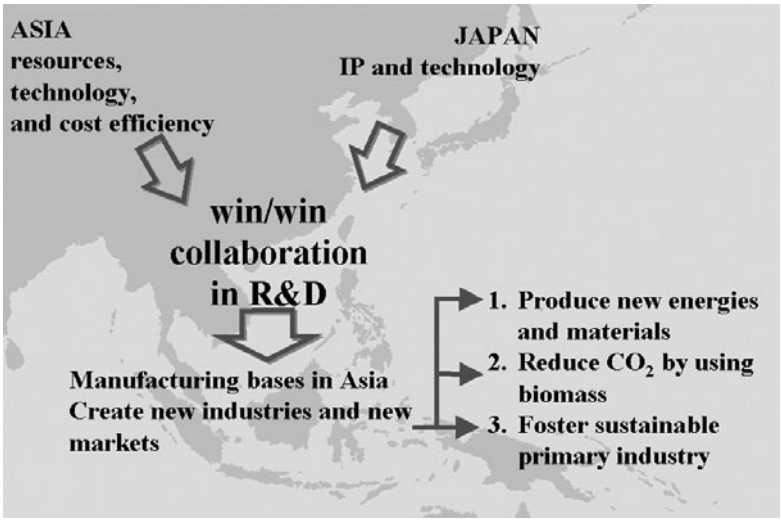

Figure 6. Asian biomass strategy for sustainable development.