9 Commercial Applications of Bioplastics

9.1 Introduction

Biodegradable plastics are the type of plastics that undergo decomposition over a period of time under composting conditions. The global biodegradable plastics market accounts for less than 1% of the overall plastics market, however, it is expected to grow at a fast pace over the next 5 years. The market growth is driven by continuous R&D activities, increased environmental awareness, and implementation of stringent environmental regulations. However, the high cost of biodegradable plastics has been a major barrier in the growth of the market [1].

The growth of biodegradable plastics is driven by the following factors:

1. Consumer preference toward environmental-friendly products
2. Use of renewable and bio-based raw material
3. Biodegradability
4. Government policies toward green procurement

Top players in the biodegradable plastics industry include Metabolix Inc. (U.S.), BASF SE (Germany), Corbion N.V. (Netherlands), NatureWorks LLC (U.S.), Biome Technology Plc (U.K.), and others [1].

The two most important commercial, biodegradable polymers are polylactic acid (PLA) and starch-based polymers, accounting for about 47% and 41%, respectively, of the total biodegradable polymer consumption. Starch sources vary worldwide, but include corn, potatoes, cassava, and sugar beets. In Europe, starch-based biodegradable polymers are the major type consumed, accounting for 62% of the market, due to Europe’s large, starch-based capacity and their use in many applications. This is followed by PLA, with 24% and other biodegradable polymer types with 14%.

Biodegradable plastics have found their end-use in a variety of commercial applications. It is estimated that packaging and disposable housewares drive the biodegradable market. Foam packaging continues
to represent significant market share for biodegradable plastics. Compostable bags, as well as single-use carrier plastic bags, follow foam packaging in terms of volume. Another developing use for biodegradable plastics is in the shale gas industry, where they are used during hydrofracking as more environmentally friendly proppants to “prop open” fractures in rock layers so oil and gas can be released [2].

Other areas where biodegradable plastics have seen their use are:

- Bags
- Agriculture and horticulture
- Disposable housewares
- Medical devices
- Consumer electronics
- Automotive

This chapter focuses on discussing different areas of commercial applications of biodegradable plastics such as packaging, bags and sacks, disposable housewares, agriculture and horticulture, medical devices, consumer electronics, and automotive.

### 9.2 Packaging

Biodegradable plastics, like conventional plastics, offer a large range of packaging applications. Some of the packaging options include bags for compost, agricultural foils, horticultures, nursery products, toys, and textiles. Other areas include packaging for contact articles including disposable cutlery, drinking cups, salad cups, plates, overwrap and lamination film, straws, stirrers, lids and cups, plates and containers. **Fig. 9.1** shows a range of packaging options made from biodegradable plastics [3–9].

It is expected that the bioplastic materials used in food packaging applications perform by protecting the food from the environment and maintaining the food quality [10]. These protecting functions are obvious as it is important to be able to control and modify their mechanical and barrier properties which depend on the structure of the biopolymer. It is also important to study the change in properties of the packaging material during the length of time it was in contact with the food [11].

**Fig. 9.2** shows two grades of biodegradable resins from Solaplast [12,13]. Both, Solaplast1723 and Solaplast1223 have found their use in the packaging industry. These two biopolymers that are derived from
Figure 9.1 Range of packaging options made from biodegradable plastics [3–9].
algae are used for diverse applications. They can be bio-based, biodegradable, or durable. Each application depends on the type of biopolymer used. Packaging made from these biopolymers can be processed with all customary plastics processing technologies. No special machinery is required. Depending on the type of bioplastics used, only the processing parameters have to be adjusted [12].

### 9.3 Bags

Biodegradable shopping bags are made of polymers that degrade, or decompose, when exposed to air, water, or sunlight. Currently, CU Dining Services is promoting their use of biodegradable bags from Grab-n-Go’s [14].

There are three main types of biodegradable bags:

1. **Type 1**: The original biodegradable bags, still found today, are made from resins containing starches, polyethylene, and heavy metals such as cadmium, lead, and beryllium.
2. **Type 2**: A second type has been invented using starches combined with biodegradable polymers such as PLA or BASF.
EcoFlex. These bags meet ASTM compostable standards, while others do not [15].

Type 3: Oxo-Biodegradable bags use Totally Degradable Plastics Additives (TDPA™) to stimulate the breakdown of polymers and thus speed up the biodegradation process of conventional plastics [16,17].

