Opportunities for growing crops for biopolymers

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Summary

Polymers derived from renewable resources offer the opportunity to benefit society and the environment by reducing demands on fossil resources. Sugars, oils and other compounds in renewable feed-stocks can be converted into platform chemicals and polymers using processes similar to those employed by the petrochemical industry today. Recent reports have identified several building block chemicals produced from sugars via biological or chemical conversions. Examples are ethanol (C2), glycerol (C3), fumaric acid (C4), xylitol (C5), and sorbitol (C6). These, together with starch derived directly from plants, enable the synthesis of biopolymers. The use of biomass-derived chemicals represents an area with extensive R&D potential for the development of a renewable feedstock-based technology platform. Improvements and innovations to existing biological and chemical processing of sugars and starches, often made possible through advances in catalysis, will provide an opportunity for the production of high-value chemicals and polymers from biomass and reduce reliance on petrochemical-derived products.

Introduction

It is often taken for granted that polymers are made from fossil derived oil. The rising cost of oil, regulation and mounting concern over climate change has necessitated a move towards renewable sources of polymer feedstock.

Production of polymers from plant products and biomass offers the potential to replace non-renewable materials derived from petroleum with renewable resources, resulting in reliable supply, jobs in rural communities, sustainable production, lower greenhouse gas emissions, and competitive prices.

Crops to polymers

Bioplastics compete with petrochemicals-based equivalents, the production of which has been optimized over the last decades. Optimization of these production methods according to green or sustainable chemistry principles may still significantly reduce costs, waste production, energy and raw materials use for petroleum-based polymers. However, many chemical processes are mature and have little room for optimization, while biotechnological processes are in their infancy; there is great potential for streamlining and improved process integration. In petrochemical refineries, the raw materials cost is critical as processing costs have gradually decreased, more products are developed, and less waste is produced.

While biotechnology provides new routes to renewable polymers; biomass can be converted to glucose, fatty acids, or other small compounds, either as the main product or as a waste stream from other production processes. These small compounds serve to produce polymers by microbial fermentation or chemical polymerization. For example, poly- β-hydroxyalkanoates, biocellulose, xanthan, silk, and polythioesters, can be produced by fermentation processes, while polylactic acid (PLA), poly-caprolactone, and other (partially renewable) polyesters such as Sorona (Dupont), and Bionolle (Showa) are produced using chemical polymerization of substrates that are at least in part produced by bacterial fermentation. It is likely that these processes will be part of future biorefineries, which are now in a very early stage of development, with the exception of starch and paper mills. This implies that in biorefineries, the processing costs still determine the economic viability of bio-products. As biorefineries mature, the focus will also shift to the cost of producing the raw materials.

The cheapest and easiest to handle biopolymer is starch. Due to its abundance and low price it has found numerous applications in the non-food sector, which includes its use in renewable plastics. The current rise of the oil and natural gas prices is reflected in the plastics market, and is making renewable plastics more competitive.

Renewable plastics and other biomaterials have a marketing advantage due a perceived lower environmental impact. However, this idea must be supported by data. According to some reports, the production of petroleum-based plastics consumes less raw material and energy, and produce less CO_2, compared to the production of renewable plastics by fermentation, especially when energy and materials consumed for the production of fertilizers, pesticides, transport, and process energy are factored in. Accordingly, life cycle, eco-efficiency, ecological footprint, carbon efficiency, and sustainability analyses are key to determining whether the production of renewable plastics truly makes sense. For example, recycling of classical plastics may be better than composting renewable plastics. Furthermore, the energy content of renewable plastics can be recovered by incineration or conversion to biogas, which may create a critical advantage.

The possibility that it is more eco-efficient to use biomass for fuel and energy, while continuing the use of oil-based plastics should also be considered, although evidence points in the other direction. In the end, the net greenhouse gas production may be crucial as evidence for climate change is mounting. On a timescale of 10-20 years it is practically certain that carbon-credits will exert an sizeable influence on the market, favouring (bio)plastics and materials with a good carbon-balance.

As a consequence of the development of new markets, energy consumption and waste production are increasing at a fast rate. Emerging countries are requiring more and more fossil resources whilst the developed countries are hesitant in introducing energy saving programmes and controlling the release of greenhouse gases. The amount of goods produced and packed is also growing, making waste disposal a big issue. These problems represent a powerful driving force stimulating the growth of renewable polymers. At an industrial level, several biopolymers have been developed, the first drive being towards biodegradable polymers.

The continuing market development of renewable polymers gives far more opportunities to close the loop from raw material to end of life disposal than is possible with fossil derived materials. It should also not be forgotten that reusing and recycling equally apply to renewable polymers as they do to fossil derived polymers; it is just a question of scale.

Conclusion

The renewable polymers market will increase rapidly in the next 10-20 years as the fossil feedstock costs rise and the drive for carbon savings is established. Research and the enhancement/refinement of industrial scale-up processes will introduce a wider array of products into the marketplace at competitive prices. The feedstock for these renewable polymers will be either directly (crop) or indirectly (biomass) derived from agriculture. The agricultural industry will have to change its historical supply chain to one more in line with providing an industrial raw material.

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