General Electric Company

Using Corn To Manufacture Plastics

Engineering thermoplastics are used worldwide in applications such as automotive and airplane parts, computer and appliance housings, and bullet-resistant glazing. Engineering thermoplastics could be used in a much wider array of products and industries, but high raw material costs for the monomer parahydrobenzoic acid make such applications prohibitively expensive. Therefore, industry cannot utilize the superior qualities of these materials without a scientific breakthrough that would significantly reduce the material costs of these largely petroleum-based products. General Electric Company (GE), one of the largest producers of engineering thermoplastics, recognized the possibility that corn could be used to make plastics through the use of bioprocessing technologies. Using corn, one of America's most plentiful agricultural products, rather than more expensive fossil fuels, could reduce the costs for certain engineering thermoplastics by 50 percent.

The bioprocessing, however, required such stringent temperatures and controlled environments that the high research costs, along with the technical risk, deterred GE from investing in the project on its own. In 1995, the company submitted a proposal to the Advanced Technology Program (ATP) to replace petroleum-based products with corn that had gone through a series of biochemical processes. GE would conduct the scientific research and initial product tests, then another manufacturer would fabricate the monomer. By the project's end in 1997, however, GE was unable to produce monomers pure enough to make thermoplastics that would meet the needs of industrial applications. However, GE gained valuable knowledge and has been conducting related research since the end of the ATP-funded project.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)

No Stars

Research and data for Status Report 95-05-0031 were collected during October - December 2001.

Current Raw Material Costs Are Too High

Because they require high-cost, petroleum-based monomers (a monomer is a chemical unit forming the base of the plastic) as a foundational building block, engineering thermoplastics manufacturers limit their products to relatively high-priced items that compete in non-price-sensitive markets such as automotive, high-end electrical and appliance, and business machine applications.

The high cost of petroleum-based monomers prevents wider industry use of engineering thermoplastics, thereby limiting access to a product with many properties that are superior to those of similar plastics, including processability, strength, resistance to chemicals and extreme heat, and recyclability. Before the ATP-funded project, the best available cost for the monomer was $6 per pound. The superior properties of the monomer could not be utilized within more price-sensitive markets, however, unless costs were reduced by at least 50 percent.

Corn Viewed as Potential Substitute for Petroleum

GE scientists developed a research plan that envisioned corn as a potential replacement for petroleum for the production of a key ingredient in

certain plastics (especially liquid crystal polymers). In theory, corn sugar (glucose) could be turned into an acid, parahydrobenzoic acid (PHB), that would be identical to the acid derived from the petroleum-based products. Specifically, the scientists hoped to develop a biocatalyst of recombinant E. coli with enhanced enzymes to produce PHB from the glucose via fermentation. GE marketing and product development staff determined that the market for engineered thermoplastics could sustain 10 to 30 million pounds of corn-derived PHB annually. To create this new form of PHB, however, GE needed to develop a partnership with a corn wet-miller that had both in-house fermentation experience and access to low-cost glucose.

ATP Provides Funding Support for Corn-Based Polymer Research

GE's internal research and development (R&D) department could not meet rate-of-return requirements to fund the project because of the complexity of the chemical reactions and the risk of failing to generate PHB from the process. Nevertheless, the potential environmental benefit from a corn-based plastic and the superior qualities of this monomer would convince the business community to use PHB if the process could be made more economical. Engineering thermoplastics could be incorporated into electronics, automotive lighting, and automotive drivetrain parts.

The GE research team was unable to achieve its goal of replacing petroleum-based products in engineering thermoplastics.

By enabling commercially viable PHB production, a successful GE project would provide a low-cost, multiuse product with improved processability, strength, chemical resistance, heat tolerance, and recyclability. Moreover, expansion of the corn-based engineering thermoplastics market could have spillover effects for the U.S. agricultural market. If successful, the market for U.S.-produced corn would increase, and the market for imported petroleum would decrease.

To achieve those goals, and to give thermoplastics manufacturers the chance to investigate a biosynthetic process for engineering thermoplastics monomers from corn, ATP provided funding support to GE. Using these cost-shared funds, GE planned to develop an improved set of enzymatic reactions using E. coli, particularly at the end of the bioconversion pathway to PHBs. GE also planned to remove the PHB earlier in the fermentation process to prevent overfermentation, which would lead to less pure PHBs.

