Molecular Microbiology and Biotechnology Group

1. Introduction: The Current Status of Biofuels and Molecular Microbiology and Biotechnology Group

With crude oil prices topping $145 a barrel in June, 2008, worldwide prices of grains used in biofuel production also soared. At the 34th Group of Eight Summit held in Toyako, Hokkaido in July, 2008, the soaring of food prices was a big issue. By the second half of the year, attention had shifted to the chaos in global financial markets occasioned by failures of major financial institutions originating from the collapse of sub-prime housing loans in the United States. Though 2009 started with such an unprecedented and rapid downswing, the incoming US President brings renewed focus to an energy policy that supports production increases of biofuels such as bioethanol. Based on the US National Biofuels Action Plan (NBAP) announced in October, 2008 in partnership between United States Departments of Agriculture (USDA) and Energy (DOE), a progressive approach toward the commercial application of second-generation biofuels such as cellulosic ethanol from non-food based biomass is emphasized. The plan prospectively will contribute to the creation of employment and by supporting farmers producing biomass feedstocks for biofuels while at the same time addressing the environmental concerns of reduction of greenhouse gases. In the United States, to improve energy security and meet increasing demand for transportation fuel, former President Bush's "Twenty in Ten Initiative", aiming to reduce gasoline consumption by 20% in ten years, and the Energy and Independence Security Act (EISA) Renewable Fuels Standard goal of expanded use of 36 billion gallons of renewable fuel by 2022 were set forth. Accordingly, President Obama has emphasized acceleration of commercialization and use of biofuels.

In our group, we undertake joint research and development of bioethanol production technologies established under the "RITE-Honda Process" based on a novel and growth-arrested bioprocess. The goal of this project is to produce ethanol from soft biomass such as rice straw on a commercial basis. At the 75th Session of the Council of Science and Technology Policy held on May 19, 2008, the bioprocess was featured under the theme Current Science and Technology Trends: Contribution of Genetically Modified Micro-organisms to the Realization of Post-Oil Society. The characteristics of the bioprocess as a production system for bioethanol and commodity chemicals using recombinant coryneform bacteria were hailed as an innovative means to a low-carbon society of the future. Subsequently, the Cabinet Office and the Ministry of Foreign Affairs sanctioned a display of the bioprocess during the 2008 G8 Summit. The then Prime Minister of Japan Yasuo Fukuda emphasized biofuels in his discussions with the other G8 leaders. The advancements of the RITE-Honda Process were afforded special mention in his session with Germany Chancellor Angela Merkel (www.mofa.go.jp). Regarding biofuels, G8 leaders' statement included sustainable production of biofuels to be compatible with food supply and acceleration of effort toward research and development of second-generation biofuels from non-food based biomass. In October, 2008, RITE-Honda Research Team (Head; Hideaki Yukawa) won the 18th Nikkei Global Environment Technology Award's Grand Prize for efficient bioethanol production from rice straw. The RITE-Honda Process, which enables efficient production of bioethanol from non-food based biomass such as rice straw as an alternative fuel to gasoline, shows great potential for industrialization. It should enable us to meet increased energy demand without affecting food supply, consequently contributing to stabilizing food-supply while eschewing harmful traits that lead to global warming. Please refer to RITE Topics for a pictorial view of these achievements.

2. Current Trends in Biorefinery

Biorefinery production of fuels and commodity chemicals from biomass is based on advanced biotechnology, completely different from petrochemical technology. The products from biorefinery are made in a new production system based on C_3-C_6 building blocks, which is different from the conventional petrochemical system based on C_2 building blocks. There are two recognizable trends; one is, as discussed previously, commercialization of second generation biofuels, starting from cellulosic ethanol, and the other is green chemical industry, of which implementation is at hand. In green chemical industry, the starting material is the same as that of petrochemical products, except that it is made from biomass. Ethylene can be made from bioethanol, and propylene from biopropanol. The Petrochemical industry is turned into the green chemical industry, with "petro" removed (Fig.1).

