Concept and challenges of modern biorefineries

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Abstract

international R&D community and technology developers for the last decades. However, despite intense efforts, real breakthrough has not been achieved yet. This has been mainly due to a biased view, focusing solely on a certain end product – for example cellulose pulp or ethanol and considering by-products as low value waste streams for energy applications. With the new wave of lignocellulosic biomass fractionation technologies being demonstrated at a pilot scale, success stories are closer than they have ever been. Biomass fractionation to high purity intermediate building blocks of cellulose to C6 sugars and hemicellulose to C5/C6 sugars and lignin, instead of just one main product, provides a way to produce a diversity of products and establish novel bio-based value chains. Especially important is the availability of higher purity lignin for different direct drop-in or after processing (depolymerization etc.) applications, which compared to the conventional lignins derived from pulp mills or ethanol refineries provides totally new applications and perspectives to enable the increased use of biobased raw materials in various industries.

A biorefinery is a facility where different low-value renewable biomass materials are the feedstock to the processes where they are transformed, in multiple steps including fractionations, separations and conversions, to several higher-value bio-based products. Examples of these products can include fibres, food, feed, fine chemicals, transportation fuels and heat. A biorefinery can be formed by a single unit or can combine several facilities targeted for a single purpose that further process products as well as by-products or wastes of combined facilities. In biorefining one can find similarities to oil refining, with the exception that in oil refining the raw material comes from fossil resources. According to the International Energy Agency 'Biorefineries will contribute significantly to the sustainable and efficient use of biomass resources, by providing a variety of products to different markets and sectors. They also have the potential to reduce conflicts and competition over land and feedstock, but it is necessary to measure and compare the benefits of biorefineries with other possible solutions to define the most sustainable option.'1 Although it is possible to produce the same products in a biorefinery as in an oil refinery, this is not the target, which instead is to produce products which can replace the products from oil refining.

In the development of biorefinery processes, as well as any industrial processes, it is crucial for the future of the Earth that the new processes follow the principals of sustainable development and green chemistry. It is good to remind what these terms really mean.

The term 'sustainable development' was famously used by the Brundtland Commission in its report to the United Nations. In the report the term 'sustainable development' was defined as, 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs.'2 In other words, it can be said that we have every right to utilize resources that the Earth provides to us for our needs as long as we make sure that future generations have the same possibility. The United Nations Millennium Declaration identified principles and treaties on sustainable development, including economic development, social development and environmental protection.3

'Green Chemistry' is a term which is often applied when chemistry and chemical processes are defined as environmentally benign. Paul Anastas and John Werner developed and introduced widely accepted 12 principles of Green Chemistry. The following list briefly presents the principles which, if followed, would make chemical processes or products greener.4 Prevention: it is better to prevent waste than to treat or clean up waste after it has been created. Atom economy: synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product. Less hazardous chemical syntheses: where ever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment. Designing safer chemicals: chemical products should be designed to affect their desired function while minimizing their toxicity. Safer solvents and auxiliaries: the use of auxiliary substances should be made unnecessary wherever possible and harmless when used. Design for energy efficiency: energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure. Use of renewable feedstock: a raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable. Reduce derivatives: unnecessary derivatization should be minimized or avoided if possible, because such steps require additional reagent and can generate waste. Catalysis: catalytic reagents are superior to stoichiometric reagents. Design for degradation: chemical products should be designed so that at the end of their function they break down into harmless degradation products and do not remain in the environment. Real-time analysis for pollution prevention: analytical methodologies need to further develop to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances. Inherently safer chemistry for accident prevention: substances and the form of a substance used in chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions and fires.

Biography

Alex Michine is a Founder and CEO of MetGen since 2008. MetGen is a biotechnology company committed to serving industrial customers with enzymatic solutions tailored for their specific needs. He is a serial enterpreneuer in industrial biotechnology sector. He has relentlessly been promoting the future technologies for bioeconomy and has been an active spokesperson for great potential of cross-disciplinary collaboration.

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