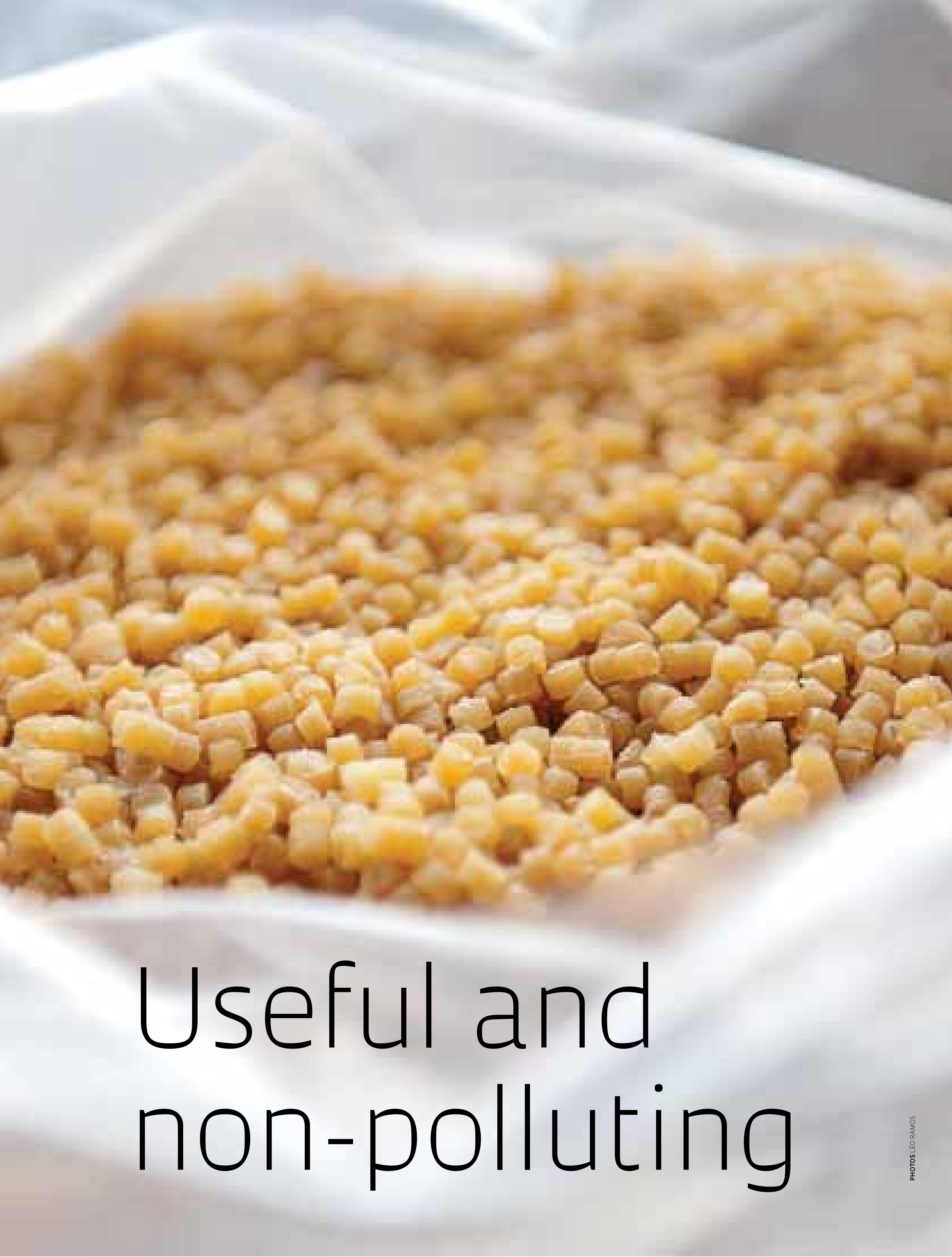


Useful and non-polluting

PHOTOS LÉO RAMOS

Plastic made from sugarcane breaks down in the environment in one year, thanks to the action of the bacteria used in its production

Evanildo da Silveira

The first factory in Brazil to produce biodegradable plastic made from sugarcane is scheduled to start operations by 2015. It will be built by PHB Industrial, a company in the Irmãos Biagi Group from Serrana (SP), and the Balbo Group from Sertãozinho (SP). With production capacity of 30,000 tons a year, this factory is one of the results of a project financed by the FAPESP Innovative Research in Small Businesses Program (Pipe), between 2001 and 2004.

