Business

September 29, 2008
Volume 86, Number 39
pp. 21-25

Growing Plastics

Producers of biomass-derived polymers will seize the day, if they can get price and performance right

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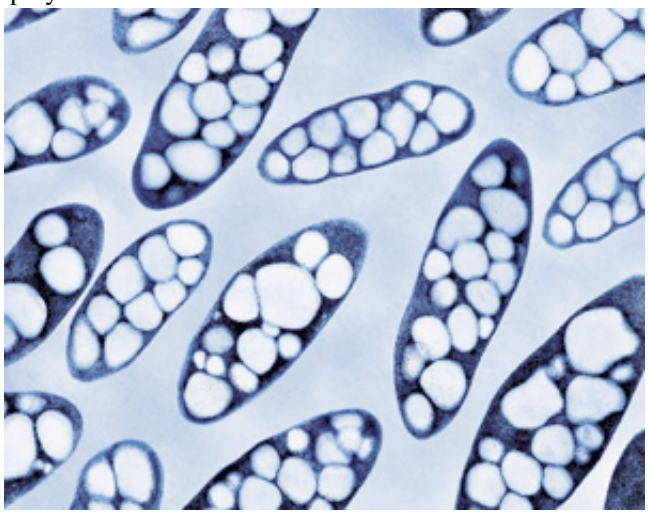
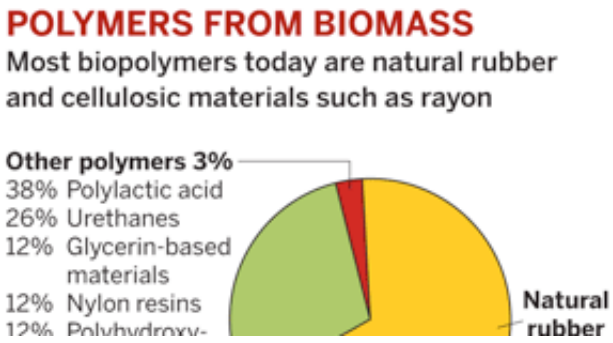
NOT LONG AGO, biobased plastics were a mere curiosity. Although plastics made from raw materials such as corn instead of petrochemicals were considered a nice idea and perhaps even a virtuous pursuit, few companies were visionary enough to invest a lot of money in them.

Now, between oil that is four times more expensive than it was in 2000 and a public that is becoming aware of problems like global warming, industry is giving biobased plastics a closer look. A plethora of companies ranging from start-up firms to old-line chemical makers are taking multiple approaches to entering the market.

TINY FACTORIES Telles, a joint venture between Metabolix and Archer Daniels Midland, will make polymers in bacteria.



Metabolix

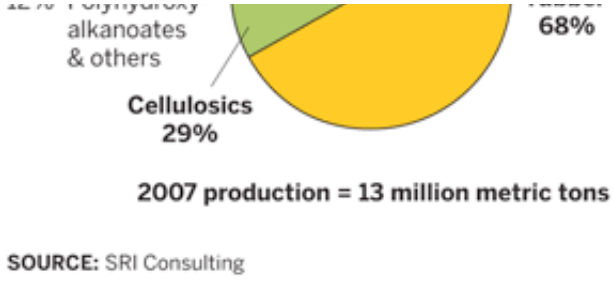


Some are staking a claim in new-to-the-world materials such as polylactic acid (PLA), polyhydroxyalkanoate (PHA), and plastic starches. Others are making traditional plastics from plant-based raw materials. But all players agree that biopolymers are ready to compete in a global plastics market that is measured in the hundreds of millions of tons per year.

Biobased polymers do have a way to go to capture a big chunk of that market. According to Robert Davenport, a director of Menlo Park, Calif.-based SRI Consulting, global production of polymers from biomass—including older materials like cellulose-based rayon and the natural rubber found in tires—was about 13 million metric tons in 2007. At best, a mere 250,000 metric tons of that were newer polymers such as PLA and biobased polyurethanes.

And Davenport points out that taking a significant share of the vast polymers market will be no easy task. "If you look at the history of the polymer-consuming industry, such as packaging, you will see that it is relatively conservative; there is not a lot of product substitution," he says. "But once somebody hits upon something that does have benefits, you can get fairly rapid growth over a short period." He points to the replacement of glass in soda bottles by petrochemical-based polyethylene terephthalate (PET).

