Good for the Environment

Agricultural by-products, such as switchgrass, pine bark and corn straw provide the raw material base for bio-PET Pepsi-Cola bottles (photo: PepsiCO)

"Green" Packaging. Bioplastics are on the march in packaging, a field in which they are becoming firmly established. The trend was evident at this year's interpack 2011 in Düsseldorf, Germany. Exhibitors demonstrated their wide variety of bioplastics with innovative products. More and more brand-name manufacturers are betting on bioplastics.

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The term "bioplastics" is ambiguous and needs to be differentiated with respect to functionality and raw materials base. To begin with, the prefix "bio" can stand for two different properties: "bio-based" and "biodegradable".

A bio-based plastic is one that is generated partly or entirely from renewable resources and can just as likely be biodegradable as it may also be non-degradable. When we speak of "biodegradability", we mean the capability of the plastic to be transformed into CO_2, water and biomass by means of microorganisms. Whenever this process takes place within a certain time period (4 to 12 weeks) and under conditions present in an industrial composting plant, we can speak of "compostability" as defined by the standard DIN EN 13432 and EN 14995. One of the most important examples of this class is bio-based and also biodegradable polylactide (PLA) which is manufactured mainly from the vegetable materials starch or sugar.

By contrast, standard polymers such as PE, PVC and PA are not biodegradable, however, for some time now, new processes have made it possible to manufacture them on a vegetable base, i. e., bio-based. Since these polymers differ from their fossil counterparts particularly with respect to their source of raw materials and manufacturing method, they are additionally designated as, e. g., bio-PE, bio-PA etc.

As for its raw materials base, a biodegradable polymer can – as mentioned above – be generated from renewable resources (PLA) or ultimately from fossil raw materials, as well, since biodegradability does not depend on the

Biodegradable and biobased	Biodegradable and petroleum-based	Non-biodegradable and petroleum-based
Polylactide PLA (NatureWorks, Purac/Synbra, Futerro)	Synthetic polyester (BASF, Mitsubishi etc.)	Bio-PDO based polymers (DuPont)
Thermoplastic starch products (Novamont, Sphere-Biotec, Plantic etc.)	Polyvinyl alcohols PVOH	Bio-PE from bioethanol (Braskem, Dow)
Cellulose products (Innova etc.)	Polycaprolactone PCL	Bio-PVC from bioethanol (SolVin)
PLA blends (BASF, FKuR et al.		Bio-PP from bioethanol (Braskem)
Polyhydroxyalkanoates PHA (Telles, Kaneka, Tianan etc.)		Polyamide types Bio-PA 669/610/11 (Arkema, DuPont, BASF etc.)
		Polyurethane bio-PU (BASF and others)
		Polyethylene therephthalate bio-PET (producer unclear, yet)

Table 1. Examples of biopolymers and their manufacturers

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raw materials base. Rather it depends entirely on the chemical structure of the polymer and its capability to transform itself into naturally occurring metabolic waste products. Some typical examples of petroleum-based biodegradable polymers are polyvinyl alcohols (PVOH), polybutylene adipate terephthalate (PBAT) or polybutylene succinate (PBS).

Among the most important biopolymers are polylactide (PLA), polyvinyl alcohols (PVOH), polyhydroxyalkanoates (PHB), polycaprolactone (PCL), cellulose products, thermoplastic starch (TPS), as well as bio-PE, bio-PP, bio-PA and bio-PU **(Table 1)**.

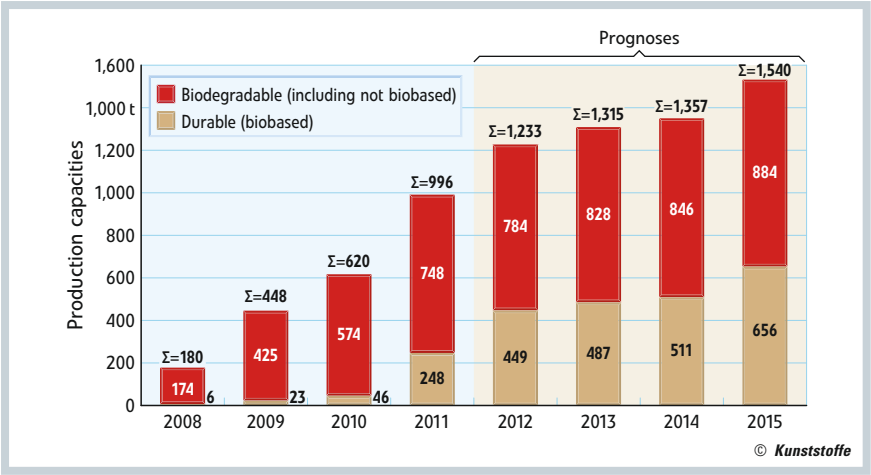

Fig. 1. The worldwide production capacity for bioplastics as of 2011 (source: European Bioplastics, University of Applied Sciences and Arts of Hanover)

