MAKALAH UTAMA

BIOTECHNOLOGY: OPPORTUNITIES FOR CHEMICAL ENGINEERS

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1. INTRODUCTION

Biotechnology has been acknowledged as one of the important growth area in this century. In fact it has been widely predicted that the first century of the new Millennium will belong also to biotechnology which will is expected to bring unprecedented advances in human and animal health, agriculture and food production, manufacturing and sustainable environmental management [1].

What is biotechnology? The United Nations Convention on Biological Diversity defines biotechnology as:[2] "Any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use." Biotechnology has applications in four major industrial areas, including health care (medical), crop production and agriculture, non food (industrial) uses of crops and other products (e.g. biodegradable plastics, vegetable oil, biofuels), and environmental uses.

The main objectives of this paper are (i) to describe the different areas of biotechnology, (ii) the scope of biotechnology in which chemical/biochemical engineers can play active roles, and (iii) the biotechnology activities currently happening in Malaysia and at the Universiti Kebangsaan Malaysia.

2. DIFFERENT FOCUS AREAS FOR BIOTECHNOLOGY

The scope of biotechnology, as the definition above implies, is very wide. The fundamental of biotechnology are very much multidisciplinary covering aspects of biology, microbiology, biochemistry, bioprocess engineering down to computing and mathematics. The application of biotechnology itself is so wide that almost everybody can stake his/her claim to be involved in biotechnology. In order to clearly delineate the scope of biotechnology, the focus areas have been defined into the the following terms [3]:

- **Blue biotechnology** is a term that has been used to describe the marine and aquatic applications of biotechnology, but its use is relatively rare.
- **Green biotechnology** is biotechnology applied to agricultural processes. An example would be the selection and domestication of plants via micropropagation. Another example is the designing of transgenic plants to grow under specific environments in the presence (or absence) of chemicals. One hope is that green biotechnology might produce more environmentally friendly solutions than traditional industrial agriculture. An example of this is the engineering of a plant to express a pesticide, thereby ending the need of external application of pesticides.
- **Red biotechnology** is applied to medical processes. Some examples are the designing of organisms to produce antibiotics, and the engineering of genetic cures through genetic manipulation.
- **White biotechnology**, also known as industrial biotechnology, is biotechnology applied to industrial processes. An example is the designing of an organism to produce a useful chemical. Another example is the using of enzymes as industrial catalysts to either produce valuable chemicals or destroy hazardous/polluting chemicals. White

biotechnology tends to consume less in resources than traditional processes used to produce industrial goods.

- **Bioinformatics** is an interdisciplinary field which addresses biological problems using computational techniques, and makes the rapid organization and analysis of biological data possible. The field may also be referred to as computational biology, and can be defined as, "conceptualizing biology in terms of molecules and then applying informatics techniques to understand and organize the information associated with these molecules, on a large scale." Bioinformatics plays a key role in various areas, such as functional genomics, structural genomics, and proteomics, and forms a key component in the biotechnology and pharmaceutical sector.

3. WHITE BIOTECHNOLOGY: THE FUTURE FOR CHEMICAL ENGINEERS

As shown in Figure 1, the growth of white biotechnology or industrial biotechnology is expected to outpace the red and green biotechnology in the near future [4]. The so-called white biotechnology is very much relevant to what chemical engineers have been taught in their undergraduate curriculum which is to deal with processes for sustainable production of various useful products. White biotechnology has thus been described as the modern use and the application of biotechnology for the sustainable production of biochemicals, biomaterials and biofuels from renewable resources, using living cells and/or their enzymes. This results generally in cleaner processes with minimum waste generation and energy use [5].

