



## Realizing a Recycling-Oriented Society Through Agricultural Biotechnology

The Biotechnology and Afforestation business is a distinctive element in the Toyota organization. Automotive manufacturing, which belongs to the field of mechanized industrial production, and agricultural biotechnology seem at first sight to be unrelated.

But looked at in a different way, these two disparate areas make an excellent match. In April 2002, Toyota published a medium- to long-term business plan called the Global Vision 2010, in which the company looks ahead to the advent of a "recycle-oriented society." In light of this key phrase, Toyota's entry into the agricultural biotechnology field can even be seen as inevitable. This key phrase is also the starting point for our efforts as well as the final goal that Toyota is aiming to achieve.



Chairman Okuda inspects research results at an executive worksite visit in October 2001

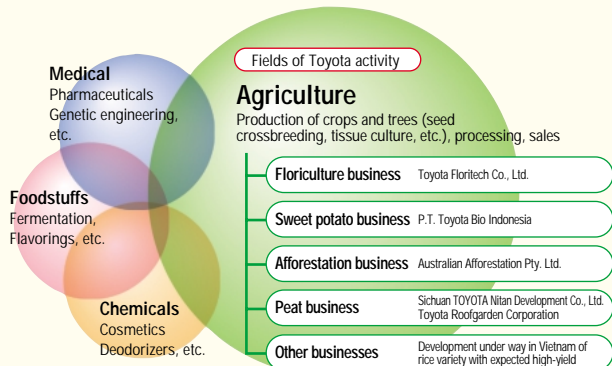


### How Toyota and Biotechnology Came Together

In the summer of 1996, Toyota Venture Enterprise Fund head administrator Kozaburo Tsukishima (now General Manager of the Biotechnology and Afforestation Business Division), who was responsible for new business projects, was entrusted with a mission by Toyota president Hiroshi Okuda (now Chairman). The mission was to think of a business project that would help solve problems of food and water supply.

Why food and water? According to Tsukishima, "This is probably because the Chairman is in touch every day with informed opinion from around the world and thus has a critical awareness of issues that will have a future global impact. In a conversation with a certain analyst, Chairman Okuda once said, "Japan needs to always have technology that can lead the world; if new technologies are continually created, particularly in such areas as bio- and environment-related technology and nanotechnology, Japan will have no trouble in continuing to make its way in the world." It is not difficult to imagine that underlying the words "food and water" is a clear vision of the advent of a recycling-oriented society and Toyota's role in it.

#### Areas of Toyota Activity in Biotechnology

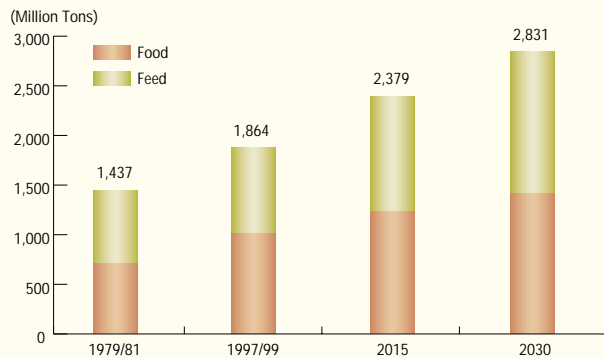


### Saving the Earth with Sweet Potatoes!

An investigation into the business potential of sweet potatoes and other foodstuffs was immediately begun. This process turned up a scientific paper by Professor Toyoki Kozai of Chiba University Faculty of Horticulture entitled "Sweet Potatoes to Save the Earth in the 21st Century." The main points of the paper were: (1) The manufacture of biodegradable plastics from sweet potato starch would become common; (2) Hydrogen derived from sweet potatoes by way of alcohol would become an energy source for fuel cell and electric vehicles; and (3) Sweet potatoes would be developed as a livestock feed as an alternative to corn. This seemed like an attractive business prospect worth giving a try, and right away a relevant business vision, including development of livestock feed, was drafted and brought to Chairman Okuda. His answer after seeing the document was just two words: "Thank you." With this simple phrase, Toyota's Biotechnology and Afforestation business was set on the path to realization.