Growth for "Green" Packaging

Interest in bioplastics is rising proportionately with public debate about climate change, sustainability and the drive for independence from fossil fuels, such as crude oil and natural gas. To be sure, the quantities of bioplastics produced remain small. Currently, bioplastics' share of the overall plastics market is just short of 1 %, but their market potential is considered to be very great. This is supported by a recent study presented at the interpack in Düsseldorf, Germany, by the branch association, European Bioplastics, in cooperation with the University of Applied Sciences and Arts of Hanover, Germany: Worldwide production capacities for bioplastics will more than double between 2010 and 2015. Already in 2011, capacities are expected to cross the 1 million ton threshold. Hasso von Pogrell, executive secretary of European Plastics declared: "The pleasingly positive trend in production capacities allows us to assume that the figures presented will even be exceeded in the years to come **(Fig. 1)**. Especially in those areas where their ecologically meaningful properties, such as a biobase and biodegradability, have important additional usefulness, they can, in part, replace classic plastics products." Thus, even among technical products, we see an increasing trend toward substituting purely petroleum-based plastics with combinations of bio- and petroleum-based plastics.

Fig. 2. "Plant Bottles" for Coca-Cola and Heinz are made from up to 30 % sugar cane and molasses; in Europe, an additional 50 % recycled PET is used (photo: Coca-Cola)

Besides this, Hasso von Pogrell called attention to a turnaround in the bioplastics branch, away from an emphasis on biodegradability and toward an increased use of renewable resources for bio-based plastics. Parallel to this shift, there are geographic differences, as well. A north-south shift is taking place on the German bioplastics market from bio-based to biodegradable polymers, according to Denise Winkelmann, press officer at FKuR Kunststoff GmbH of Willich, Germany. Jan Ravenstijn, an expert on biopolymers at Kaneka Corporation of Nakanoshima, Japan, sees the awareness for biopolymers as being generally more strongly pronounced in Europe. Reporting from the Asian market, Kevin Yang, general manager of the Shenzhen Bright China Industrial Co, Ltd., of Guangdong, China, says only the younger generation there exhibits an appreciable awareness of bioplastics.

The knowledge that fossil resources are becoming harder to obtain is increasingly forcing plastics producers to replace petroleum-based plastics with plastics based on renewable resources. One of the first companies to understand and successfully implement this insight is Brazil's Braskem S.A. of São Paulo which was strongly represented at the interpack 2011 in Düsseldorf. With a current annual capacity of 200,000 t, Braskem is the world's leading manufacturer of bio-based polyethylene (Green PE). Starting with sugar cane, via bio-ethanol and ethylene, they generate a new Green PE that is subsequently processed further on conventional equipment to, e.g., films, bottles and containers. The sustainable production of renewable resources and long-term planning for the use of food waste as a raw materials source are important to the company. The company markets its Green PE products under the slogan "I'm green". One customer for Green PE is the consumer products manufacturer Proctor & Gamble. They are using it first to produce bottles for their Pantene-Pro-V line of shampoos and hair rinses. In summer and fall 2011, the new bottles will come on the Western European market. By 2015, Proctor & Gamble intends to produce a quarter of its packagings from plastics with a biomass base.

In addition, Braskem plans to market a bio-based polypropylene by 2013. Once again, the initial raw material is bio-ethanol from which the new bio-based PP →

Fig. 3. Polylactide is the raw material base for Activia yogurt beakers (photo: Danone)

will be manufactured using the same plant technology.

Planning for production of bio-based polybutylene succinate (bio-PBS) was announced at the interpack by Japan's Mitsubishi Chemical Corporation. In a 50:50 joint venture with the Thai PTT Public Company Limited of Bangkok, Thailand, a pilot plant with an annual capacity of 20,000 t of bio-PBS is to be built in Thailand.