Environmental benefits may be what the industry needs to challenge traditional plastics. Brian Igoe, chief brand officer at PHA specialist Metabolix, describes a "perfect storm" of opportunities for biobased plastics because of high oil prices, concerns about climate change and plastic waste, and worries over U.S. dependence on foreign oil. "In 1992, when our company was founded, no one could have predicted that the environment for business would be this opportune at this point in time; it clearly is," he says.



View Enlarged Image

Oliver P. Peoples, Metabolix' chief scientific officer and a company founder, recalls delivering early slide presentations to chemical executives on materials based on renewable resources. "They didn't quite show us the door, but they pretty much fell asleep," he says.

James Stoppert, chief executive officer of Segetis, a Minneapolis-based biochemicals start-up, had similar experiences 10 years ago, when he became the first CEO of Cargill Dow, the joint venture that was the predecessor of the PLA maker NatureWorks. "When we first started, we had to apologize because we were going to be higher cost," he recalls. "That just isn't the case anymore. As petroleum gets above about $70 per barrel, that is the inflection point at which most renewable processes have the potential to be lower cost."

Other companies are also excited about the prospects of more expensive oil. The engineering firm Uhde Inventa-Fischer, in marketing literature promoting its PLA technology, boasts that "at crude oil prices above $80 per barrel, PLA even will be cheaper than PET!"

It's in this environment that Telles, a joint venture between Metabolix and agricultural processing giant Archer Daniels Midland, will complete its first facility. Due on stream during the second quarter of 2009 in Clinton, Iowa, the plant will have the capacity to make 50,000 metric tons of PHA per year.

The plant represents a twist on fermentation bioprocesses such as NatureWorks' process for making lactic acid and converting it into PLA or DuPont's technique for producing 1,3-propanediol, which is reacted with terephthalic acid to make a polyester. Metabolix' facility will house giant fermenters full of the K-12 strain of Escherichia coli genetically modified to make PHA directly.

By changing the growth conditions for the bacteria, Telles can put out different varieties of PHA, which Metabolix trademarked Mirel, for different applications. "We can control our bioreactors in an analogous way to how you can control the polyethylene reactor by changing the temperature and pressure," Peoples says.

With properties ranging from soft and elastomeric to rigid and crystalline, Mirel is positioned to compete in applications that are usually the domain of polypropylene, polyethylene, and polystyrene, which together span most imaginable plastics applications, Peoples adds. Mirel's target markets include stakes, films, and pots for agriculture; lab equipment; consumer products such as gift cards and compost bags; marine applications; and packaging.

PHA's selling point, its creators say, is that it combines good properties with environmental benefits, including, they note, the consumption of only about 3.5% of the energy required to make conventional plastics. In addition, the materials are biodegradable. Some biobased plastics, such as those based on starch, are biodegradable but do not have the same physical properties as traditional plastics. Other materials, such as PLA, biodegrade only in industrial composting conditions. "We marry this broad range of environmental benefits with good usable characteristics," Igoe says.

Peoples admits that despite the lower energy input, PHA's exotic production process renders it more expensive than conventional plastics. But he contends that customers will get the money back on their bottom lines. For example, he says that making disposable agricultural products out of a biodegradable material eliminates the need to collect them from the field.

Cereplast

PICNIC TIME Cereplast says disposable items are an ideal application for compostable plastics.

Peoples also believes that ordinary consumers are willing to pay a premium for products containing Mirel because of its environmental benefits. Half of the respondents to a survey conducted by Insight Express on behalf of the joint venture said they would pay 5 to 10% more for biodegradable plastics. "If a lipstick costs $10, the public would be willing to spend $11 for that," Peoples says.

But not every observer agrees with that statement. Back in 2005, when Dow sold its 50% interest in Cargill Dow to Cargill, Dow CEO Andrew N. Liveris told analysts that "customers are not willing to pay a premium for environmentally friendly polymers." Cargill has since brought in the Japanese firm Teijin as a partner in NatureWorks.

Ramani Narayan, a professor of chemical engineering at Michigan State University (MSU), agrees that to be successful, biobased plastics need to be reasonably priced. "There seems to be a general sentiment that consumers would pay a premium, but I'm not convinced that is such a big driver," he says. "You have to be almost cost competitive to be in the marketplace."

Randy Woelfel, president of Cereplast, a Hawthorne, Calif.-based start-up that compounds bioplastics, believes a good combination of cost and performance is essential to the future of bioplastics. And his company wants to ensure that for the nascent industry.

For example, Cereplast works with PLA from NatureWorks to make the material more heat resistant and able to compete with polypropylene and polystyrene. Cereplast can also improve PLA's biodegradability, reinforcing it as a selling point over conventional plastics. In addition, the company has what it calls "hybrid resins," which are blends of industrial starches and traditional polymers such as polypropylene. "Our business concept," Woelfel says, "is to take the customer's requirements and bring them materials that are close to drop-in substitutions for traditional 100% petroleum-based materials."