In January 1998, a Biotechnology and Afforestation Business Department was established within the Business Development Division. It was a small beginning with just seven staff members to start with.

#### World Cereal Balances



Source: World agriculture: towards 2015/2030 - Summary Report (FAO, 2002)



### Search for an Original Approach as a Late Starter

So how was a new business started from scratch in a completely new field? One important factor was the Toyota corporate culture in which there is a strong orientation toward new businesses. Chairman Okuda himself has said, “We must not become prisoners of our own success; the greater the success a person has had, the more that person insists on their own way of doing things. But when the situation changes, that way doesn’t work anymore.”

However, there were many issues associated with being a late starter in the development process. The first task was to narrow down the scope of the project. It was essential to hone in on some area within the field where Toyota would not be following the lead of other companies, and which offered a potentially large market in the future. After researching the overseas and domestic markets, the patent situation, and other factors, it was finally decided to select agricultural biotechnology as the area within biotechnology to focus on.

### Active Recruiting of External Talent

Securing human resources was also an urgent task. Unlike the automotive field, where the basic technology is already well established, research in biotechnology is advancing quickly. In order to see income benefits at an early stage, it is essential to develop technology full of originality. To achieve this, an outstanding team was assembled by recruiting new graduates as well as seeking cooperation from other related companies.

In the field of biotechnology, there are a number of areas in which researchers are quite content to dedicate themselves even if it is not clear that their work will be useful in the future. With the limited number of staff, however, there was no possibility to engage in research in such areas. Instead, researchers were actively recruited in areas capable of delivering results. Patent rights were acquired from other companies where required. From Shimadzu Corporation, for instance, personnel were recruited for the development of biodegradable plastics and the relevant patent rights were acquired. In May 1999, less than one and a half years after the creation of the department, the Toyota Biotechnology and Afforestation Laboratory was completed. The original seven staff members had now grown to more than thirty.



Toyota Biotechnology and Afforestation Laboratory

### Business Development Centered around a Biotechnology Core

The business developed at a rapid pace. First, in August 1998, the tree-planting company Australian Afforestation Pty. Ltd. was established in Australia, and the planting of eucalyptus trees began in partnership with Nippon Paper Industries Co., Ltd. and Mitsui & Co., Ltd. In October 1999 came the founding of a floriculture business, Toyota Floritech Co., Ltd., in Aomori. These ventures were designed to strengthen bio-related technology and the business base. In April 2001, P.T. Toyota Bio Indonesia was established to work on developing livestock feed from sweet potatoes, followed in December of the same year by Toyota Roofgarden Corporation, established to work on the creation of roof



Harvesting sweet potatoes in Indonesia

gardens. In June 2002, there followed the establishment of Sichuan TOYOTA Niton Development Co., Ltd. to excavate peat in the Chinese province of Sichuan. The idea was to use peat, with its excellent moisture retention properties, in rooftop greening.

In this way, the scale of the business was expanded, with affiliates established at the rate of almost one every year from the time of the establishment of the Biotechnology and Afforestation Department in 1998 through 2002. And the process did not stop with the establishment of the companies — within a few years all of them had guaranteed profitable prospects and laid down a stable business base. There are now 352 related patents, either granted or pending, and the technology base is also steadily being implemented. In the last five years, the number of staff in the Biotechnology and Afforestation Division has reached 70, and is around 300 when affiliated companies are included.

