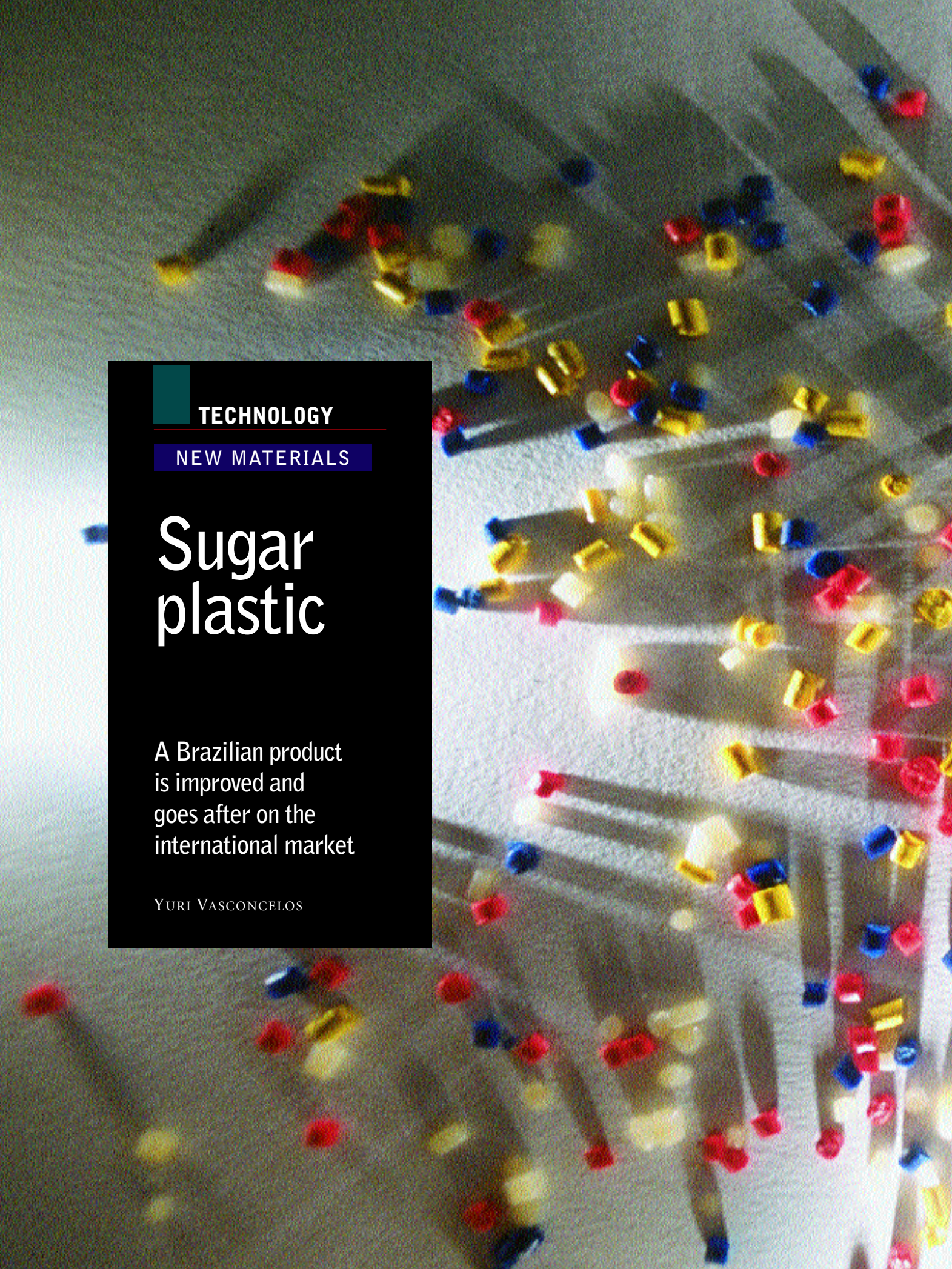


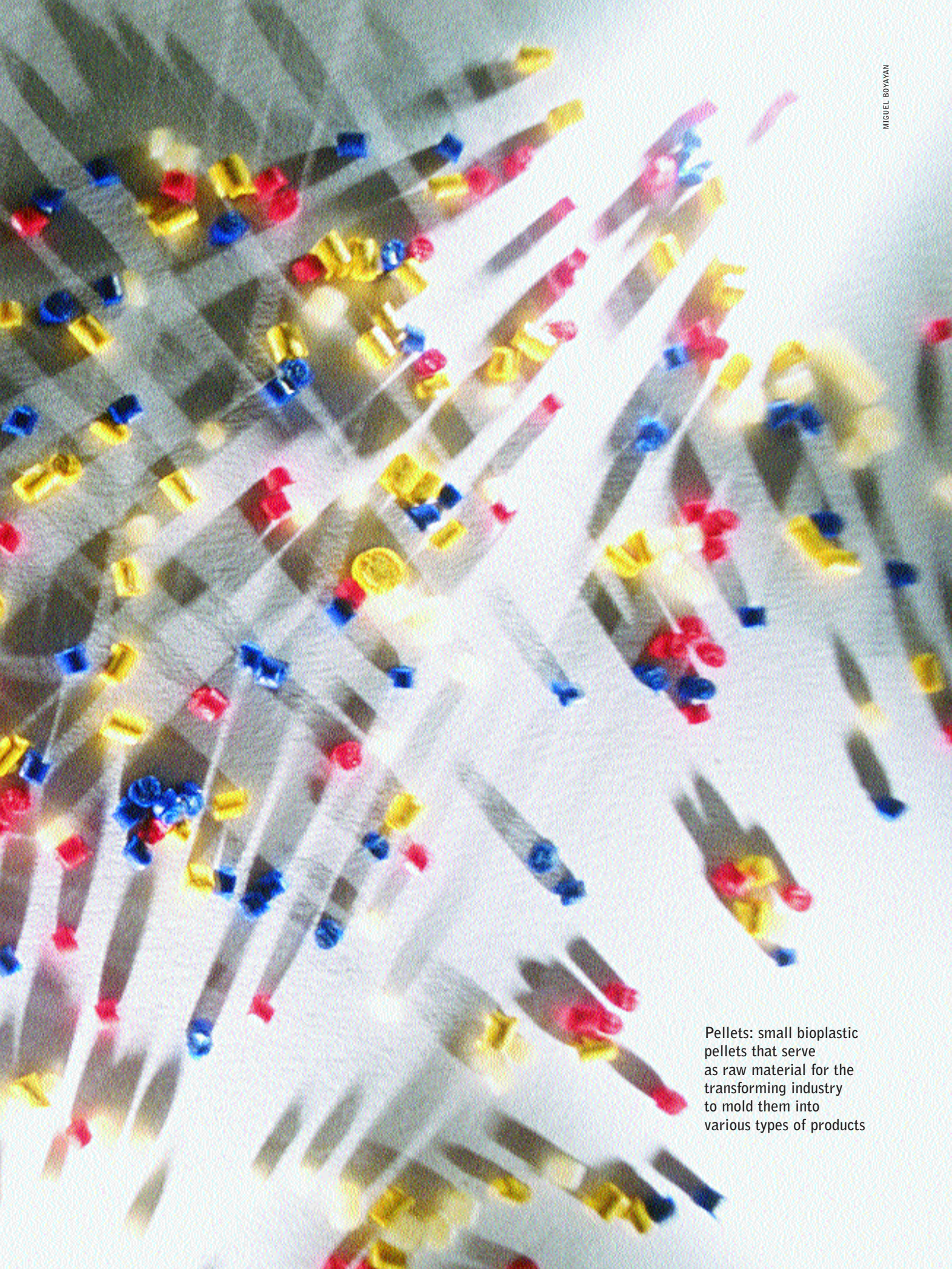
TECHNOLOGY

NEW MATERIALS

Sugar plastic

A Brazilian product is improved and goes after on the international market

Yuri Vasconcelos



MIGUEL BOYAYAN

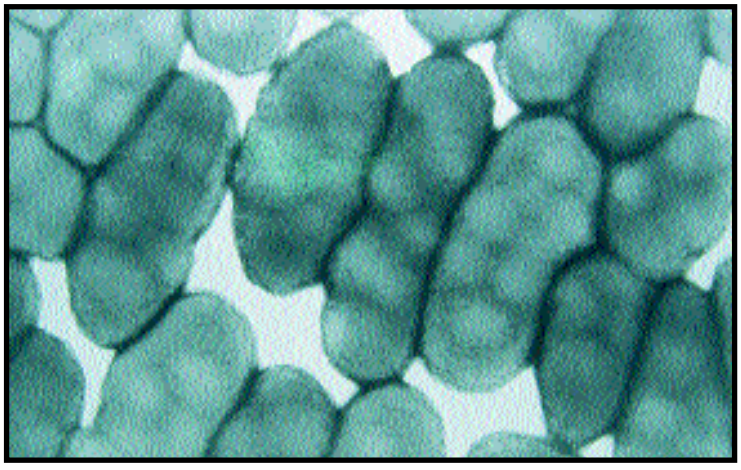
Pellets: small bioplastic pellets that serve as raw material for the transforming industry to mold them into various types of products

Sugar and alcohol are no longer the only products of commercial importance extracted from sugarcane. Now, also joining this pair is the production of a biodegradable plastic from sugar. Since December of 2000, the company PHB Industrial, belonging to the Irmãos Biagi group, in the town of Serrana (SP), and to the Balbo group from Sertãozinho (SP), have had the capacity to monthly produce through a pilot plant between four and five tons of biopolymer from the sucrose present in sugar. All of the production obtained at the company's industrial plant, built at the side of the Usina da Pedra mill in Serrana, is being exported to countries such as the United States, Germany and Japan.