Biodegradable bag labeled as a no. 4 (type 1) carries no information on meeting ASTM standards. Testing of the EPI Oxo-Biodegradable bags (type 3), as reported by the Biodegradable Products Institute, has found presence of moisture or humidity which inhibits onset of oxidation, which means that composting slows down the degradation of these bags [18]. Fig. 9.3 shows examples of different types of biodegradable bags [15−17,19,20].

A number of companies are developing bags made of biodegradable polymers for use in municipal and institutional composting programs. Such products would have to be truly compostable and conform to ASTM standard D6400−99; under the right environmental conditions, a compostable polymer breaks down into nothing more than carbon dioxide, water, a humus-like organic material, and some innocuous trace inorganics. Composting bags for yard waste or food scraps would also have to satisfy the operational requirements of composting facilities.

9.4  Disposable Housewares

Disposable housewares made from biodegradable plastics are now seen as marketable options, replacing traditional plastics such as polystyrene and polyolefin. Housewares such as kitchen tools and utensils, washable storage containers and cups, bathroom accessories, toys, hangers, and hooks are now being produced using biodegradable plastics. One such example is the Fantastic Beach toys by Zoë b Organic which are made with Mirel bioplastic from corn as shown in Fig. 9.4 [21].

Cutlery made from Cereplast, a biodegradable resin made from corn and potato starch, qualifies as a compostable plastic [22] and is marketed under the brand name Nat-Ur. NaturBag markets Natur-Ware cutlery which is both bio-based and certified compostable shown in Fig. 9.5 [23].

Fig. 9.6 shows biodegradable hangers from United Colors of Benetton which are 100% recyclable and biodegradable [24].
Figure 9.3 Different types of biodegradable bags [15–17,19,20].
Figure 9.4 Disposable housewares made from biodegradable plastics [21].

Figure 9.5 Natur-Ware bio-based and compostable cutlery [23].

Figure 9.6 Biodegradable hangers from United Colors of Benetton [24].
9.5 Agriculture and Horticulture

Production of agricultural mulches, seeding strips, and tapes made from biodegradable polymers shown in Fig. 9.7 is another strong potential market [25,26]. The tape biodegrades in the soil as the seeds germinate and take root. Plastic mulch films are then used to give the new seedlings a head start in the spring; the mulch helps reduce evaporation and conserve moisture, increases soil temperature, and keeps control on the weeds. Compostable seed belts and active component capsulations made out of bioplastics have also proven to be beneficial.

Foils and nets made from degradable bioplastics are used in farming of mushrooms and the coating of tree and bush-roots. Foils, yarns, and nets made out of bioplastics help to secure freshly created slopes and mounds and protect them from erosion until the roots of the plants have developed sufficiently.

Solaplast mulching films are generally making rapid advances in this area. Solaplast 2100 series resins applications in agriculture and...
horticulture include films for banana bushes and grapevine bushes which have to be protected from dust and environmental influences. Fig. 9.8 shows Solaplast films for agriculture and horticulture sectors [27–29]. These films offer opportunities for marketing pot-planting. An example is potting herbs. The herb can simply be planted into their pot. Once the herbs are harvested, everything including the film can be composted. Some of the other applications of Solaplast 1223 may be for durable applications such as: fastening technology; plant pots for propagation/cultivation; fertilizer rods; or pheromone traps.

Fig. 9.9a shows plant baskets and pot made out of biodegradable materials. They are commonly used in cemeteries because of their biodegradable nature, convenience, and cost-efficiency. Operators of golf courses can benefit from the use of bioplastics by using degradable bioplastic tees as shown in Fig. 9.9b. This makes the collection of the remaining tees an obsolete practice; the tees simply remain in the ground to decompose [30,31].

9.6 Medical Devices

Nontoxic biodegradable polymer sutures are being used each year by surgeons in life-saving heart operations and other procedures. Easily sterilized, the sutures remain strong and intact until the surrounding tissues have healed. The sutures dissolve and are readily metabolized in the body leaving no trace.

Both pliable braided sutures as well as wiry monofilament sutures are available, depending on: (a) the type of surgery, (b) the knots to be used, (c) the tensile strength needed, and (d) the potential for infection. Fig. 9.10a shows biodegradable plastic staples which are used to close wounds and incisions. Plastic sutures are largely made from lactic or glycolic acid and account for about 95% of the total market, with various pins, implants, and dental devices making up much of the remainder. Fig. 9.10b–d shows biodegradable plastic pins, tacks, and screws which are used to hold shattered bones together while they heal, to reattach ligaments, and for delicate reconstructive surgery on ankles, knees, and hands [32–34].

