Technological Innovation of Bioenergy

By Hideaki YUKAWA

1. Introduction

The United States threw strong support behind the biomass resource-based energy/chemical-manufacturing industry (called the biorefinery industry today) in the 1990s, positioning it – together with the IT industry – as a new, important industrial sector for the 21st century. To spur technological development, the country in 1999 designated the biorefinery industry as its strategically important science theme under a presidential decree, prompting industrial circles to boost research & development efforts. Against the background of the 2006 State of the Union address, in which President George W. Bush pledged support for biofuels, coupled with soaring crude oil prices, production of biofuels based on food resources increased sharply. A subsequent spike in food prices and excessive burdens on the environment stemming from the cutting down of rainforests have globally aroused concerns and debate over "negative effects." Currently, international environmental nongovernmental organizations (NGOs), UN agencies such as the Food and Agriculture Organization (FAO), member states of the European Union (EU), and other quarters concerned are strongly urging regulations meant to make sustainable biofuels indispensable and develop traceability technology so as to ensure sustainability.

This report introduces the current state and future of technological development to manufacture biofuels based on nonfood resources, paints the future of the biorefinery industry as a whole, and overviews technological development by the Research Institute of Innovative Technology for the Earth (RITE).

2. Overview of Cellulose-Based Ethanol-Manufacturing Technology

Economic Efficiency of Cellulose-Based Production Method

Manufacturing costs were estimated at about $1 per gallon before the crude oil price surge. Currently, however, those companies which announced plans to launch demonstration production in 2010-2011 put their target costs at $1.7 to nearly $2, a cost level that can be viewed as economically competitive versus oil-based gasoline. In order to attain that cost level, it is deemed essential to utilize "soft biomass" as material for cellulose, and create and produce new microbes based on post-genome technologies.

Soft biomass is a collective term for grass plants whose content of lignin is low relative to hard biomass, with switchgrass cited as one of the candidate materials. These materials have high growth potential and low hurdles to clear for use relative to corn and other commercial crops in terms of weather and soil conditions for cultivation. In addition, potential areas for cultivation are much wider. The combination of bioprocesses using soft biomass as material and microbes with high productive functions is expected to make it possible to produce ethanol that can compete well with crude oil priced at $25-$35 per barrel anywhere in the world.

Effect on CO_2 Reduction

There are numerous reports on the effect of reducing carbon dioxide (CO_2) emissions to be brought about when ethanol is used as an alternative source of fuel to gasoline. Some reports say little or negative effect is expected as far as technological levels for ethanol production remain unimproved. Today, however, the accepted theory is that use of 1 liter of ethanol will have the effect of cutting CO_2 emissions by 1.7 kg, thanks to a substantial improvement in technologies. Transportation has been criticized as a major factor contributing to CO_2 emissions since the adoption of the Kyoto Protocol in 1997. The widespread view that use of cellulose ethanol enables steep reduction in CO_2 emissions has had no small impact on automakers and major international oil companies.

Feasible Production Volume

The use of soft biomass makes it possible to produce ethanol in a one-digit higher level of volume per certain land area than under the current corn-based ethanol production method. In the United States, more than 200 million kl of ethanol are projected to be turned out in 10 to 15 years – a production level that is about a third of the current US gasoline consumption of 600 million kl.

3. RITE's Technological Development Efforts

The establishment of a highly efficient bioprocess holds the key to creating the biorefinery industry, including bioethanol. Based on a new concept, RITE has established a base technology, dubbed the RITE bioprocess, for highly efficient production *(Chart 1)*. This process features manufacturing chemical compounds, with growth of microbial cells artificially halted. Just like a catalytic agent in chemical processes, cells can be utilized under the newly developed bioprocess, which has led to higher production efficiency than that under ordinary chemical processes.

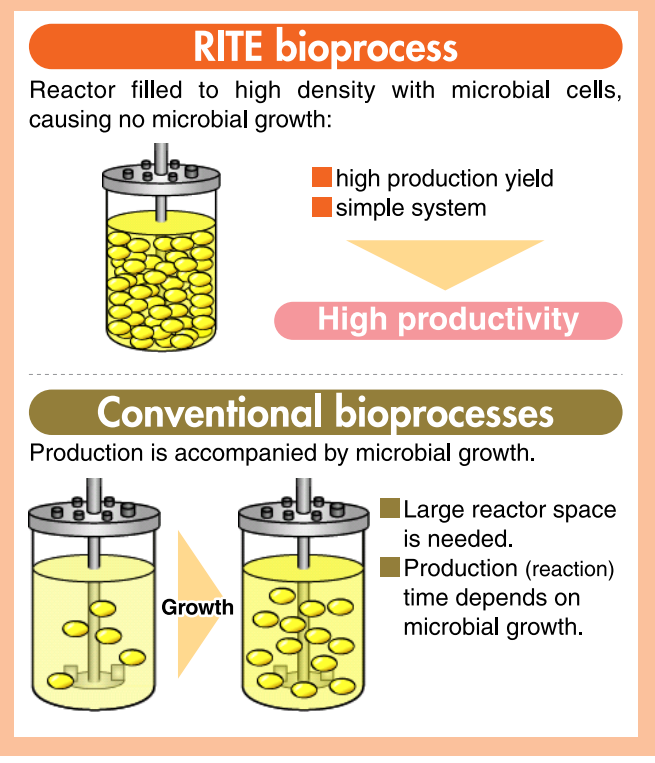
In order to utilize C5 sugars like xylose and arabinose, a RITE strain (*Corynebacterium glutamicum* R) used in the RITE bioprocess was genetically modified. As a result, the RITE strain-based bioprocess has enabled efficient use of materials, with simultaneous use of C6 and C5 sugars confirmed.