"We intend to start our commercial operation between 2004 and 2005 with the construction of a plant with the capacity of producing 10,000 tons per year of bioplastic", says the physicist Sylvio Ortega Filho, responsible for the development of biodegradable plastic at PHB, a company that received funding through FAPESP's Small Business Innovation Research (PIPE) program. "We do not know of another industrial complex in the world that has commercial production of this type of bioplastic resin", says Ortega Filho.

The development of the technology for this polymer, that undergoes rapid decomposition by microorganisms when it is discarded on landfills, rubbish dumps or exposed to an environment with active bacteria, is the result of a very successful partnership between the Technology Research Institute (IPT), the Cooperative of Sugarcane, Sugar and Alcohol Producers in the State of São Paulo (Copersucar) and the Biomedical Sciences Institute (ICB) of the University of São Paulo (USP). The first studies on the theme were carried out at the beginning of the 90s, and ten years later, the country is being recognized as having one of the most advanced centers in research and development into bioplastics in the world.

The technology led the area to further advance. This was the development of a process that facilitates obtaining this polymer from hydrolyzed sugarcane bagasse, the waste product of the alcohol and sugar industry. The project, also financed through FAPESP, was coordinated by the researcher Luiziana Ferreira da Silva, a biochemist with the Biotechnology Group within the IPT, which made up part of the team that created the bioplastic. The hydrolysis process (the structural breaking up of the product) releases the sugars present in the bagasse that can be consumed by bacteria used in the process of the transformation of sugar in this type of natural polyester.



LUIZIANA FERREIRA DA SILVA/IPT

Ralstonia eutropha transform sugars into intracellular granules (the polymer) used by them as energy reserve

However, the hydrolysis also induced the formation of toxic compounds for the bacteria. The IPT developed a procedure for detoxifying the hydrolyzed material and making possible its use by the microorganisms. "With this process it is possible to manufacture the same biopolymer already being exported, which received the name of polyhydroxybutyrate or simply PHB, from the sugar extracted from the bagasse", explains Luiziana.

