Production of Wood-based Ethanol for Automobile Fuel

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Ethanol Production from Woody Biomass

When biomass, containing carbon fixed from carbon dioxide in the air by photosynthesis of plants, is burned, the net amount of global carbon dioxide remains the same. Furthermore, the use of biomass-derived ethanol as fuels results in the decreased energy dependence on petroleum. Fuel ethanol is already consumed in large quantities in Brazil and the United States. However, because it is produced from agricultural products such as sugarcane or corn at the present time, the future supply of these commodities is not assured considering the increasing food demand. Under these circumstances, the development of ethanol production technologies from plentiful woody biomass resources, which do not compete with foods, is anticipated.

The major components of wood are cellulose, hemicellulose, and lignin. The cellulose molecules in wood are systematically arranged, while the hemicellulose and lignin fill in the gaps between the cellulose molecules, giving the strength of wood. Among those components, only cellulose and hemicellulose have molecules composed of sugar and can be converted into ethanol by saccharification and fermentation.

In the conventional ethanol production procedure by saccharification and fermentation of wood, the hydrolysis with sulfuric acid has been the mainstream for saccharification. Even though the saccharification rate is higher in the sulfuric acid process, it is difficult to control the reaction due to high reaction temperatures. Therefore, problems arise, such as the generation of substances which inhibit fermentation, and the decrease of yield due to the excessive decomposition of sugar. Furthermore, the cost of collecting the sulfuric acid used and wastewater treatment is expensive, along with a high environmental load. In consequence, an enzymatic saccharification process, which does not exhibit excessive decomposition and has less environmental influence, is receiving much attention. However, appropriate pretreatment is necessary for enzymatic saccharification.

Development of Pretreatment Techniques for a Non-Sulfuric Acid Process

We are advancing the development of a hydrothermal and mechanochemical treatment process as pretreatment techniques for enzymatic saccharification which does not require large quantities of chemical agents such as sulfuric acid and is environment-friendly. In the hydrothermal process, it is possible to decompose and separate selected components of wood using hot-compressed-water (HCW).

Fig. 1 shows the process results using Japanese cedar in a HCW flow type reactor. With the HCW temperature increased to between 140 and 230°C, saccharide from hemicellulose, such as xylose, elutes. And at between 230 and 260°C, the glucose elutes from cellulose. In the mechanochemical treatment, the energy from crushing grinds the wood into fine particles and induces chemical reactions (bond breaking and formation).

Fig. 2 shows the results of a basic experiment to improve enzymatic saccharification with mechanochemical treatment. Without mechanochemical treatment, enzymatic saccharification generates very little glucose, however, increasing treatment time improved enzymatic saccharification degree significantly. Macroscopically, during mechanochemical treatment the wood is finely ground to approximately 20 µm, though with increased treatment time the wood cannot be ground any smaller.

Detailed analysis has shown that mechanochemical treatment destroys the strong network of woody components, which enhances the mobility of cellulose molecule bundles and lets enzymes approach more easily, therefore allowing accelerated enzymatic saccharification. In the next stage, we will try to reduce treatment time and improve efficiency of saccharification by using additives that will not influence saccharification and fermentation and by the appropriate combination of hydrothermal and mechanochemical treatment processes.

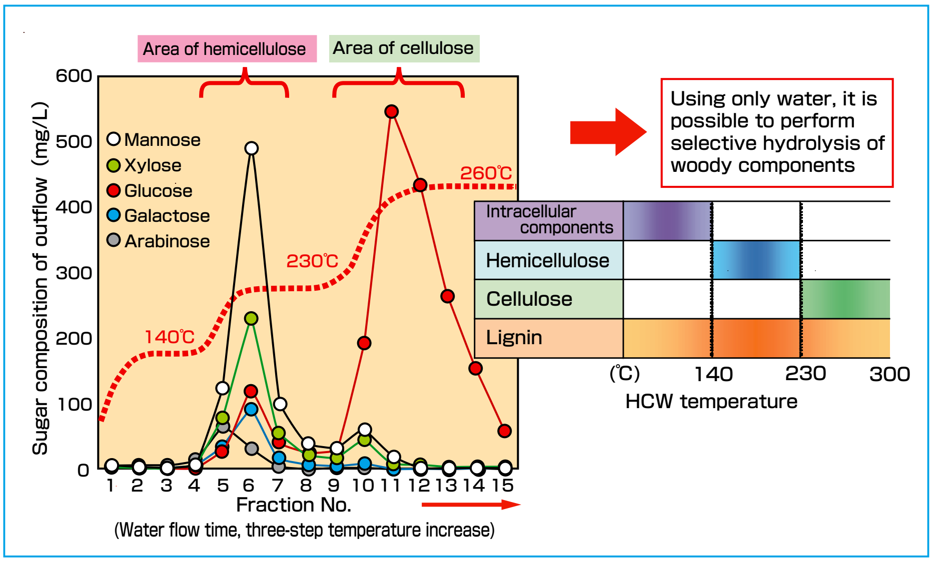

Fig.1 : Sugar composition of Japanese cedar extract treated with HCW using a HCW flow type reactor

Research and Development for Saccharification and Ethanol Fermentation

We also advance the research and development of saccharification and ethanol fermentation. Regarding saccharification, we will examine saccharification enzymes, such as cellulase and xylanase (xylanase breaks down xylan, a major structure of hemicellulose) to establish an enzymatic saccharification technology suitable for hydrothermal/mechanochemical pretreatment. Regarding fermentation, since the conventional ethanol fermentation yeast cannot use pentose originating from hemicellulose, the biggest research challenge will be to overcome this problem. We will develop microorganisms which can convert both pentose and hexose into ethanol at a high yield by the genetic engineering of yeast and thermophilic bacteria. And we will investigate a fermentation method to produce high yields of ethanol using the developed microorganisms . In this method, after hydrothermal-mechanochemical pretreatment and enzymatic saccharification of the woody biomass, the resultant product will be fermented with high concentrations of microorganisms using the agglutination and immobilized method in order to obtain high yields of ethanol.