The various breakthrough in other areas of biotechnology namely in genomics, molecular genetics, metabolic engineering, and catalysis has helped to provide rapid growth in the activities and opportunities in this field. As shown in Figure 2, the value chain of industrial biotechnology is very promising. The advance in cell biotechnology, for example, has allowed the use of cells as tiny micro-factories, which can be optimised with respect to productivity, safety and minimal environmental load. Raw materials, including crops and organic byproducts from agricultural sources and households, can be converted into sugars, which can be readily converted by tailor-made (micro-)organisms into the desired products. Typical products include enzymes, vitamins, flavours and fine chemicals such as chiral building blocks for the pharmaceutical industry [6].

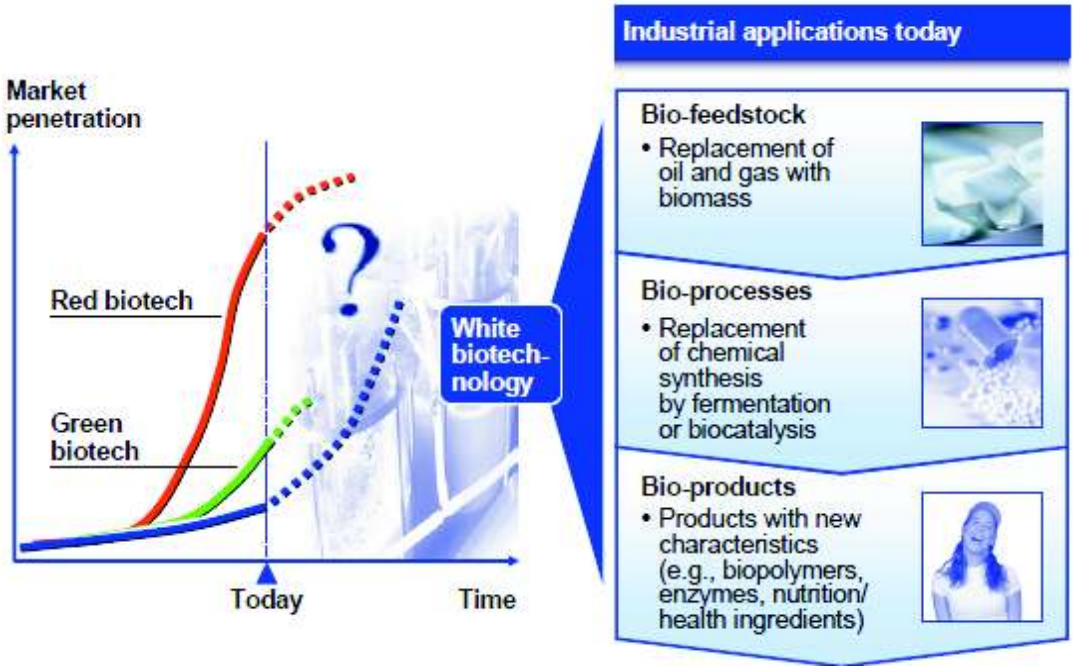

Figure 1 White biotechnology growth and application [5]

