ANALYSIS

Experts disagree over color of biomass

In the latest of a series of major government and corporate initiatives to use biotechnology and biological feedstocks for industrial processes, chemical giant Dow (Midlands, MI) has announced a new Oilseed Engineering Alliance (OEA)—a \$10 million project to develop new strains of crops that will produce starting materials for manufacturing plastics and other products. However, new research suggests that “green” biomanufacturing could be muddying the environment.

Under Dow’s alliance, scientists at Dow, Michigan State University, the US Department of Energy’s Brookhaven National Laboratory, and several other institutions will collaborate to develop better feedstocks for bioplastics manufacturing. Synthesizing polymers from renewable feedstocks, like sugars and oils from crops, eliminates the need for nonrenewable petroleum-based starting materials, and in recent years, researchers have improved the efficiency of fermentations and developed genetically engineered plants to produce more chemically useful precursors (*Nature Biotechnology* 16, 1022, 1998). Instead of extracting simple sugars or naturally occurring oils from ordinary crops and then chemically modifying them, companies now aim to produce materials from genetically engineered plants that synthesize nearly complete plastics, simplifying the manufacturing process.

Early success in the field has inspired corporate and government funding (*Nature Biotechnology* 17, 949, 1999), but some experts now suggest that the excitement may be premature. “What I’m concerned about is that funding agencies... are all going to spend a lot of money without looking at the bigger picture,” says Tillman Gerngross, an assistant professor of biochemical engineering at Dartmouth College (Hanover, NH).

For Gerngross, the bigger picture includes the energy required to produce a product, as well as the feedstocks from which it is made. In recent research, currently under review for publication in *Industrial Ecology* (MIT Press), Gerngross, in collaboration with scientists at Monsanto (St. Louis, MO), found that producing bioplastics directly in plants, rather than by fermenting plant sugars, requires four times as much energy as producing the same quantity of petrochemical-based plastics.

This follows an analysis published last year (*Nature Biotechnology* 17, 541–544, 1999), in which Gerngross found that producing a kilogram of poly-3-hydroxybutyrate (PHB)—a widely studied bioplas-

tic—requires the combustion of 2.39 kg of fossil fuels, compared with burning 1 kg of fossil fuels to produce the same amount of polystyrene.

This equation is complicated by the fact that total fossil fuel use for the two processes is very close: For 1 kg of polystyrene, which is made from petrochemical precursors, a kg of fossil fuel is required as a starting material, in addition to the kg burnt for energy. This additional kg of fossil fuel is not

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required for PHB because PHB is made from plant-derived precursors, but the combustion of fossil fuel needed to generate 1 kg PHB product is greater. And it is the combustion that creates environmental problems by releasing greenhouse gases such as methane and carbon dioxide into the atmosphere. However, other factors must also be considered, such as the impact of farming necessary to produce plant-based precursor materials, the eventual degradation of biodegradable plastics into greenhouse gases, and the consumption of carbon dioxide by plants grown for feedstocks. “This naive gung-ho attitude that if [the feedstock] is renewable, it’s a good thing for the environment, I think has to be really closely examined,” says Gerngross.

His study was based on current PHB fermentation technology and US agriculture. Although Gerngross concedes that results would differ in other parts of the world, he says the process of manufacturing bioplastics would still exact a steep environmental cost. In France, for example, a greater reliance on nuclear energy might mean that less fossil fuel would be burned to operate a PHB-producing facility, but generating nuclear power presents a separate environmental concern. Gerngross also notes that areas using predominantly hydroelectric power could avoid using fossil fuels to make bioplastics. The drawback to that plan, he says, is that the major crop-growing areas are usually far from the major hydroelectric power-producing areas.

Not surprisingly, some industry researchers take a different view, contending that Gerngross’s analysis is very preliminary. Robert Dorsch, director of biotech-

nology development for DuPont Central Research (Wilmington, DE), points out that Gerngross “was comparing polystyrene, which is made in a 40-year-old highly optimized process to a pilot-scale process [used to produce PHB] that frankly no one would ever practice commercially, for all of the reasons that he outlined.” In addition to the environmental inefficiency of the pilot-scale PHB manufacturing process, the increased energy needs result in higher production costs, making the system unprofitable in a market saturated with cheap petrochemical plastics that have similar characteristics.

Predicting that the use of biomass-derived feedstocks will follow the same type of evolution in efficiency seen in other industrial processes, Dorsch insists that “when you start from a renewable base, you have... an opportunity to get to a more efficient position than if you start with a nonrenewable base.”

Meanwhile, Dow researchers emphasize that environmental benefit is only one of several reasons to favor biological systems. Even if bioplastics are not an immediate boon for the environment, they are likely to allow the production of materials with novel characteristics at a reasonable price. According to Kerr Anderson, a Dow scientist working on the OEA project, enzymes in plant or bacterial cells are particularly good compared with traditional industrial chemistry at driving reactions favoring one asymmetric molecule over its mirror image. Genetically modified oilseed crops will allow the company “to get at some different chemistries that chemists can’t synthesize easily,” says Anderson. As for compounds that are “too damned expensive to make,” he says, “if we can get the plants right, we can do it cheaply.”

Alan Dove

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