Biodegradable Polymers:
A Rebirth of Plastic

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Introduction

Plastics are being used all over the world. From drinking cups and disposable silverware to parts for automobiles and motorcycles, plastics are continuing to rise. Plastics have been an environmental trepidation because of the lack of degradation. Plastics make up about 20% by volume waste per year. There are over 21,000 plastics facilities in the US, and the employment rate has increased by an average of three percent over the past two and a half decades. Plastics are extremely important to the job market as well as packaging throughout the world. Since plastics are vital to people's everyday lives, production of biodegradable plastics to make plastics more compatible with the environment is necessary.

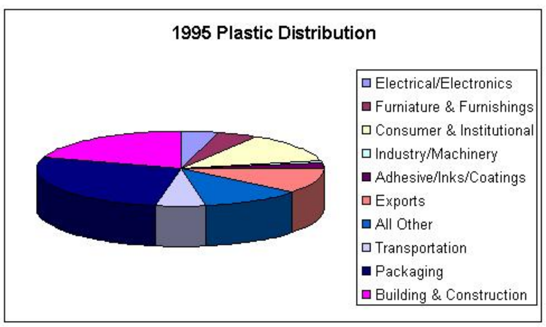

Figure1.1 The Distribution of Plastics in 1995

Brief History

Biodegradable plastics began being sparking interest during the oil crisis in the 1970's. As oil prices increased, so did the planning and creating of biodegradable materials. The 1980's brought items such as biodegradable films, sheets, and mold-forming materials. Green materials (or Plant-based) have become increasingly more popular (Mohanty, 2004). This is due impart to the fact that they are a renewable resource that is much more economical then they were in the past (Mohanty, 2004).

What they are made of?

Biodegradable plastics can be made from many different sources and materials. One research group from Cornell is working with “a number of fibers including those obtained from kenaf stems, pineapple and henequen leaves and banana stems” (Replace Landfills, 2002). Their team is working with resins made from microorganisms and commercial resins as well as composites made from soybean protein and plant based fibers (Replace Landfills, 2002). Australian Researchers are working plastics that are used from either starches or bacteria (Packaging Greener, 2004). The development of new materials is constantly in progress. Researchers must balance many variables in order to make a suitable biodegradable material.

Starch Based Plastics

Starch based plastics are mainly harvested from wheat, potatoes, rice, and corn. Of these four starches, corn is the most commonly used and is the least expensive starch. Most sales of starch come from the United States, which makes about $1.8 million annually. Being an extremely versatile product, about 20% of starch is used for non-food items (Mohanty, 2004). Starch is used for many non-food items such as making paper, cardboard, textile sizing, and adhesives (“Green Plastics”, 2004). Starched based plastics have already been processed into eating utensils, plates, cups and other products (“Green Plastics”, 2004).

Figure 1.2 Harvested Starch

Starch when harvested is turned into a white, granular product. According to the Australian Academy of Science, “starch can be processed directly into a bioplastic, but because it is soluble in water, articles made from starch will swell and deform when exposed to moisture, limiting its use”(Packaging Greener, 2004). The starch must be transformed into an altered polymer in order to solve the issue of starch deformation. Biodegradable starches can be processed “using conventional plastic technologies such as injection molding, blow molding, film blowing, foaming, thermoforming and extrusion” (Mohanty, 2004). These starch-based plastics resemble many conventional plastics and are as, “biodegradable as pure cellulose”.

The process changes the starch from a lactic acid monomer into a polymer chain called polylacitide (PLA) (Packaging Greener, 2004) or polygloycolic (PGA). Both PLA and PGA are crystalline polymers, but PLA is more hydrophobic than PGA. PLA’s are very brittle and stiff and they require plasticizers for most applications. High gloss and clarity are other features of PLA plastics. PLA is distinctive because it is available in renewable resources such as the starches (Mohanty, 2004). These renewable resources are on the leading edge of technology in Germany where they are being used for pharmaceuticals (Mohanty, 2004). PLA can also be processed like most thermoplastics into fibers, or it can be thermoformed as well as injection molded. “PLA’s can be used in a wide range of applications such as packaging (wrapping film, film for dry food packaging, board lamination etc.), stationery (pens, cartridges, pencil sharpeners etc.), and personal care items" ("Green Plastics", 2004).