Under the RITE bioprocess, productivity does not decline due to fermentation inhibitors such as phenols and furans that arise in the pre-treatment of soft biomass. This is because growth of microbial cells remains halted and thus does not affect ethanol production. Fermentation inhibitors usually function by impeding growth of cells.

Now that achievement of elemental technologies for soft biomass-

CHART 1

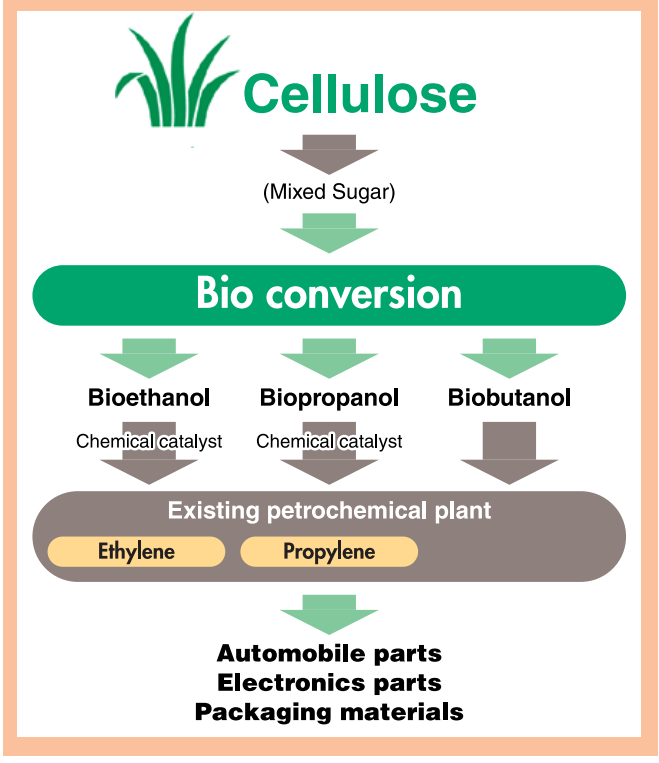
Features of RITE bioprocess



Source : Prepared by author

CHART 2

Green chemical industry



Source : Prepared by author

based ethanol production is in sight, RITE, together with Honda R&D Co., is seeking to launch commercial production of ethanol at an early date.

4. Next-Generation Fuel "Butanol"

At present, development of a butanol production process is the biggest research theme in the United States as butanol is viewed as the post-ethanol fuel. Butanol was produced in large quantities under a fermentation process during the years of World War I and World War II for use as aircraft fuel. Butanol, however, lost its economic efficiency, raising the need for the development of an innovative manufacturing process. Butanol can be mixed into diesel oil and is therefore raising high expectations as an alternative source of fuel to existing vegetable oil-based biodiesel oil that faces environmental problems.

BP of Britain and other international oil majors as well as other big businesses of the United States and Europe have already spent much on research and started a fierce R&D race. RITE recently suggested the possibility of establishing an innovative production process by applying genetic engineering. We are determined to make all-out efforts to create an innovative production process.

5. Conclusion: Outlook for Biorefinery Industry

Bioethanol, biobutanol and other biofuels are attracting strong interest in fostering the biorefinery industry. It must be remembered, however, that the creation of a "green chemical industry" is near at hand *(Chart 2)*. The new industry is designed to replace starting materials with biochemical products using existing petrochemical technologies. In particular, it is seen as an urgent challenge to make polypropylene, the main polymer for the automotive and household electrical industries, based on green sources as soon as possible. Moreover, construction of "green chemical plants" is expected to proceed at a rapid pace in the BRIC countries (Brazil, Russia, India and China) where strong growth of chemical product markets is expected.

The creation of the biorefinery industry with nonfood, renewable biomass resources as its starting materials is anticipated to bring about a paradigm shift in the industrial structure as well. JS

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