Bio-based standard plastics continue to be more expensive than their conventional counterparts, but due to the anticipated rise in the price of crude oil, we can expect the production of petroleum-based plastics to become more expensive.

Bioplastics in the Packaging Branch

Among the areas for applying bioplastics, the numerous and varied opportunities for application in the packaging branch are putting it in the important role of an avant-garde. For instance, Coca Cola began marketing its Plant Bottle as early as 2009, a bottle produced from a vegetable base as high as 30 % (sugar cane and molasses). Above and beyond that in Europe, 50 % recycled PET is used for producing the bottles. According to the company, more than 14 million l of crude oil could be saved in the first two years.

This project has been expanded within the framework of a partnership with Heinz, the American ketchup producer. All of their conventional 500 ml ketchup bottles have been replaced by the vegetable raw material based "plant bottles" developed by the Coca Cola Company **(Fig. 2)**. Still this year, Heinz Ketchup intends to put as many as 120 million "plant bottles" on the market. According to company information, Coca Cola is already working on the development of a bottle produced from 100 % renewable raw materials.

Also the giant US beverage concern, Pepsi, announced a PET bottle made from vegetable materials that utilizes agricultural by-products such as switchgrass, pine bark and corn straw for its raw material base **(Title photo)**. Research is currently being done on additional sources for raw materials from organic agricultural wastes, the company reports.

Parallel to this, the French food products maker Danone presented its Volvic mineral water for the first time in Germany in an eco-PET bottle consisting of 20 % bioplastics based on renewable raw materials and an additional 25 % recycled PET. According to Danone, the consumer price of the mineral water will remain the same despite its new bio packaging.

Strongly advertised and excellently marketed at the interpack, Danone's Activia brand yogurt has been on supermarket shelves in new yogurt beakers made from bioplastic polylactide (PLA) **(Fig. 3)** since April. As early as 1998, Danone attempted to market a sustainable packaging. However, customers rejected the compostable beaker, forcing the milk products producer to go back to petroleum-based beakers. Now, after more than ten years, customer interest in ecology and climate protection is stronger than ever, so Danone is convinced their bio-based yogurt beaker will become established in the market. Thanks to cooperation with the WWF, the WWF logo printed on the yogurt beaker reinforces customers in the awareness of having done something for ecological protection. By the end of 2011, Danone plans to be packaging 80 % of its Danone fresh milk products in renewable raw materials.

Fig. 4. Examples of applications for Ingeo polylactide (photo: NatureWorks)

The leading producer of biopolymer polylactide is NatureWorks LLC of Minnetonka, Minnesota, USA, that markets its PLA under the brand name Ingeo. Its annual capacity of 140,000 t makes NatureWorks LLC the world's largest PLA producer. A second PLA plant in planning for Asia is intended to supply the growing demand for PLA. For the seventh time now, NatureWorks presented the variety of Ingeo products in a new version of its Ingeo Earth Month Look Book. **Figure 4** shows some applications for Ingeo.

One of Ingeo's processors, FKuR Kunststoff GmbH, presented new bioblends at the interpack. Under the motto "Plastics – naturally!", the company can draw from a wide spectrum of bioplastics: In addition to Fibrolon, a natural fiber-reinforced PLA compound and its cellulose based Biograde, FKuR presented Bio-Flex F 2201 CL, a new PLA-based transparent and flexible bioplastic. Besides high stretchability, this material is especially characterized by high puncture resistance. By combining it together with 4100 CL Bio-Flex type A, degradable multi-layer films with excellent transparence are produced that are both flexible and tough **(Fig. 5)**. By introducing Bio-Flex F 2201 CL and doing without a primer, the share of renewable raw materials in this multi-layer film was increased to 60 %.

Fig. 5. Multi-layer film produced from a new, transparent and flexible bioplastic based on PLA and an additional flexible PLA type (photo: FKuR)

For the China market, BioPla presented itself as a processor of NatureWorks PLA. The BioPla Products factory, with production sites in Shanghai and Ninbo, was founded in China in 1989 and specializes in the development and production of "green friendly products!" based on PLA. The company exhibited a wide variety of products that are 100 % compostable according to EN 13432, says Mike Ge, general manager of BioPla Products factory. In addition to the 110 °C heat resistant "corn cup" made from Bio-pla 305 D, they supply various products from the areas of thermoforming, blow molding and injection molding, as well as PLA-coated paper. BioPla exhibited bio-based building blocks with Corn Building Blocks and a transparent, thermoformable PLA film with BioPla sheet.