Known by its commercial name Biocycle, this plastic can be used to manufacture rigid items like car panels, sporting goods, and toys, as well as disposable objects such as razors and toothbrushes, pens and cards. One of the advantages it offers is that it breaks down in the environment within a year, while regular plastics can last up to 200 years.

This biopolymer is from the family of the polyhydroxyalkanoates (PHA) that are one of the results of the natural metabolism of several species of bacteria. What the new factory will produce is polyhydroxybutyrate, or PHB, hence the name of the company. Its production process begins by growing bacteria of the species *Alcaligenes eutrophus* in bioreactors in which they are fed cane sugars, principally sucrose. In their metabolism, the microorganism ingests the sugars and transforms them into intra-cellular granules (tiny balls) that are actually polyesters.

These polyesters, which are simply biodegradable plastic, act as a reserve of energy for the bacteria, as occurs with fat in mammals and other animals. The next step in the production process is extraction and purification of the PHB accumulated inside the microorganisms. This is done using an organic solvent, more specifically an alcohol called isoamyl propionate, which does not harm the environment upon disposal. It breaks down the cell wall of the bacteria, releasing the biopolymer granules. "One kilo of biodegradable plastic is produced from three kilos of sugar," says materials engineer Jefter Fernandes do Nascimento, coordinator of the Pipe project, and now a consultant at PHB Industrial.

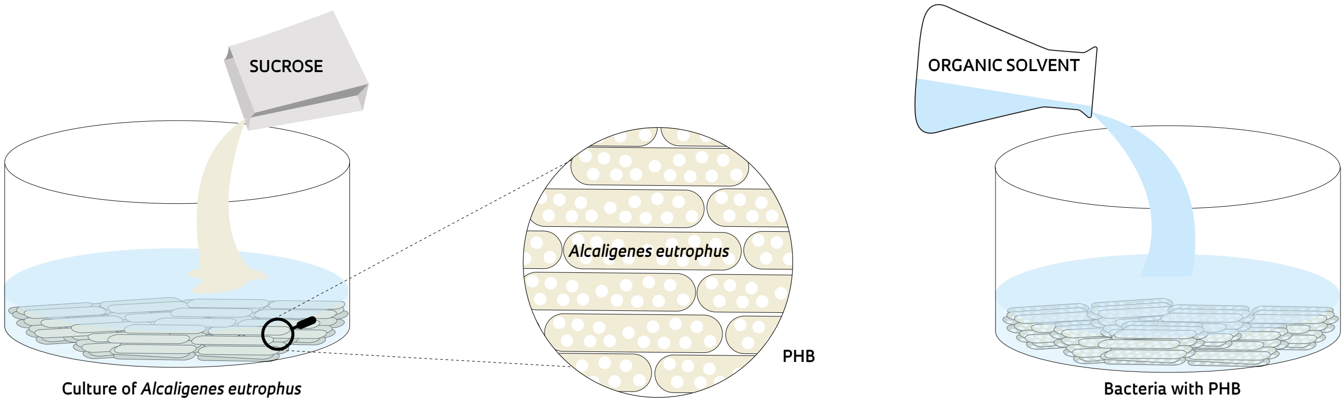
Before reaching this phase, biopolymer development had a long history. It began in 1992, when a group of scientists from the São Paulo Institute for Technological Research (IPT) began to conduct research in this area. In a successful partnership with the Sugarcane, Sugar and Alcohol Producers Cooperative of the State of São Paulo (Copersucar) and the Institute of Biomedical Sciences (ICB) of the University of São Paulo (USP), they discovered new species of bacteria capable of transforming sugar into plastic.