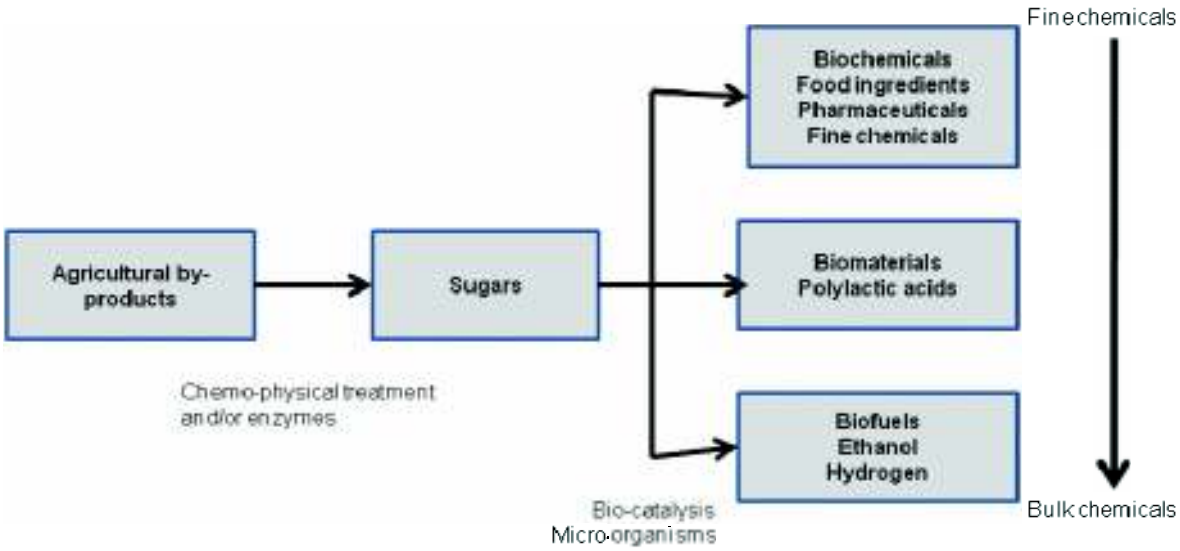

Figure 2 White biotechnology value chain [6]

Two good examples of how white biotechnology has transformed the industry has been recently reported [5]:

- ***Production of vitamin B-2 by BASF***: Traditionally vitamin B-2 is produced using a complex eight-steps chemical process. BASF new biotechnology process has allowed the production to be done in only one step. The single step is through fermentation whereby the raw material is fed to a microorganism (mould) that converts it into finished products. Vitamin B2 is recovered directly through crystallization directly from the fermentation. The biotech process reduces overall costs by up to 40% and the overall environmental impact by

40% which includes 30% reduction of CO2 emission, 60% reduction of resource consumption and 95% reduction of wastes.

- ***Production of antibiotic Cephalexin by DSM***: Traditionally Cephalexin is produces through a series of complex chemical processes involving many steps. Metabolic pathway engineering helped to establish a mild biotransformation route which has reduced the process steps substantially. The biotech process uses less energy and less raw materials, is water-based and generates less wastes in the process.

It has been estimated that white biotechnology will be applied in the production of 10 to 20% of all chemicals sold by 2010, starting from the current level of about 5%. Whilst different chemical markets introduce and use biotechnology at different rates, the McKinsey study indicates that the greatest impact of industrial biotechnology will be on the fine chemical segment, where up to 60% of products may use biotechnology by 2010. McKinsey estimates that between € 11 and € 22 billion additional added value could be created by the chemical industry alone in 2010, through cost reduction and the introduction of novel products [6].

Starting with the chemical industry, white biotechnology will make inroads into a number of other industries. For example, enzymes will transform production processes in the pulp and paper industry and new polymers will find multiple applications in the automotive and consumer industries.

Industrial biotechnology is not an "end-of-the-pipe" cleaning technology: it is a key tool in the development of sustainable production processes [7]. As the previous case studies have shown, industrial biotechnology has a substantial potential to reduce environmental impact: air and water pollution could be reduced, energy use lowered, fewer raw materials needed, and waste could be diminished or substituted by bio-degradable materials.

4. THE BIOTECHNOLOGY SCENARIO IN MALAYSIA

Recognising the importance of biotechnology, the government of Malaysia has established the Malaysian Biotechnology Corporation to spearhead the development of biotechnology in Malaysia. The objective of the establishment of BiotechCorp amongst others is to identify value propositions in both R&D and commerce and support these ventures via financial assistance and developmental services. Table 1 shows the nine thrusts of the National Biotechnology Policy [8].