The difference between the technique created by Luiziana and the previous one, developed jointly with IPT, Copersucar and USP, that is being used by the PHB company, is in the raw material used. While Luiziana makes use of xylose (a sugary substance contained in the sugarcane bagasse), the previous process, the research of which was coordinated by professor José Geraldo Pradella of IPT, makes use of the saccharose present in the sugar.

The researcher also identified two new bacteria (*Burkholderia sacchari* and *Burkholderia cepacia*), the first until that moment unknown, highly efficient in the process of the synthesis and production of bioplastic through the hydrolysis of the bagasse. The *sacchari* bacterium can also be used to produce PHB from molasses or saccharose.

The physical and mechanical characteristics of biodegradable plastic are similar to some synthetic polymers, which use petroleum derivatives as their raw material, but offers the benefit of being decomposed much more rapidly after it has been thrown away than conventional plastics. "This is the great advantage of the product" says Luiziana. While the packaging made from Polyethylene Terephthalate – called PET and mainly used for soft drinks – takes more than two hundred years to degrade, and the traditional plastics, more than one hundred years, the biodegradable plastic resins decompose in approximately twelve months, depending on the environment in which they find themselves. In septic tanks the loss in mass of around 90% occurs in six months, while in landfills the degradation reaches 50% in two hundred and eighty days. When they decompose they turn themselves into carbon dioxide and water, without releasing any toxic residues.

Energy reserve - The start of the production process of PHB, used in the pilot plant, begins with the cultivation of

bacteria of the species *Ralstonia eutropha* inside bioreactors impregnated with sugars (sucrose, glycose, etc.) as the raw material. The microorganisms feed on these sugars and transform them into intercellular granules (very small solid lumps) that are in truth polyesters. "For the bacteria, these polyesters (the biodegradable plastics) are an energy reserve, similar in nature to the fat reserve in mammals", says Luiziana. The next stage in the production process is the extraction and purification of PHB accumulated in the bacteria. Using an organic solvent (which does not provoke damage to the environment when discarded), the breakdown of the cellular walls of the microorganisms is brought about along with the natural liberation of the biopolymer granules. Calculations carried out in the laboratory point towards obtaining one kilogram of plastic for every three kilograms of sugar.

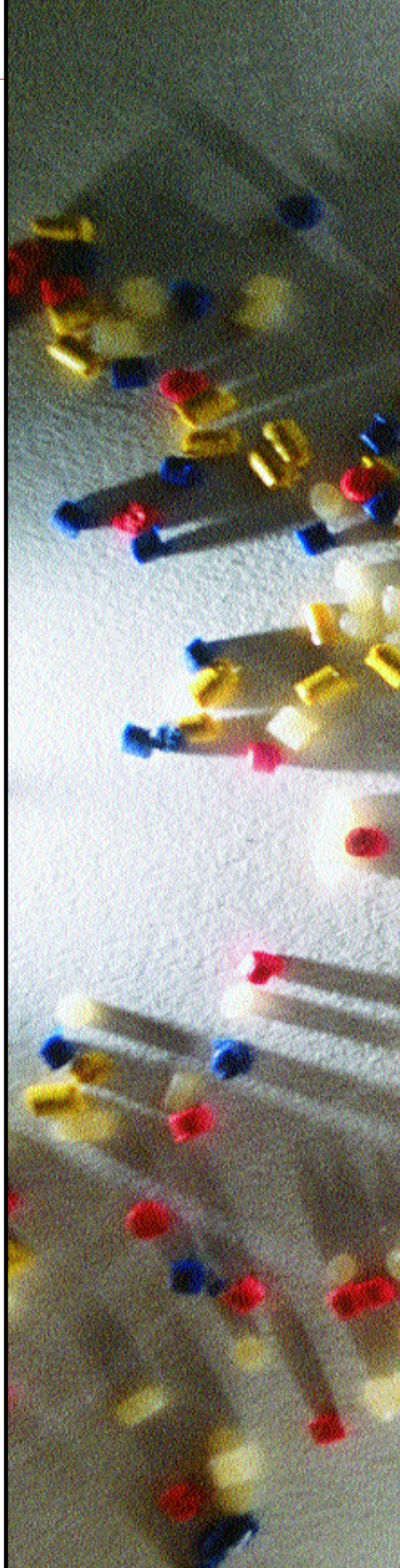
The PHB can be used as a raw material in a wide field of applications, mainly in those sectors in which characteristics such as purity and biodegradability are necessary. It may be used in the manufacturing of packaging material for cleaning, hygiene, cosmetic and pharmaceutical products. Also it can be used to produce bags and containers for fertilizers and insecticides, vases for seedlings and injection mold products such as toys and school material. Furthermore, since it is biocompatible and easily absorbed by the human body, it can be useful in the area of medical pharmaceutical products, as thread for stitches, bone prostrates and capsules that gradually liberate medicine into the blood stream. "Thanks to its property of acting as a barrier to gases, the bioplastic can also be used in food packaging of paper cartons such as those used in "long life" milk, for storing natural juices, pasteurized milk and isotonic drinks", says Ortega Filho. The FDA (Food and Drug Administration), the organ that oversees the food and drug sectors in the United States, has already approved the use of PHB biodegradable plastic in food packaging.