The laboratory studies for the production phases, ranging from pre-fermentation to fermentation, extraction and purification of the biopolymer, were concluded in 1994. That same year, studies began on the construction of a pilot

Biodegradable polymer in granular form

Sugar reserves

The bacteria *Alcaligenes eutrophus* produce bioplastics that take only one year to break down after they are used



The bacteria are fed only sucrose

Later, they begin to create reserve pockets (sucrose) in the form of Polyhydroxybutyrates (PHB)

Bacteria are dipped into an organic solvent to separate the PHB

factory so that the technology developed in the laboratory could be tested on an industrial scale. It was inaugurated the following year, at the Pedra Mill in Serrana, and is able to produce five tons a year of biodegradable plastic.

In 1996, the first quantities produced began to be sent to different research institutes and companies in Brazil as well as in Europe, the United States and Japan. The objective was to evaluate the properties of the product and identify possible uses. Based on this stage of development and the test results and applications by research institutes and companies, several adjustments were made to the pilot factory. In 2000, it was renovated and adapted, and its production capacity was increased to 50 tons per year.

BACTERIA SELECTION

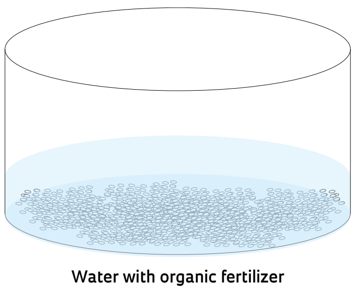
At the same time, another project financed by FAPESP led to the development of a different technology to obtain biodegradable plastic. Coordinated by biochemist Luiziana Ferreira da Silva, who was then a member of the Biotechnology Group at IPT, the objective of this effort was to find bacteria that would be capable of using hydrolyzed sugarcane bagasse to produce biopolymers. Entitled "Selection, genetic improvement and development of the fermentation process to use hydrolyzed sugarcane bagasse for the production of polyhydroxyalkanoates (PHA)," a polymer used in biodegradable plastics, the project also sought to develop a process to produce these materials in bioreactors on a bench scale.

Ferreira da Silva was also a member of the team that developed bioplastics from sucrose. She explained that hydrolysis (structural breakdown of the product) releases the sugars (glucose, xylose and arabinose) present in bagasse, a waste product of the sugar and ethanol industry. It is only after this that the bacteria can consume them and transform them into a biopolymer. She said that at that time, the bagasse was used only to generate electricity by burning it, and there was a surplus of this product. "Its potential use as a raw material for other products, like its potential use today to manufacture second-generation ethanol, was not yet seen at that time," she explains. "Then we proposed its use for producing polyhydroxyalkanoates and creating biodegradable plastics using hydrolyzed sugarcane bagasse."

In order to do this, the team identified and selected two species of bacteria (*Burkholderia sacchari* and *Burkholderia cepacia*). The former had been previously unknown, and both are highly efficient in the process of synthesis and production of bioplastic from hydrolyzed bagasse. But to reach this point, a series of obstacles had to be overcome. "In our project, hydrolysis was done in an acid medium that releases the sugars, but

3 kilos of sugar are needed to produce one kilo of biodegradable plastic

Day-to-day examples: rulers, a cup, and key chains made from bioplastics



The resulting PHB powder will be used to produce bioplastics

INFOGRAPHIC TIAGO CIRILLO, SOURCE: BIOCYCLE WWW.BIOCYCLE.COM.BR/SITE.HTM

also produces a series of compounds that are toxic to the micro-organisms," Ferreira da Silva explains. "So we had to develop a methodology to eliminate the toxicity of the hydrolyzed bagasse, and thus allow it to be used by the bacteria." In spite of the success, this technology is not yet used commercially.