Cereplast is targeting mainstream plastics applications, which means performance can't come at an exorbitant price. "We aren't particularly interested in being a niche supplier," Woelfel says. "We tailor and formulate materials that we hope will be in the vicinity of either straight-out parity or perhaps at premiums in the neighborhood of 10 to 20%, but not at 50% or 100%," he says. "As long as what is available demands that sort of premium compared to a traditional alternative, you are going to remain somewhat of a green curiosity."

The company just completed a plant in Seymour, Ind., that has 25,000 metric tons of annual capacity.

THE PERFORMANCE of biobased plastics is "getting close" to that of conventional plastics, MSU's Narayan says. But he notes that petrochemical plastics have set a standard in many applications for decades that is impossible to duplicate. After all, the specifications for those applications are based on the properties of the dominant materials themselves.

And Narayan wonders whether getting close to the dominant product's performance is really necessary. "My submission is that it is appropriate to come back and ask, 'What are the real performance requirements for a product? What do I need and what do I get?' " he says. "Some of our products are overengineered."

Daniel Tein, vice president of sales and marketing for PSM North America, an affiliate of packaging supplier Teinnovations, agrees. His company makes Plastarch Material (PSM) at a 100,000-metric-ton plant in China. There, the company mixes about 80% industrial starch and 8% cellulose with sodium stearate, oleic acid, and other ingredients to produce a resin that can be processed like a petrochemical plastic. Tein says the product can withstand moisture and has a tolerance to heat that makes it suitable for packaging.

The company uses the material for packaging peanuts, cups, bowls, cutlery, and other disposable goods for which its high biodegradability is an advantage. Tein readily admits that in trials the tines on a fork made with polystyrene can withstand about 6 lb of pressure before they snap off, while a fork made with PSM bends at only about 4 lb. "The probability that you will be consuming a top-end steak with a cheap disposable fork is quite low," he says.

As the prospects for biobased plastics improve, more companies are jumping into the market. Dutch lactic acid maker Purac has developed a PLA technology with Swiss process engineering firm Sulzer. The Dutch plastics company Synbra will be the first to use the technology in a 5,000-metric-ton plant due to start up in the Netherlands next year. Similarly, Total Petrochemicals and Belgian lactic acid maker Galactic are opening a pilot PLA plant in Belgium next year.

The 70-Year Biopolymer

Polyamide 11 Is Older Than Most Plastics

One biobased polymer was around for decades before the idea of making plastics out of biomass became trendy. In fact, it has existed as a commercial product longer than most petrochemical-based plastics have.

The polymer is polyamide 11, made by Arkema. And for 70 years, it has been derived from plants—not out of concern for the environment but because that has always been the most economical way to make it.

Polyamide 11, also known as nylon 11, is polymerized 11-aminoundecanoic acid, says James Mason, technical service and applications manager for polyamides at Arkema. The company derives the monomer from castor oil via a circuitous six-step process that has many coproducts and intermediates. Among the latter is undecanoic acid, used in topical antifungal remedies. "We investigated many different ways to try to get to this polymer, and there's really no way that's more efficient," Mason says.

In the 1930s, scientists at the French chemical firm Thann et Mulhouse, influenced by Wallace H. Carother's work at DuPont on polyamides, decided to try to polymerize an amine based on 11-aminoundecanoic acid. Mason says the polymer was a commercial success owing to the ready availability of castor oil in Europe during subsequent years. And

DSM's venture capital arm has invested in Tianjin Green Bio-Science to help that company construct a 10,000-metric-ton PHA plant in Tianjin, China. BASF is expanding capacity for Ecoflex—not a biobased plastic but a biodegradable petrochemical polymer based on adipic acid, butanediol, and terephthalic acid—by some 300%. The firm is also launching Ecovio, a blend of Ecoflex and PLA.

And there will be wholly new entrants that will usher new chemistries into the biobased plastics market. For instance, Segetis, backed by the venture capital firm Khosla Ventures, plans new categories of monomers generated from sugars. One platform, for example, would be based on reacting levulinic acid with carbohydrates. Segetis will initially develop products such as performance-enhancing additives for existing bioplastics, but it plans to eventually make biobased engineering plastics of its own.

SRI's Davenport says the new suppliers are good for the industry. More production from a variety of companies means that customers feel secure enough to risk adopting a new technology. "If there is more than one supplier out there, that will make the consumer much happier," he says.