### Sweet Potatoes: A Powerful Secret Weapon

The Biotechnology and Afforestation business has thus begun to develop on many fronts, but there is one area that has the potential for future development as a major business: the development of biodegradable plastics. This project is being advanced together with the development of livestock feed being carried out in the sweet potato business. This development of biodegradable plastics, in the words of Tsukishima, is a “secret weapon with the potential to become as great a homerun batter as Hideki Matsui (a leading Japanese baseball player).” As well as resolving food problems, it is also a project essential to the advent of a recycling-oriented society.

See p. 46 for details of each business



Growing sweet potato seedlings

# Special Story

## Making the Most of Toyota's Special Advantages

For Toyota, a company used to manufacturing vehicles, the biotechnology business is a completely new field. But there is no question that Toyota has expertise that can be introduced. Methods for quality control, plant operation, and setting up an efficient production line using energy-saving measures are among the many things where ability goes with the Toyota name.

Toyota has even bigger advantages in the field of developing biodegradable plastics. In addition to its aim of becoming a manufacturer of biodegradable plastics, Toyota is also an end user of such plastics. In other words, before it even starts making biodegradable plastics, Toyota has a concentrated demand on its own doorstep. As a company starting up a new business, there is nothing more reassuring than having a view of the needs of the market before beginning development.

### If It's Strong Enough for Cars...

The fact that up to now Toyota has mainly produced cars is also a great advantage. Quality standards for products used in cars are incomparably higher than for general household appliances such as air conditioners and audio equipment.

As an example, few complaints are heard when a computer breaks down because it has been dropped or left in direct sunlight for a long time. But with cars, consumers will not accept that a little knock might cause a breakdown. This means that Toyota can be quite confident in advance when adapting products and materials that have been used in cars to other fields. So once Toyota biodegradable plastics have undergone practical use in cars, they should be perfectly adaptable to other fields. In this way, two complete opposites, like cars and biotechnology, can make use of each other's strengths. This seems to be a case where one plus one equals more than two.



Starch processing plant

## A Revolution in Plastic Materials!

So what kind of a material is biodegradable plastic? Basically, it can be defined as a material with the same function as conventional plastics but which is broken down after use by microorganisms in the soil.

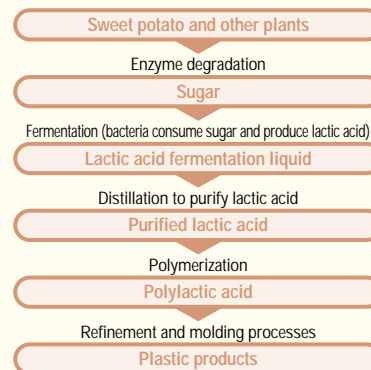
Plastic has the advantage of being lightweight and easily molded, but its material stability becomes a disadvantage after use and makes it resistant to degradation. How to deal with plastic after disposal is therefore seen as a problem.

How will this be different with biodegradable plastics? Take for instance garbage bags used for kitchen waste. With biodegradable materials, the whole bag, including its contents, can be turned into compost. In the case of plastic sheeting used in agriculture, which has been troublesome to dispose of, one would only have to plow up the soil where it lies. Such examples give a good idea of the degree to which it will be possible to reduce environmental impact. With items ranging from sundries and foodstuffs to fiber materials, medical supplies, and construction materials, the potential scope of application of biodegradable plastics is unlimited. This wide range of applications means that both the contribution to reducing environmental impact and the size of the market will be great.

### Bioplastics: Recyclable Materials that do not Use Petroleum Resources

The name biodegradable plastics emphasizes the post-use disposal aspect, but actually the term bioplastics, which emphasizes the manufacturing process, is also used. Biodegradable plastics can be made like conventional plastics using petroleum resources, in which case despite degrading following disposal, they use up limited petroleum resources. Bioplastics, being plant-based, are different. The carbon dioxide and water which is generated when they degrade is simply returning to where it came from; the carbon dioxide into the atmosphere and the water into the ground, so that over their whole lifecycle they cause no additional generation of carbon dioxide, apart from the energy consumed in their manufacture. These are the bioplastics that Toyota is currently developing.