BiotechCorp's key mandates are as follows:

- Act as a one-stop-centre
- Nurture and accelerate growth of Malaysian biotechnology companies
- Actively promote foreign direct investments in biotechnology
- Create conducive environment for biotechnology

Table 1 Malaysia's National Biotechnology Policy [8]

The Nine Thrusts of the National Biotechnology Policy	
Agricultural Biotechnology	Transform and enhance the value creation of the agricultural sector through biotechnology.
Healthcare Biotechnology	Capitalise on the country's biodiversity for commercialising the discoveries of health related natural products and bio-generic drugs.
Industrial Biotechnology	Leverage on the country's strong manufacturing sector to increase opportunities for bio-processing and bio-manufacturing.
Research & Development Technology Acquisition	Establish centres of biotechnology excellence, through research & development, as well as technology acquisition.
Human Capital Development	Build the nation's human capital through education, training and research activities, with the aim of producing knowledge generation capabilities.
Financial Infrastructure	Provide the right financial support via competitive lab to market funding and incentives to encourage committed participation from academia and the private sector, including Government-linked companies.
Legal & Regulatory Framework	Strengthen the legal and regulatory framework by reviewing ownership of intellectual properties and regulations relating to biotechnology processes and business.
Strategic Development	Build internatonal recognition for Malaysian biotechnology and find a niche in the global technology value chain.
Government Support & Commitment	Realise the execution of policy through the establishment of a dedicated and professional Government agency to spearhead the development of the biotechnology industry with the incorporation of Malaysian Biotechnology Corporation Sdn Bhd (BiotechCorp).

For the industrial biotechnology, three key areas have been identified [8]:

- Bio-catalysts: Development of biocatalysts such as enzymes for food and feed preparations, cleaningproducts, textile processing and other industrial processes.

- Bioprocessing: A growth area which can be applied in the production of biomaterials such as bioplastics, biofuel, fine and specialty chemicals such as cosmetic ingredients and electronic chemicals.
- Biomanufacturing: as applied to the development of bio-materials, enzymes (biocatalysis), biofuels, microbes technologies, biomass, bio-degradable plastics, oleochemicals and contract bio-process engineering

In Universiti Kebangsaan Malaysia (UKM), biotechnology has also been identified as one of niche areas for UKM. Under this niche three clusters have been formed namely on (i) Exploration of biological diversity, (ii) industrial biotechnology, and (iii) genomic and system biology.

5. CONCLUSIONS

The increasing application of biotechnology in this era cannot be denied. It is important that chemical engineers take active roles in research and development especially in the so called are of white biotechnology. White biotechnology, if successfully used for the sustainable production of biochemicals, biomaterials and biofuels from renewable resources, will certainly transform the development of the chemical industries into a more sustainable, less wastes and improved economic benefits for the society. The activities of biotechnology in Malaysia has also increase when the government established the Malaysian Biotechnology Corporation to spearhead the biotechnology activities in Malaysia.

6. REFERENCES

[1]. "The Convention on Biological Diversity (Article 2. Use of Terms)." United Nations. 1992. Retrieved on February 6, 2008.

[2]. Gerstein, M. "Bioinformatics Introduction." Yale University. Retrieved on May 8, 2007.

[3]. Biotechnology, Wikipedia at http://en.wikipedia.org/wiki/Biotechnology.

[4]. Jens Riese, White Biotechnology, McKinsey & Company Press Briefing, February 2009.

[5]. EuropaBio, White Biotechnology: Gateway to a More Sustainable Future, April 2003 (http://www.europabio.org/upload/documents/wb_100403/Innenseiten_final_screen.pdf);

[6]. Industrial (White) Biotechnology, An Effective Route to Increase EU Innovation and Sustainable Growth, POSITION DOCUMENT ON INDUSTRIAL BIOTECHNOLOGY IN EUROPE AND THE NETHERLANDS, DSM at www.europabio.org/positions/DSM-WB.pdf

[7]. OECD, Report: "The Application of Biotechnology to Industrial Sustainability" (2001) (http://www1.oecd.org/publications/e-book/9301061e.pdf);

[8]. Overview: Malaysian Industrial Biotechnology, A Frost & Sullivan Whitepaper (2009), Malaysian Biotech Corporation at http://www.biotechcorp.com.my/