Other chemical companies are entering the biobased plastics market in a way that customers won't have to adjust to new material properties. They are using biological routes to make plastics that have been around for more than a half century. Dow and Brazil's Braskem are planning polyethylene plants in Brazil based on ethylene derived from sugarcane ethanol. Likewise, Solvay Indupa is planning Brazilian polyvinyl chloride production based on bioethylene.

Braskem's project entails building a plant in Triunfo, in the southern Brazilian state of Rio Grande do Sul, that will catalytically dehydrogenate ethanol into ethylene. This ethylene will then feed existing high- and low-density polyethylene plants with a combined capacity of 210,000 metric tons per year. The company expects to start making the polymers during the second half of 2010 and intends to target traditional polyethylene applications such as shopping bags and personal care and food packaging.

Luiz A. Nitschke, the commercial leader for green polymers at Braskem, says ethylene manufactured this way is cost-competitive with traditional ethylene made by steam cracking naphtha or natural gas. And, he notes, the resulting polyethylene is cheaper than PLA or PHA. However, Nitschke expects to sell the polyethylene at up to a 50% premium over conventional polyethylene. "It is a marketing strategy," he says. "It is not a cost decision."

Nitschke is squarely in the camp that says consumers are willing to pay more to feel good about the plastics in the products they use. A 50% premium for the plastic in packaging, which normally represents about 10% of the cost of a good, amounts to only a 5% increase in the final cost at the supermarket. And he points out that consumers around the world are eager to pay a premium for products like the Toyota Prius hybrid car.

DOW IS COMING at biobased polyethylene from a different angle. It cannot significantly expand its ethane-based ethylene and polyethylene complex in Buenos Aires because Argentina lacks a sufficient supply of natural gas. In Brazil, local chemical companies like Braskem are lining up with the state oil company Petrobras to lock up hydrocarbon ethylene. "The mission of this project is to ensure our market share and participation in Brazil," says Carlos R. Pereira, Dow's project leader. "This is our gate access to ethylene."

Unlike Braskem, which intends to buy its ethanol, Dow is teaming up with sugarcane processor Crystalsev on an integrated complex targeted for completion at a yet-to-be-determined location by the end of 2011. The complex will process the sugarcane, ferment the sugar into ethanol, dehydrate the ethanol, and use the resulting ethylene to make linear low-density polyethylene. The partners will use bagasse, a solid by-product of processing sugarcane, to fuel a power plant that will supply electricity and steam to the complex. Vinasse, a liquid distillation by-product, will fertilize sugarcane fields.

it was used in many applications, such as stockings, that were early mainstays of DuPont's polyamide 6,6.

Use of polyamide 11 dropped off significantly after World War II. Still, it has carved out a sizable niche—tens of millions of pounds per year globally—thanks to some advantageous properties. It resists swelling when exposed to water and has high resistance to hydrocarbons. Some of its major applications, such as natural gas pipelines, pressure barriers for offshore oil pipelines, fuel tanks, and air brake hoses, take advantage of these properties.

Arkema

CALL BEFORE YOU DIG Polyamide 11 is used to make gas distribution pipes.

Mason is bemused by all the fanfare over newer biobased plastics such as polylactic acid and polyhydroxyalkanoate. He says some of his customers don't even know they are buying a biobased polymer. "We are the original engineering bioplastic," he says.

Pereira says the resulting plastic will be competitive with traditional polyethylene "by a safe range." However, a premium for the material over the market price of polyethylene is not part of the plan. "We are not predicting any greater price at this point in time," he says. But he does note that producing 1 ton of polyethylene by this route saves the environment about 4 tons of carbon dioxide. And he says the partners are looking into getting carbon credits, which could be used to meet their greenhouse gas reduction mandates or could be sold to other firms on a climate exchange.

MSU's Narayan says companies involved with biopolymers ought to get carbon credits. The question, he adds, is whether the credits would be granted to retailers such as Wal-Mart or to the plastics producers themselves. "The use of biobased plastics could help a company and a country in managing their carbon footprint," he says.

Whether or not producers get such credits, biopolymer proponents say the industry has enough forward momentum to make dramatic gains. "Today, we joke that bioplastics aren't even the mouse looking up at the elephant; we are the flea on the mouse looking up at the elephant," Cereplast's Woelfel says. "We do believe that there is incredible potential for us to very rapidly move up to the mouse stage, and then we will see where we can go from there. But we aren't interested in remaining at the flea stage."

Chemical & Engineering News
ISSN 0009-2347