#### Outline of Bioplastic Production





## High Quality with Carbon Neutrality

This feature of not increasing the volume of carbon dioxide is called carbon neutrality. Achieving widespread use of carbon-neutral materials is a major hurdle on the way to a recycling-oriented society.

The bioplastics which Toyota aims to create are carbon-neutral materials using sweet potatoes, sugar cane, etc. as raw materials. The manufacturing process starts by taking the starch of the sweet potatoes and other materials and breaking it down with enzymes to turn it into sugar, which is then fermented to produce lactic acid. This is then polymerized to form polylactic acid, and a process of refinement and molding is used to produce a range of plastic products.

Various companies around the world are working on bioplastics, but apart from Toyota, the only other major company using polylactic acid seems to be the U.S. firm Cargill Dow. Because of the difference in the degree of purification, the technology Toyota has established will yield



Examples of bioplastic products

products whose quality will easily match the competition. With regard to cost, including recycling costs in the equation, Toyota is now confident of being able to produce bioplastics at only slightly more than the cost of conventional petroleum-based plastics.

The future plan is to undertake verification in the middle of next year at a plant capable of producing 1,000 tons a year. If results are positive, plans call for production at a full-scale plant as soon as possible.

The present size of the market is around 20,000 tons, but in 2020 the target is for production of 20 million tons at Toyota alone, generating sales worth 5,000 billion yen. This figure may seem exaggerated considering that total demand for plastics in Japan in FY2000 was only around 14 million tons. But looking at the world market, where the amount used every year is 150 million tons, and supposing that 30 million tons of that is replaced by bioplastics by the year 2020, the figure does not seem unrealistic. This annual production figure of 20 million tons, which seems at first wildly optimistic, is the reason why bioplastics are being heralded as a homerun batter as great as Matsui.

## Market Debut as Toyota Eco-Plastic in New Model Raum

The ES<sup>3</sup> concept car displayed at motor shows in 2001 was fitted with automotive parts made of bioplastics. This was no more than a trial use, but now they have been used for the first time on a vehicle for the commercial market, with the launching of the new Raum in May 2003. The bioplastic used has been named Toyota Eco-Plastic, and plans call for keeping an eye on developments and successively extending its use.



Floor mats used in the new Raum made with Toyota Eco-Plastic

Compared to the total amount of parts used in a car, this introduction of bioplastics represents just one small step. But if this step is followed by another and another, it will eventually become one giant leap forward on the path to a recycling-oriented society. It is now certain that the development of clean-energy vehicles in the automotive sector, such as hybrid or fuel cell vehicles, will link up with the biotechnology business, which comes from a completely different starting point, to constitute the twin engines propelling us toward a recycling-oriented society. Additionally, areas in which the Biotechnology and Afforestation Division is active are not limited to those mentioned so far. Presently data is being gathered in the search for areas with potential for commercialization. It is quite possible that one of these areas will turn up a batter who tops Matsui.

## Problems are Opportunities – Springboard to Mass Production

Naturally, the biotechnology business too has many technological issues to resolve. When questioned on this point, Tsukishima answers: "There are some technological issues, but that is because nobody has succeeded in this before. That means a great business opportunity. Problems should not be called problems. Problems represent an opportunity." He goes on to describe his aspirations for the future: "Bioplastics is a field where there is still room for development and progress. Indeed, this is the reason I think that research and development, including fundamental technology, is important at this stage. I want to carry this out with enthusiasm so that if we continue, ten years down the road Toyota will produce a Nobel Prize winner in this field."

Even putting aside all partiality to one's own company, it does seem that if further advancements are made in the field of bioplastics, it will be a revolutionary technology that leads towards a recycling-oriented society. And future generations will no doubt be moved to express their gratitude with the same words as Chairman Okuda: "Thank you."



Young staff members conducting experiments at the Biotechnology and Afforestation Laboratory