For the production of more flexible artifacts, such as shampoo bottles, or those that need the process of extrusion via a blower, such as plastic bags, the researchers have already developed another product of the same family, a type of polymer named PHB-HV (polyhydroxybutyrate –hydroxyvalerate), produced from sugar and propionic acid.

The main difficulty in the development of PHB is centered around the right choice of bacteria. "In order to find the ideal bacterium, which gives a better transformation of the sugar into plastic, we tested more than fifty species until we arrived at the two most adequate strains, in this case the species *Burkholderia sacchari* and *Burkholderia cepacia*", Luiziana reports, who completed her study during the first semester of this year. The two microorganisms attained the best performances as a function of velocity and growth rate, efficiency in converting the xylose into PHB and the capacity of accumulating the polymer. In order to increase the production of the bioplastic, the bacteria were and continue to be submitted to techniques of genetic improvement.

"The advantage of this new technology is in the transformation of a waste product of the sugarcane/alcohol industry, in this case bagasse, into top quality material, bioplastics", Luiziana says. Currently between 60% and 90% of the bagasse (of an annual total of 81 million tons) produced by the mills, is used in the generation of electrical energy. The surplus of this waste product, which during 1999 reached some eight million tons, causes serious problems of stocking and environmental pollution. "The use of bagasse to produce PHB will minimize these problems", says the researcher.

The technique of obtaining PHB through bacteria is not new. It has been know since the start of the 20th century. However, the commercial use of this polymer has not been implemented due to the high costs involved in its production. The merit of the Brazilian researchers has been in managing to considerably reduce this cost when compared with the biodegradable products synthesized in the United States and Europe. There, they are manufactured only in pilot plants and in laboratories starting from other sources of raw material such as beet root and corn sugar. This reduction occurred mainly as a function of the low cost of growing the sugarcane, which inclu-



MIGUEL BOYAYAN

Utensils made with biodegradable plastic: varied market and similar to commun plastic

des the cheap electrical energy produced through the sugarcane bagasse. "For this reason, to have a competitive price, the ideal situation is to have a biodegradable plastic production unit working alongside a sugar/alcohol mill", Ortega Filho of PHB explains.