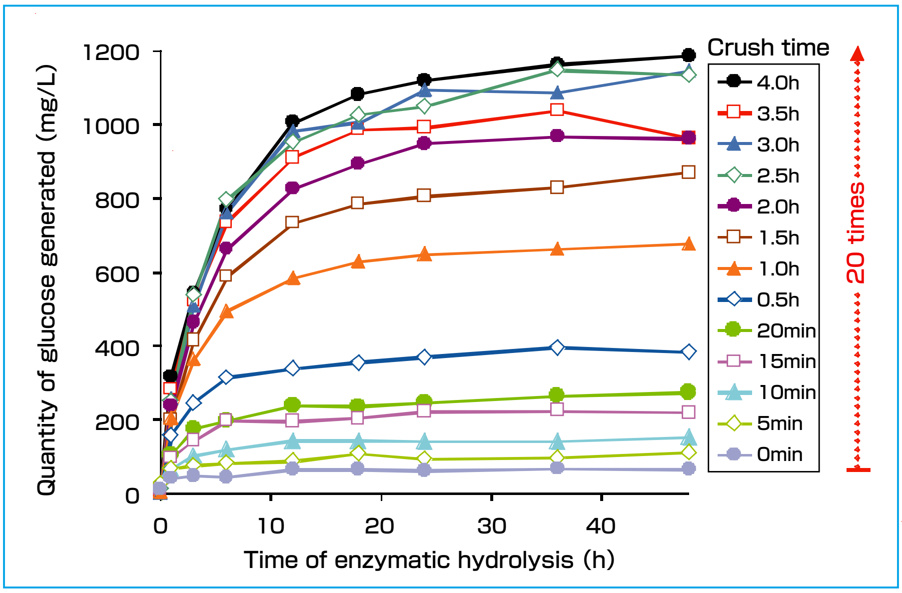

Fig.2 : Improved enzymatic saccharification of eucalyptus by mechanochemical treatment

Process Development and Utilization as Automobile Fuel

In the first phase of research and development, the hydrothermal treatment, mechanochemical treatment, rapid saccharification, fermentation using genetically modified microorganisms, and the essential techniques in each process will be investigated. In the second phase we would like to develop a practical combined method which consists of the hydrothermal, mechanochemical and chemical treatments, and simultaneous saccharification and fermentation (Fig. 3). In addition, we will work on the research and development of ways to add value to lignin and wastes as polymer materials, which cannot be utilized in saccharification and fermentation, in order to improve the profitability of an integrated woody biomass utilization system.

To be used as automobile fuel, ethanol can be simply mixed with gasoline. However, its utilization as Ethyl Tertiary-Butyl Ether (ETBE), obtained in a reaction between ethanol and isobutylene, has attracted much attention recently. ETBE is an excellent gasoline additive because it has a higher octane number than ethanol and is easily handled as it is not hygroscopic like ethanol. Since both ethanol and ETBE can be used directly in the existing cars, their wide use is expected as a fast acting countermeasure to global warming.

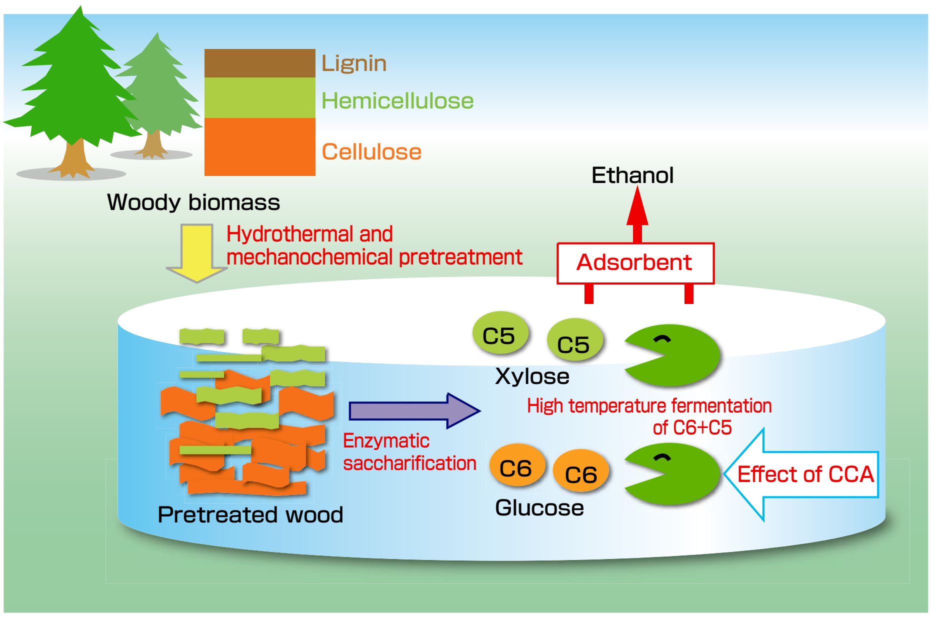

Fig.3 : Outline of the next generation high-yield bio-ethanol production technology from woody biomass
Under high temperature, saccharification and fermentation are performed simultaneously. The produced ethanol is collected using an adsorbent.