Realization of the green chemical industry is presumed to be approaching reality in a few years, as the raw material, mixed C_6, C_5 sugars, can be produced cost-effectively. This is because large-scale production of bioethanol from soft biomass is in the final countdown stage. When realized, it should enable

production of "green" ethylene from bioethanol. Also "green" propylene can be produced from biopropanol by using the mixed sugars. Furthermore, there should be no concerns about product quantity as the amount of biomass needed for green chemical industry is much less than that needed for biofuels. Technology to produce bioethanol applied for ethylene is basically the same as for fuels, except for the effect on catalysis in ethylene production. The green chemical industry is at its very early stages.

3. Approach to Research

We have established the base technology for a growth-arrested bioprocess, christened the "RITE bioprocess" based on a novel concept (Fig. 2). The key to its enhanced efficiency is that, unlike conventional bioprocesses in which productivity is dependent on microbial growth, actual production under the RITE bioprocess utilizes bacterial cells under growth arrested conditions in the same manner as inorganic catalysts are used to produce chemicals. Because productivity occurs in lieu of growth, the RITE bioprocess is not hampered by the major limitations (STY: Space Time Yield) of growth-dependent conventional bioprocesses. Yields under the RITE bioprocess therefore are close to those of chemical processes. We have pioneered complete and simultaneous utilization of both C_6 and C_5 sugars under RITE bioprocess.

4. Future Development

In the joint R&D on bioethanol production by the RITE-HONDA Process, we aim to develop an industrial process to produce ethanol from non-food biomass resources. Further, we seek collaboration with an oil company and a trading company to fast-track the practical application of the bioprocess. We believe that technologies resulting from our R&D will contribute to global warming solutions. To produce useful commodity chemicals from biomass, work on the project, "Research and Development of Biorefinery Technologies", was commissioned in 2006 and funded by NEDO. As spelt out in a progress report prepared last year, our interim goal of a technology to enable production of 3 classes of chemicals, namely, organic acids, amino acids and sugar alcohols at 10g/L/h was achieved on schedule. We are committed to further research toward the final goal. In the meantime, other ongoing projects such as development of effective utilization of woody biomass, ethanol production from syngas gasified from biomass and development of utilization technology of water-soluble polysaccharides (produced by sea algae) as well as the next generation fuel (hydrogen, butanol) production from biomass feedstock under the themes, "Programmed Methods CO_2 Fixation and Effective Utilization Technology Development" are supported by METI. In preparation for a potential expansion of biomass demands, development of effective utilization technology is underway.

5. Conclusion

Biorefinery technologies have the potential to lead to an industrial paradigm shift in the 21 century, just as the blooming of petrochemistry in the 20 century drastically changed modern society. Our approach to collaborative research and development with the private sector should enable future application of the RITE bioprocess in the production of a broader range of chemicals and biofuels.

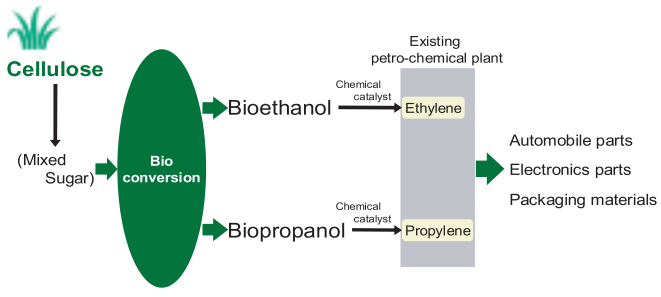

Fig.1 Green chemical industry

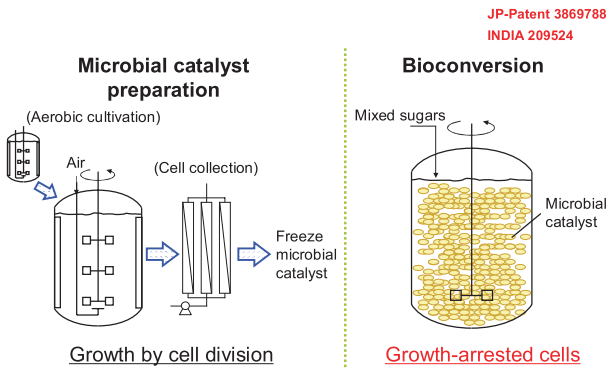

Fig.2 Highly efficient bioprocess –RITE bioprocess– (growth-arrested bioprocess)