However, this did not mean that the project did not have any impact. In 2004, Ferreira da Silva transferred from IPT to USP, where one of her lines of research today seeks to improve the use of the sugars found in hydrolyzed bagasse to generate biopolymers and other materials. "Here at the Bioproducts Laboratory, we have studied a variety of aspects that are key to understanding and improving consumption of xylose, or of mixtures of xylose, glucose and arabinose, to obtain organisms that are efficient in the production of polyhydroxyalkanoates," she says.

According to Ferreira da Silva, one of the main contributions of her group in this area is to propose that biopolymer production from xylose be incorporated into the sugar and alcohol mills, which are the best model of what is today defined as a biorefinery. "At biorefineries, biodegradable polymers would be produced from xylose, using inputs as both raw materials and for the separation processes, which could result in a green and self-sustainable process," she explains. "The ethanol-producing yeast might use only the glucose that is also present in the hydrolyzed bagasse and our bacteria would use the xylose."

PARTNERSHIP WITH UFSCAR

In the meantime, "Obtaining and characterizing environmentally degradable polymers (PAD) from renewable sources: sugarcane," the project coordinated by Nascimento with support from Pipe, was making progress in consolidating the path it had begun there in the early 1990s. During the three years of project duration, the product was tested by final clients and evaluated with regard to its market possibilities. "At the end, we had developed specific products and applications for some niche markets," Nascimento says. "These included the food packaging, pharmaceutical, toy and automotive industries, as well as agriculture."

The partnership with the Department of Materials Engineering of the Federal University of São Carlos (UFSCar) was vital in enabling PHB Industrial to achieve these results. It was there that in 2001 studies began on the development of blends and composites based on the PHB. "During the project supported by Pipe, here at our department, we did all the characterization of the biopolymer and we developed potential uses for it," explains researcher José Augusto Agnelli, of UFSCar. "Prototypes of several products were also created here at our university."

First, the necessary characteristics had to be given to the plastic produced by the bacteria, so that it could be transformed into industrial products. In other words, new formulations were made by adding other materials to the biopolymer. "We added natural materials, like sisal fibers or wood flour," Agnelli explains. "We also add residues from industrial processes and other degradable polymers to the formulations. The objective of these blends is to facilitate and accelerate decomposition and reduce production costs."

The company PHB Industrial was not the only beneficiary from the project financed by FAPESP through the Pipe program. UFSCar also came out ahead. "All the equipment that was purchased with FAPESP funds for the project is still installed here in our department," Agnelli says. "In the third phase (Phase III of the Pipe), PHB Industrial built a laboratory here, inside the facilities of the Federal University of São Carlos, linked to the Department of Materials Engineering, known as the Biodegradable Polymer Laboratory. The University provided the land and PHB Industrial was in charge of building it." ■

PROJECTS

1. Obtaining and characterizing environmentally degradable polymers (PAD) from renewable sources: sugarcane – no. 2001/02909-9 (2001-2004)
2. Obtaining bacteria lines and development of technology for production of biodegradable plastics based on hydrolyzed sugarcane bagasse –no. 1999/10224-4 (2000-2002)

GRANT MECHANISMS

1. Innovative Research in Small Businesses Program (Pipe)
2. Regular research assistance line

COORDINATORS

1. Jefter Fernandes do Nascimento – BPH Industrial
2. Luiziana Ferreira da Silva – IPT

INVESTMENT

1. R$338.840,00
2. R$107.740,17

SCIENTIFIC ARTICLE

CASARIN, S. A. *et al.* Study on In-Vitro Degradation of Bioabsorbable Polymers Poly (hydroxybutyrate-co-valerate) – (PHBV) and Poly (caprolactone) – (PCL). **Journal of Biomaterials and Nanobiotechnology**. v. 2, p. 207-15, 2011.

FROM OUR ARCHIVES

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