Industrial biotechnology

Uncoupling economic growth from environmental impact

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The chemical processing industry provides the building blocks for many products. By chemically transforming natural materials, it helps to meet the world's most fundamental needs for food, shelter and health, as well as products that are vital to such advanced technologies as computing and telecommunications. The chemical industry is one of many industries facing major challenges to meet the needs of the present without compromising the needs of future generations, and one way industries are changing to meet these demands is through the adoption of biotechnology.

Biotechnology is not new — its underlying processes have been used by humankind for thousands of years, for example, in the production of wine and cheese. Industrial biotechnology is that set of technologies that come from adapting and modifying the biological organisms, processes, products and systems found in nature for the purpose of producing goods and services. This is achieved by the replacement of traditional chemical processes with more sustainable and environmentally friendly biological processes.

The social, environmental and economic benefits of industrial biotechnology are well recognised. Reductions in greenhouse gas emissions, energy and water usage are examples of the benefits brought about by cleaner, greener and simpler bioprocesses. Industrial biotechnology can also reduce the dependency on fossil fuels through the utilisation of renewable resources.

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Industrial biotechnology is already part of our daily life — vitamins and medicines as well as enzymes in washing powders are only a few of the many examples. Today, the application of biotechnology in large-scale industrial production is (technologically) coming within reach.

Learning from nature

The paradigm shift that is occurring in industry has been inspired by the products and processes found in natural ecosystems and the organisms that live in them.

The organisms and processes of natural ecosystems have evolved over millions of years to become highly efficient. All energy in the natural ecosystem is renewable and is initially captured from sunlight through photosynthesis. Also, all bioorganic chemicals and materials are renewable, biodegradable and recycled. Waste does not exist in natural ecosystems because the by-products of one organism are the nutrients for another. Most, if not all, metabolic processes are produced by enzymes and are highly specific and efficient. Biomimicry, the imitation of natural systems in industrial production, enables more sustainable processing and manufacturing.

Biotechnology has evolved over the last 25-30 years into a set of powerful tools for developing and optimising the efficiency of bioprocesses and the specific characteristics of biologically derived products (bioproducts). This increase in efficiency and specificity has great potential for moving industry along the path to sustainability. Increased efficiency allows for greater use of renewable resources without leading to their depletion, degradation of the environment and a negative impact on quality of life.

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Some examples of the more efficient processes now coming from the application of biotechnology are:

• Enzymes extracted from naturally occurring microorganisms, plants and animals can be used biologically to catalyse chemical reactions with high efficiency and specificity. Compared to conventional chemical processes, biocatalytic processes usually consume less energy, produce less waste and use less organic solvents (that would then require treatment and disposal).

• Plant biomass can be processed and converted by fermentation and other processes into chemicals, fuels and materials that are renewable and result in no net emissions of greenhouse gases. Also, these bioproducts are generally less toxic and less persistent than their petrochemical counterparts.

• Groups of companies can mimic the cooperative action of organisms in natural ecosystems by clustering around the processing of a feedstock such as biomass so the by-product of one is the starting material for another. Also, energy, such as waste heat, can be used efficiently. This approach is called 'industrial ecology'.

• The ability to 'evolve' bioprocesses and bioproduction systems allows for major improvements in both economic and environmental performance. This permits a manufacturing facility to increase its profitability and capacity while maintaining or even reducing its environmental footprint.

Industrial biotech in Australia

Australia's current industrial biotechnology capabilities are categorised under biofuels, biomaterials, biomining, chemicals and enzymes, and food processing. There are a range of factors that have been supporting the development of these capabilities, including government policies, R&D support and collaboration between researchers and industry. There are a number of companies involved in the production of chemical intermediaries, biomining and other biological processing, and several Australian companies are engaged in significant biomanufacturing activities.

Current applications

Biofuels

The main biofuels are biodiesel, ethanol and the direct transformation of waste into energy.

Biodiesel does not contain petroleum, though performs similarly to fossil diesel, with improved emissions performance and is non-toxic and biodegradable. Production is currently around three billion litres per annum worldwide, but in Australia there is currently limited commercial production. Australian Renewable Fuels Limited is constructing two plants to produce 44.4 million litres of biodiesel per year from tallow.

In Australia, there is significant research and industrial activity in relation to ethanol. Australia produces fuel-grade and industrial-grade ethanol, mainly from the fermentation of sugar from wheat starch or molasses from sugarcane. CSR's distillery at Sarina produces 55-60 million litres per year, and supplies around half of the Australian ethanol market.