Even with a reduction in costs, biodegradable plastic is still more expensive than conventional plastic. "A kilo of synthetic polymer costs around US$ 1, while the PHB one is in the region of US$ 4 or US$ 5, depending on its application", explains Ortega Filho. In spite of this difference in price, it is considered to be competitive, mainly in the external market. For example, in the United States, Japan and some European countries, recycling is mandatory, with as well the need by the polymer manufacturing industry to prove that recycling has been carried out effectively. The costs of these stages are not included in the cost of the plastic. In Brazil, the calculation of this cost considers the purchase of the resin and its transformation. Neither the worry nor the effective cost of recycling exist.

For example, over the next sixty years, Germany intends to substitute at least 60% of the synthetic plastic internally consumed with biodegradable polymers. Among other things, this measure is looking to solve the problem of landfills in the country. The long stay of synthetic plastics at these locations brings with it serious environmental problems, because they form an impermeable layer that blocks the passage of liquids and gases originating from the deterioration of the waste material, stalling the stabilization of the organic material. The problem is worrying when one knows that they represent around 20% of all of the urban rubbish in Brazil.

According to Luiziana, another advantage of biodegradable plastic resins is that they are produced from renewable resources, while the conventional ones use petroleum derivatives as their raw material, a non-renewable source.

Production of pellets - The world's plastics market is something in the order of 200 million tons per year. According to estimates by various specialists, the share of this market that may be occupied by bioplastics is around 1% to 2% over the next ten years. And the PHB company wants to participate in this slice. "However, in order for this to be possible, we firstly need to conclude the development of technology for the production of pellets that will be sold for transformation", he explains.

Pellets are small cylindrical solids of some millimeters in length made starting a mixture of granulated resin of PHB with other polymers or natural fibers. They are the raw material being used by the industry, that transform them into useful articles. "The industry does not buy pure PHB. It wants what it is ready to be transformed into the final product", says Ortega Filho.

In order to engineer the pellets, the company PHB Industrial has made a cooperation and research agreement with the Materials Engineering Department (DeMa), of the Federal University of São Carlos (UFSCar), and obtained funding of R$ 338,000 from FAPESP through the PIPE program. Kicked off in 2001, the project is expected to extend until next year.

The resources have been in the purchase of basic equipment in polymer technology, with an eye on manufacturing pellets. "We purchased a fluid index measurer and equipment for universal testing for analyzing traction, flexibility and compression", Ortega Filho says. "By the end of the year, we'll have received an extrusion machine, with which we can carry out studies to develop the

MIGUEL BOYAYAN

The PHB Industrial company: by 2005, the company should be producing 10,000 tons of bioplastic per year

product with the characteristics that the market demands." All of this apparatus will be installed at UFSCar, in a laboratory as yet to be built. "FAPESP's resources are essential for the commercial viability of Biocycle, the commercial name given by us to PHB", says the materials engineer Jefter Fernandes do Nascimento, the coordinator of the PIPE project.

In the meantime the 60 tons of Biocycle produced at PHB Industrial are being sent mainly to companies and research centers abroad, which are also working on the development of pellets. "We're exporting to centers in the United States and in Europe, such as the Fraunhofer Institute in Germany, and the North American company Metabolix, whose owners are researchers at the Massachusetts Institute of Technology (MIT)", says Ortega Filho. "They're doing exactly the same as us: attempting to find the ideal pellet for each application." The good point is that the PHB company is ahead, and, if all goes well, the company will shortly be exporting biodegradable plastic pellets. •

THE PROJECTS

Obtaining and Classification of Environmentally Degradable Polymers (PAD) Starting from Renewable Sources: Sugarcane

MODALITY
Small Business Innovation Research (PIPE) program

COORDINATOR
Jefter Fernandes do Nascimento – PHB Industrial

INVESTMENT
R$ 338,840.00

Obtaining Bacteria Lineages and the development of Technology for the Production of Biodegradable Plastic Starting from the Hydrolysis of Sugarcane Bagasse

MODALITY
Regular Line of Research Assistance

COORDINATOR
Luiziana Ferreira da Silva – IPT

INVESTMENT
R$52,133.47 and US$ 19,645.00