Biodegradable dental implants, made of porous polymer particles, are being used to quickly fill the hole after a tooth has been extracted. Fig. 9.11 shows films of guided-tissue-regeneration membranes [35]. These membranes made from biodegradable polymer are used by dental
Figure 9.8 Solaplast compostable films [27–29].
Figure 9.9 (a) Biodegradable burial pods and (b) PLA golf tee [30,31].

Figure 9.10 (a) Insorb absorbable skin stapler, (b) dissolvable medical screws promoting bone growth, (c) absorbable anterior and posterior cruciate ligament interference screw, and (d) absorbable orthopedic pin [32–34].
surgeons, to prevent scabbing and allow the slower-growing connective and ligament cells to regrow.

Fig. 9.12 shows TYRX absorbable antibacterial envelope, a biodegradable tyrosine-derived polyarylate which is a critical component of a new hernia repair device marketed by TyRx Pharma, Inc. This firm focuses on the development of new drug-eluting medical devices. Developed as a coating on a surgical mesh, these polymers improve the handling capabilities of the mesh to facilitate precise placement during surgery. The coating is then reabsorbed, leaving a smaller amount of material in the body [36].
Fig. 9.13 shows Parietix ProGrip™ laparoscopic self-fixating mesh that facilitates tension-free repair. It is the first bicomponent mesh composed of monofilament polyester and a resorbable PLA gripping system. The mesh’s self-gripping feature provides secure fixation, reducing, or possibly eliminating the need to place supplemental fixation. This mesh is made from lightweight, hydrophilic polyester and provides optimal porosity which helps in better tissue growth and reduction in pain. In addition, it also reduces the amount of leftover foreign material in the body [38].

Two novel classes of biodegradable polymers, PolyActive and OctoDEX are two drug delivery systems that are licensed out by OctoPlus. These biodegradable systems are used for the site-specific delivery of drugs. Because of their biodegradability and linear release properties, these two systems are an excellent technology for the controlled release of proteins and lipophilic small molecules for both local and systemic administration, and have applications in pharmaceuticals and medical technology [39].

Molecular structure of PolyActive is shown in Fig. 9.14. It represents a series of poly (ether ester) multiblock copolymers, based on polyethylene glycol (PEG) and PBT. Major advantage of this system is the ability to vary the amount and length of each of the two building blocks, creating a diverse family of customized polymers. Polymer matrix characteristics such as rate of controlled release, degradation, swelling, and strength can be precisely controlled by the appropriate combination of the two copolymer segments [39,40].
9.7 Consumer Electronics

A large proportion of today’s consumer market is made from plastics. In electronics market, plastics are used in casings, circuit boards, and data storage because of their durability, toughness, lightness, and mobility. However, there has been a surge of bioplastic products which are being introduced in the fast-moving consumer electronics sector such as touch screen computer casings, loud speakers, keyboard elements, mobile casings, vacuum cleaners, and a mouse for a laptop.

SUPLA has developed optimized PLA compounds for the consumer electronics industry based on lactides from Corbion Purac. The launching application is the world’s first bioplastic touch screen computer that is developed in collaboration with a Taiwanese OEM/ODM, Kuender, as shown in Fig. 9.15. The high gloss housing of this computer is made from high heat PLA [41–44].

The PLA blends used for the monitor screens also bring improved impact resistance, excellent high gloss finish, and stable, precise processing. Some other examples of biodegradable consumer electronics products include computer keyboards, ear phones, mobile phones, laptops, games consoles, and tablets. Some of the products are shown in Fig. 9.16 [41].

9.8 Automotive

Automotive industry is going through a major change with the focus on reducing fuel consumption and emissions by reducing a vehicle’s weight. Plastics have been a part of automotive components but there
Figure 9.15 Bioplastic touch screen computer casing developed in cooperation with leading Taiwanese OEM/ODM of consumer electronics—Kuender [41–44].