Bio-mass

Renewable bio-mass in large volume chemical production can make a large contribution to CO_2 reduction. The important difference to the use of traditional, fossil-based feedstock is the binding of atmospheric CO_2 during growth of bio-mass (plants). Consequently, the CO_2 that is emitted at the end of a product's life cycle is environmentally neutral. It is estimated that current global bio-mass waste would be sufficient for the production of up to 40% of all bulk chemicals, but this depends on the cost-effective conversion of the bio-mass to sugars, and the key enabling technologies for this process are still in development.

Bio-polymers

Bio-based polymers use sugars or corn as raw materials, in contrast to traditional polymers produced from fossil resources. Examples are NatureWorks from Cargill Dow, which is used to produce clothing, packaging materials and electronic goods with 25-55% less fossil resource consumption, and Sorona, a textile manufactured by DuPont from corn.

In Australia, Plantic Technologies Limited has developed a corn-starch-based biomaterial that is being used for plastic packaging that begins to dissolve when wet.

Biomining

Biomining uses microorganisms to recover metals, in particular copper and gold, from ores and concentrates. Having developed from a very simple operational (in terms of both engineering and biology) process, biomining has developed into a multifaceted technology, to the extent that many of the largest industrial stirred tanks and heaps throughout the world are employed for bioprocessing minerals.

Australia has the largest public domain R&D group in biomining in the world, and high intensity bioreactors are used in the processing of gold in five plants (out of eight worldwide).

Chemicals and enzymes

Enzymes are nature's method of digesting materials and catalysing reactions. Enzymes are already being used in chemical production, pulp and paper processing, food processing, mining, consumer goods and textiles. Danish-based company Novozymes, for example, produces enzymes for the scouring process in the textile industry, which is the removal of the brown, non-cellulose parts of cotton. Traditional methods involved the use of harsh hot alkaline chemical solutions, which were emitted into the water, and used 25% more energy than the Novozyme process.

Food processing

Food processing shows the most established use of biotechnology, with natural fermentation being a core process that has been used for millennia to produce many of our most common foodstuffs. The first use of gene technology two decades ago opened up the potential for many additional advances in both selective breeding and fermentation. Each specific step adds to further improvements in the nutritional quality, appearance, flavour, convenience, cost and safety of foods.

For many years, a wide range of additives, processing aids and supplements have been obtained from microbial sources by fermentation. Increasingly, modern biotechnology is being used here. Products include vitamins, citric acid, natural colourings, flavourings, gums and enzymes. Gums used as low-calorie thickening agents and low-calorie sweeteners from natural ingredients are also produced using modern biotechnology.

In improving the processes by which food is produced, biotechnology can be used to develop mild, highly specific processes using modified microorganisms and purer, cheaper enzyme products. These can offer better productivity, cost-effectiveness and energy efficiency than existing processes. They can produce top-quality foods with a reduced need for additives such as flavourings, and can also reduce the environmental impact of food processing.

Bio-safety issues

It should be noted that biotechnology is not without its risks. The microorganisms used for industrial bioprocessing or for production of industrial enzymes need to be selected to avoid the use of pathogenic organisms. Stringent environmental regulations and occupational health regulations impose rules on their handling in the workplace and, after they are used, they are inactivated by sterilisation. The resulting organic material is usually composted. This breaks down the DNA and protein components.

Lessons so far

Experiences in the development of industrial biotechnologies around the world have made it possible to draw a number of general conclusions about biotechnology developments in general:

• In effect, the application of biotechnology has contributed to an uncoupling of economic growth from environmental impacts. Its application in a wide range of industry sectors has led to both economic and environmental benefits via processes that are less costly and more environmentally friendly than the conventional processes they replace.

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• The application of biotechnology to increase the eco-efficiency of industrial products and processes can provide a basis for moving a broad range of industries towards more sustainable production. Further development will be needed however, as well as policies that provide incentives for achieving more sustainable production.

• In most cases, the adoption of more efficient bioprocesses and bioproducts by industry is driven by cost savings and improved product quality/performance, rather than environmental considerations.

• Collaboration with university and government researchers and other companies is an important contributing factor for successful introduction of new bioproducts and bioprocesses, since many companies do not have all the expertise required to develop them.

• Because the introduction of biotechnology can be a major paradigm shift for many companies, there is a long lead time for adoption.

Conclusion

It is clear that industrial biotechnology has a beneficial impact on both the environment and the economy. Energy efficiency is boosted, raw materials consumption is decreased, CO_2 emissions are substantially reduced, and production costs are usually lowered. But the application of biotechnology for developing industrial products and processes is still in its infancy. As awareness builds and the technology continues to be developed and diffused through different industry sectors over the next few decades, the economic and environmental benefits are predicted to grow.