Microbiology Research Group

Biorefinery in the post-genomic era

Introduction

In recent years, the term biorefinery has received a lot of attention. The biorefinery concept is a new concept in which renewable resources such as biomass are converted to fuel and chemicals. This is in contrast to oil refinery technology by which chemicals and fuel are produced from fossil fuels oil refineries. In the United States, where this concept was developed, massive R&D in the fields relating to biorefineries has been the result of increased environmental awareness and rapid progress in biotechnology. The biorefinery concept is expected to develop into a key industry of the 21st century, and is envisioned to bring forth an industrial revolution of the 21st century because of the significance of its fundamental technology and effect it will have on the industrial paradigm.

A novel bioprocess technology at RITE.

The main technical hurdle in the development of biorefineries is the efficiency of conversion of the biomass resources used as raw material. A suitable bioprocess to accompany biotechnological modification of microbial cells must be developed in order to achieve optimal efficiency. At RITE, we have developed novel bioprocess techniques based on a totally different concept from the conventional fermentation method (Figure 1).

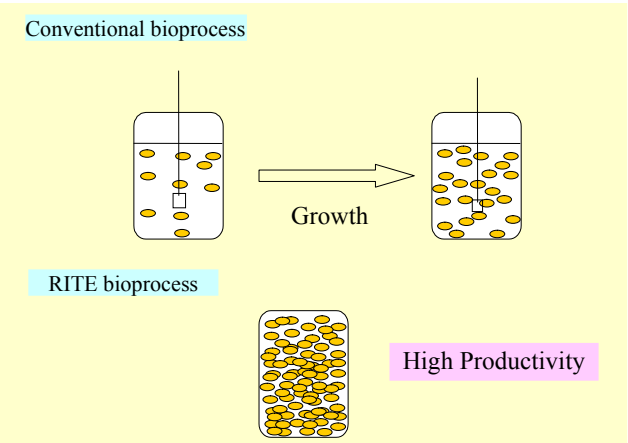

Figure 1 Illustration of conventional bioprocess and RITE bioprocess.

Unlike conventional bioprocesses, this novel process does not require "space" for growth (cell division). By using a compact bioreactor filled with "catalyst" (microbial cells) at high density, chemicals can be produced through continuous reaction. Microbial cells can be used in a similar manner as in chemical catalysis. Thus a highly efficient bioprocess can be established and productivity equivalent to or above conventional chemical processes can be expected.

This break-through technology enables us to overcome the shortcomings of conventional bioprocesses. By using this bioprocess as core technology, the RITE Microbiology Research Group, in collaboration with the private sector, is now advancing R&D aimed at environmental conservation. Our latest research regarding the highly efficient conversion of biomass to industrially useful chemicals is outlined below.

Applications in chemical production

* Succinic acid

Succinic acid is used in the manufacture of food and pharmaceutical products, surfactants and detergents, green solvents and biodegradable plastics. It is an ingredient in formulations that stimulate animal and plant growth, and an intermediate for chemical synthesis. Although known to be a fermentation by-product of anaerobic bacteria, succinic acid to date is mostly produced commercially by way of chemical processes utilizing fossil oil. However, cost effective fermentative production of succinic acid from renewable carbohydrate feedstocks for the sake of environmental conservation has recently become necessary. By adapting the RITE bioprocess to succinic acid production, we successfully synthesized succinic acid from biomass-derived sugars. The process is continuous and cost-effective, with the addition benefit of net consumption of CO_2 Now we are in collaboration with the chemical company, Showa Highpolymer Co., Ltd., toward industrial succinic acid production.

* Production of ethanol

Ethanol production using bioprocess technology gained prominence in response to the oil crises of the 1970s. However R&D for ethanol production in Japan unfortunately faded away due to the stability in the international oil trade in the 1980s and 1990s. In contrast, however, basic and applied studies aimed at bio-ethanol production in the USA continued. As a result, many companies producing ethanol from biomass are now being established. The estimated amount of bio-based ethanol to be produced in the USA is this year is 10 M tons, double the amount produced in the past 5 years. Most of the produced bio-ethanol is consumed as gasoline additive.

According to the plans of the USA Department of Energy, cost reduction of bio-ethanol to less than 20 cent/L should be realized by 2015. The basis of this reduction is the creation and utilization of ethanol-producing microbes optimized for bioindustry through biotechnology. However, it is apparent that the technology pursued by the USA cannot avoid the main drawback of conventional bioprocesses – requirement for space in a reaction chamber for cell growth. We developed a new cost-effective bio-ethanol producing process utilizing the RITE bioprocess. It may lead to a new horizon in bio-ethanol production.

* Bio-hydrogen

Biological hydrogen production occurs at ambient temperatures and pressures, thus lowering the energy requirements of the production process. In contrast, the well-established method for hydrogen production in which oil or natural gas is chemically refined occurs at high temperatures and pressures. It often produces carbon monoxide, which is an extremely harmful byproduct to fuel cells. Bio-hydrogen production has the merit of being devoid of this problem. However bio-hydrogen producing systems have the serious limitation of commercially low volumetric hydrogen productivity. Previous studies on bio-hydrogen indicate that the low volumetric productivity is attributed to low hydrogen production rate per cell and low cell density in the reactor, the latter which is a result of low growth rate under anaerobic conditions. The RITE bioprocess overcomes these limitations because microbial cells are not growing and can be used in a similar manner as in chemical catalysis. A bioreactor filled with the "catalyst" at high density. By using the RITE bioprocess, we achieved hydrogen productivity two orders of magnitude higher than that of conventional bio-hydrogen producing systems. At such productivity, a reactor the size of a coffee cup can generate enough hydrogen to supply the energy requirements of a household television set, while a 1.8-liter PET bottle-sized reactor can satisfy the electricity requirements of a typical household.

Conclusion

The key for biorefinery development is the underlying bioprocess technology. The RITE Microbiology Research Group has developed a new, highly effective bioprocess technology. By using this, we demonstrated the production of useful chemicals using biomass as raw material. We are currently advancing the R&D toward practical application in bio-industry.