The impact of biotechnology and genomics on sustainable development through potential applications for bioenergy, biofuels, biopower, and bio-based products

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Global demand for energy, fuels, materials, and consumer goods has increased significantly and will continue to spiral upwards during the early part of the 21st century. The main driver for demand is not just the expected population increase, but the large increase in per capita consumption that accompanies the improving standards of living throughout the world. The global supply of energy, and molecular structures for manufacturing consumer goods, depend on several complex socio-economic factors, including government policy and research investments. However, a critical issue with the current hydrocarbon resource base is the major reliance on a finite, and diminishing, reserve of fossil fuels. Moreover, due to associated gaseous emissions, further growth in the use of fossil fuels is projected to have increasingly negative consequences for atmospheric conditions.

Alternative renewable sources of energy and bio-based feedstocks could provide solutions to the issues outlined above and would include the following potential benefits:

- ?? More secure energy and raw material resource platforms
- ?? Direct economic contributions and decreased price volatility
- ?? Mitigation of anthropogenic impacts on the global atmosphere
- ?? Opportunities for improved rural development
- ?? Enhanced environmental acceptability in production, processing, and utilization

Today, bio-based inputs are utilized in a relatively small portion (<3%) of the manufacturing and energy production processes in the US. Lignocellulosic materials are extracted and used in paper, a variety of packaging materials, and other fiber-rich products. Corn starch is used to produce over 1.5 billions gallons of fuel ethanol per year. To some extent, proteins and carbohydrates, from processed crops have been used for bio-based polymers and building blocks for various materials. The increased industrial use of bio-based oils, with unmodified fatty acid composition, has continued to run into economic problems because of the large market for edible vegetable oils that sets a relatively high price floor.

In recent years there has been a growing recognition that more sustainable development approaches are required across both the private and public sectors, and that these must progress far beyond just cleaning up waste streams, or recycling. For example, in the Plant/Crop-Based Renewable Resources Vision 2020 [1], and associated roadmap [2], the goals for future contributions from bio-based renewable inputs call for an increase in the proportional contribution to total demand by at least five-fold within the next 20 years. Many projects are underway to meet these goals. In some cases, the contribution from traditional lignocellulosic biomass may be improved through achieving higher useful yield per unit land area, or via breeding selected alternate crop types for specific situations [3]. In other cases, advanced processing methods, and multi-product output flows, will allow new, economically viable, biorefineries. However, it is difficult to envisage a significant shift to a bioenergy and bio-based product economy without some breakthrough advances in key research areas – one such area with immense potential is biotechnology.

While it is recognized that practical success depends on the integration of progress across a range of scientific disciplines, the recent advances in biotechnology have opened significant new doors. In some approaches, biotech is being uses in the manipulation of micro-organisms, with applications in the introduction of new bio-based products: for example, 1,3-propanediol [4]. Moreover, despite the current anti-biotech stance by some activist groups, there are now over 110 million acres of transgenic crops in commercial production. Expectations are very high for biotech-based improvements: e.g. biotic and abiotic stress tolerance, compositional modifications, resource use efficiency, and production per unit area used to grow primary energy capturing organisms such as crops, trees, and algae.

In addition to the existing applications of biotech, an amazing suite of tools has been created in the past few years, including structural genomics, functional genomics, microarrays, knock-out libraries, proteomics, and bioinformatics. The outcome from using such tools to develop a bio-based platform for sustainable development [5] is perhaps only limited by the boundaries of human imagination – for example, a few of the approaches being developed are:

- ?? Unveiling the sequence code for gene structure, position, and constitutive regulation
- ?? Following the expression of inherent genes in time and space
- ?? Developing a protein-protein interaction base for *in silico* metabolic studies
- ?? Improving the unit activity of critical enzymes via gene shuffling or molecular evolution
- ?? Expanding the potential for metabolic engineering: adding, deleting, improving key steps
- ?? Enhancing natural material production via transgenic methods: e.g spider silk proteins
- ?? Building a platform for biomimetics, and designing novel materials *in silico*
- ?? Creating organisms that are optimized for the production of bioenergy, or bioproducts

Current biotech progress related to bioenergy and bio-based products will be reviewed in the presentation, and examples of future applications will be outlined. In the longer-term, a range of scientific disciplines will contribute to a more secure and sustainable economy through the integration of technology progress. However, it may be that biotech, and related tools, will provide a critical foundation for the magnitude of change required to achieve global sustainable development, while allowing for a decreased anthropogenic imprint on the environment.

References

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