Biochemical Processes Unable To Produce Pure PHB

The GE research team was able to create PHB from corn products, which represented a significant scientific achievement. Unfortunately, the PHB created from corn was not pure enough for use in commercial molding processes. Impurities in the PHB led to brittleness in molded plastic parts. Also, moving the technology to production would have required investing significant time and money in equipment and plant retrofits, yet the production volumes were expected to be relatively low. Because of scientific and technical problems, the GE research team was unable to achieve its goal of replacing petroleum-based products in engineering thermoplastics.

Research is ongoing under a newly established Biocatalysis Project that is devoted to the application of biotechnology for the manufacture of monomers.

GE gained a significant amount of information from this unsuccessful project, and the company has continued to research methods to develop pure monomers for thermoplastics from corn. According to internal accounts, the ATP-funded project put GE two to three years ahead of where it would have been without the cost-shared funds. The project saved 800 R&D hours, avoided $10,000 in equipment costs through parallel use, and led to the establishment of a focused project within GE that continued the research after the conclusion of the ATP-funded project. The project led to two patents. Further research could still lead to increases in the use of recyclable thermoplastics and to substantial economic spillover into the petroleum and agricultural industries. GE understood this potential impact and dedicated two scientists and a technician to continuing the research after the ATP-funded project ended in 1997.

Since the ATP project ended, GE has provided $1.5 million in additional funds. Research is ongoing under a newly established Biocatalysis Project that is devoted to the application of biotechnology for the manufacture of monomers and chemicals of interest to GE. Through post-ATP project research, GE has identified other potential applications to take renewable resources, such as fatty acids from corn products, and use a different biochemical process to turn those acids into monomers for use in polyester, nylon, or polycarbonates.

Conclusion

ATP funded an effort to develop a biochemical process that had the potential to turn corn into a building block for industrial-strength plastics. Although it still appears feasible to bioprocess corn as a substitute for petroleum-based products, GE did not fully achieve the project's technical goals. At the project's conclusion, GE management decided not to further invest significant time and money in equipment and plant retrofits because the production volumes were expected to be relatively low. Although the ATP-funded project was not fully successful because of the technical and financial barriers encountered, GE did advance research in using agricultural products in the manufacture of plastics. The company has continued to research other replacements for petroleum-based products in plastics since the conclusion of this ATP-funded project.

PROJECT HIGHLIGHTS
General Electric Company

Project Title: Using Corn To Manufacture Plastics (Biosynthesis of Monomers)

Project: To reduce the raw material costs of engineering thermoplastics by using corn feed stocks that have passed through several biochemical processes, rather than petroleum-based products, as the primary raw material.

Duration: 9/15/1995-10/31/1997
ATP Number: 95-05-0031

Funding (in thousands):**

ATP Final Cost	$ 542	52%
Participant Final Cost	498	48%
Total	$ 1,040	

Accomplishments: Currently, engineering thermoplastics use expensive, petroleum-based products as key raw materials, a process that makes the price of finished goods too high for many manufacturing applications. The GE research team was able to make a monomer from corn that potentially could be used in engineering thermoplastics; however, the monomer was not pure enough. Although the technology failed, the GE research team advanced the body of knowledge about biosynthesizing renewable feedstocks for plastics. The project saved 800 R&D hours, avoided $10,000 in equipment costs through parallel use, and led to the establishment of a focused project within GE that continued the research after the conclusion of the ATP-funded project. The project also led to the following two patents:

- "Method for increasing total production of 4-hydroxybenzoic acid by biofermentation" (No. 6,114,157: filed September 25, 1998; granted September 5, 2000)
- "Genetically engineered microorganisms and method for producing 4-hydroxybenzoic acid" (No. 6,030,819: filed September 28, 1998; granted February 29, 2000)

Commercialization Status: Although GE was unable to commercialize its technology because of scientific and technical failures, the company is continuing its research into creating a viable product.

Outlook: Even though the particular biochemical processes used in this project failed, continued research has led GE to investigate other bioprocesses to create monomers pure enough to make plastics. Until such research proves fruitful, however, the outlook for this technology is poor.

Composite Performance Score: No stars

Focused Program: Catalysis and Biocatalysis Technologies, 1995

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** As of December 9, 1997, large single applicant firms are required to pay 60% of all ATP project costs. Prior to this date, single applicant firms, regardless of size, were required to pay indirect costs.

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