Novamont, Novara, Italy, presented new, flexible packaging solutions based on Mater-Bi. Their new paper line, Talia, is manufactured from pure pulp and laminated by extrusion with Mater-Bi.

Fig. 6. Coffee bag made from bio-composite film (source: Wentus; photo: IKT)

Under the slogan "Back to Nature" Novamont introduced a vest bag made from Origo-Bi (bio-based polyester) specially targeted to the Italian market. The bag marketed under the brand name BioMat was developed specially for composting biowaste. Dr. Friedrich von Hesler, Novamont's manager of sales in Germany, remarked that a lot of propaganda will be required for tote bags like this to become accepted in the biowaste bins of consumers and in particular by communal waste management operations.

An entirely bio-based multilayer film was introduced by Wentus Kunststoff GmbH of Höxter, Germany. Wentoplex composite laminate consists of a cellulose-based outer layer from Innovia, Wigton, Cumbria, U. K., and a center layer of Mater-Bi from Novamont, Novara, Italy. The layers are bonded by a bio-glue from BASF of Ludwigshafen, Germany. This multi-layer film is said to exhibit barrier properties similar to those of, say, PET/PE or PA/PE composites. Karsten Buth, Wentus Kunststoff GmbH's sales manager, claims they satisfy the toughest requirements and will soon be offered as packaging for higher-priced coffee brands **(Fig. 6)**.

Fig. 7. An Aldi tote bag made from PLA and biologically degradable copolyester (photo: BASF)

BASF is contributing to the acceptance of plastic tote bags in the bio-bin. In a pilot project in conjunction with Bad Dürkheim County, Germany, it has been testing waste bags made from Ecovio FS for their suitability for use and disposal since April. 65,000 households were provided with biodegradable waste bags. The test is intended to show how the bags behave when they are supposed to decompose in large quantities together with other biological wastes in the composting plant of waste management operations (see also article p. 26). Ecovio FS consists of PLA and PBAT, a biologically degradable copolyester with a petrochemical base that also belongs to BASF's product range. While PBAT makes the bag flexible, tear resistant, watertight and printable – i. e., lends to it the properties of a classic plastic – stiff PLA contributes a portion of renewable raw materials. This combination of Ecovio and an additional PBAT enables film producers such as Victor to tailor the properties of the tote bags **(Fig. 7)** and other film products they make.

Fig. 8. This cell phone shell consists of a mixture of thermoplastics with a fossil base and biobased polymers (photo: PolyOne)

The Kaneka Corporation of Osaka, Japan, presented Aonilex, the first stretchable, up to 100 °C heat resistant, 100 % bio-based biopolymer (vegetable polyester) made from polyhydroxyalkanoate (PHB). Riichi Nishimura, asst. project director at the Kaneka Corp., explained that, starting in May 2011, a test plant with an annual capacity of 10 t would be available and, in 2012, production will be increased to 1,000 t. As he sees it, a clear trend toward bio-based polymers is apparent, but market acceptance continues to be greater in Europe.

Under the brand name reSound, the PolyOne Corporation, Ohio, USA, presented polymer compounds made from petroleum-based thermoplastics and bio-based polymers, such as PLA, PHB, PHBV and bio-polyesters for technical applications. Depending on requirements, they can achieve, at a current bio-share of at least 30 %, a temperature resistance similar to that of PP or ABS and a notched impact strength similar to that of polycarbonate. At present, work is being done on alternatives for polyamide materials **(Fig. 8)**.

With plastics based on amylose cornstarch, Plantic Technologies Ltd. of Victoria, Australia, became established. Plantic Technologies exhibited again this year at the interpack, now with eco Plastic, a new product consisting of as much as 75 % renewable raw materials. Films made from eco Plastic possess an excellent gas, taste and smell barrier. Food trays from it exhibit high impact toughness as well as improved mechanical properties and better handling qualities compared to their conventional counterparts.

A moisture barrier is created by applying an extremely thin polyester layer. These laminate materials are produced with varying amounts of eco Plastic and make up their eco Plastic EHB line. Themoformed trays find use mainly as cling packaging, e. g., for meat. ■

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