Figure 9.16 Consumer electronics products—(a) Fujitsu’s® new computer keyboard, (b) EOps Noisezero i+ Eco edition using cornstarch bioplastics, (c) Fujitsu’s® biodegradable mouse, (d) Ventev™ element case made from 100% Naturacell™, (e) biodegradable iPhone case realized with Apinat, (f) drum cover of Fuji Xerox copy machine, (g) solar charger Xindao sunshine, and (h) XD design Ginkgo solar tree [41].
has been a concern toward plastics recyclability. For this reason, automotive industry is making a big leap toward using bioplastics components. Some of the bio-based plastics such as bio-based polyamides and bio-based polyesters are already successfully being used by leading automotive brands around the world today with the aim of reducing their products’ environmental impact. Besides these evident advantages, for example bio-based performance polymers (bio-based polyesters and polypropylene/bio-based polyamides, bio-based polypropylene)
feature all the performance criteria important for high-quality car components [45].

Bioplastics have reached maturity as a suitable material for a large number of automotive applications, offering high performance and a unique potential for reducing a product’s environmental impact. Manufacturers have turned to bio-based or partly bio-based durable bioplastics to produce sturdy dashboard components as well as solid interior and exterior features. Components made completely or partially from bioplastics can provide a standard of safety that is of ultimate importance in the transportation sector. The products include seat and airbag covers as well as steering wheels.

The world’s first commercial automotive application for DuPont’s Sorona EP PTT polyester is interior vent louver vanes for the Toyota Prius shown in Fig. 9.17 [46]. Sorona EP has 37% renewable content derived from fermentation of corn sugar. Sorona 2045G with 45% glass was chosen for its combination of surface appearance and mechanical properties—environmental benefits were not the primary driver. PTT allowed design of thinner vanes because it is stronger and stiffer than PBT or nylon 6 at similar glass loadings [45].
A front-runner in adopting bioplastics is Japanese car manufacturer Toyota which uses bioplastics such as bio-based polyesters, bio-based PET, and PLA-blends in its production process. Toyota has set the target of replacing 20% by weight of all oil-based plastics for cars with bioplastics by 2015. The Toyota SAI and Toyota Prius models already feature a number of bioplastic applications such as headliners, sun visors, or floor mats. Up to 60% of the interior fabrics are made of bio-based polyesters, which provide mechanical properties equal to or even better than PBT [47].

Compared to PBT bio-based polyesters [45,47]:

- provide a higher stiffness
- feature very good dimensional stability and lower warpage
- feature better thermal shock resistance
- provide good electrical properties
- are easier to process
- provide a better surface gloss

Toyota has typically used bio-based polypropylene/polylactic acid (PP/PLA) composite derived from plant material. They have developed a new plant-derived bio-based plastic more suitable for auto interiors than other bio-based plastics. Fig. 9.18a shows the list of vehicles containing bio-based plastics. Toyota began using the new material in the luggage compartment liner of the new Lexus CT200h hybrid-electric compact car. This is the world’s first use of a bio-based polyethylene terephthalate (PET) resin in the auto industry. Fig. 9.18b shows an example of eco-plastic usage in Lexus HS 250h [48].

Fig. 9.19 shows an automotive air filter box and interior trim parts supplied by Röchling automotive [49]. These parts are produced using high heat PLA compounds, based on lactides from Corbion Purac, under the name of Plantura. Plantura is a material family based on PLA, suitable for automotive applications as well as for durable goods. These materials are said to show improved hydrolysis and thermal
### Table 9.18

<table>
<thead>
<tr>
<th>MODEL</th>
<th>PART</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prius</td>
<td>Seat cushions, scuff plate, cowl side trim, register blades</td>
</tr>
<tr>
<td>Corolla</td>
<td>Seat cushions</td>
</tr>
<tr>
<td>Matrix</td>
<td>Seat cushions</td>
</tr>
<tr>
<td>RAV4</td>
<td>Seat cushions</td>
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<tr>
<td>Lexus RX 350</td>
<td>Seat cushions</td>
</tr>
<tr>
<td>Lexus HS 250h</td>
<td>Luggage trim upholstery, cowl side trim, door scuff plate, tool box area, floor finish plate, seat cushions, package tray</td>
</tr>
<tr>
<td>Lexus CT 200h</td>
<td>Luggage compartment liner, carpeting</td>
</tr>
<tr>
<td>Camry</td>
<td>Radiator end-tank</td>
</tr>
</tbody>
</table>

(a)

(b)

**Figure 9.18** Vehicles containing bio-based plastics [48].
resistance up to 140°C with fiber reinforcement as well as a good scratch and UV resistance [49].

Figure 9.19 PLA used for (a) air filter box and (b) interior trim supplied by Röchling automotive [49].

References


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