Figure 1.3 Injection molded PLA

Australia is using cornstarch as a base in their biodegradable plastic research. The cornstarch based material has the, "look, feel, and flexibility of conventional plastics and can be used for a range of items, from cellophane to plant pots and medical devices" ("Zero Waste", 2004). When water is added, it completely disappears into the soil over a period of time. This is excellent for food packaging and farming. This cornstarch blend of plastic is now cheap enough to compete with conventional plastic. There is a cornstarch based organic waste bag now on the market. It is called the Biobag (see figure 1.4) and is 100% biodegradable and 100% compostable ("Bio Bag", 2004). The Biobag is made up of cornstarch, biodegradable and compostable polyester and vegetable oil. After 10-45 days, it is said to be completely biodegraded depending on the certain conditions and methods. The Biobag is compliant with the FDA and EU requirements and can be printed using flexo printing. "Another feature of this Biobag is that it "breathes", and reduces the weight of its contents by up to 25% in five days" ("Bio Bag", 2004).

Figure 1.4 Biobags can be used for trash and compost disposal

A potential re-use feature of the Biobag and other starch-based composites is that they can be used as feed for farm animals. Some animal feeds are required to contain some starch along with 13-24% protein (“Green Plastics”, 2004). Starch-protein plastics were used for food containers from fast food restaurants. They could then be pasteurized into animal feed, rather than sending the starch-based trash into a landfill, cutting costs in many areas of society.

The International Food Manufacturer and Packaging Science in Australia have been on the forefront of developing low cost biodegradable plastics (“Food Industry”, 2002). To reduce costs, case studies are being done that mix lower cost biodegradable materials with higher cost polymers. In their testing they used, “a low cost starch based biodegradable polymer blended with higher cost, higher performance polymer” (“Food Industry”, 2002). This produced a plastic film that when put into the soil fully diminished after two weeks (“Food Industry”, 2002).

Figure 1.6 Plastic polymer parts

Bacteria Based Plastics

Bacteria are an additional treatment used to create a different type of biodegradable plastics. Using the polymer chain polyhydroxyalkanoate (PHA). PHA is produced inside bacteria cells. The bacteria are harvested after they are grown in the culture, (Packaging Greener, 2004) and then created into biodegradable plastics. The mechanical properties of their resins can be altered depending on the needs of the product.

Procter and Gamble has recently begun testing using PHA material, in nonwoven biodegradable polyesters meant for disposable products. The intent is to use them for items such as drapes and surgical gowns, which will be thrown away after one use (“Scheduled”, 2003). The PHA fibers “degrade aerobically and anaerobically, can be digested under alkaline conditions.” (“Scheduled”, 2003).

Soy Based Plastics

Soy based plastics use another alternative material used for biodegradable plastics. Soybeans are composed of protein with limited amounts of fat and oil. Protein levels in soybeans range from 40-55%. The high amount of protein means that they must be properly plasticized when being formed into plastic materials and films. The films produced are normally used for food coatings, but more recently, freestanding plastics (used for bottles) have been formed from the plasticized soybeans. Ford has taken advantage of the soy protein plastics and has been using it to manufacturer parts for automobiles (Mohanty, 2004). Both compression and injection molding processes can use soy protein plastics. Dr. Amar K. Mohanty is a professor at Michigan State University whose research is primarily in the diverse types of biodegrable plastic polymers. Mohanty states, " Less than 0.5% of the available soy protein is used for industrial products". Soy proteins are used for making adhesives and coatings for paper and cardboard ("Green Plastics", 2004). Soy protein may be a first rate material for engineering plastics when a proper moisture-barrier is applied (Mohanty, 2004). To lower the water sensitivity, the soy protein can be blended with a polyphosphate filler (Mohanty, 2004). In research laboratories it has been shown that, "soy protein, with and without cellulose extenders, can be processed with modern extrusion and injection molding methods" ("Green Plastics", 2004). See table 1.

Table 1

Properties of some biodegradable plastics					
Material	**Film preparation**	**Moisture barrier**	**Oxygen barrier**	**Mechanical properties**	**Cost, $/kg**
Starch/PVOH	Extrusion	-	+	+	3-7
PHB/V	Extrusion	+	+	+/-	7-13
PLA	Extrusion	+/-	-	+	2-11

NC-W = Nitrocellulose-wax
PVOH = Polyvinylalcohol
PHB/V = Polyhydroxybutyrate/valerate

Biodegradable Polymers vs. Conventional Polymers

Biodegradable materials are beginning to be accepted in many countries. These materials are thought to help the environment by reducing waste issues. The two main reasons for using biodegradable materials, according to Mohanty are, "the growing problem of waste resulting in the shortage of landfill availability and the need for the environmentally responsible use of resources". As the government and many organizations are working to save the environment, there is a definite advantage to making biodegradable plastics more of a reality.

Conventional plastics have widespread use in the packaging industry because biodegradable plastics are cost prohibitive. The key, bringing the costs down, is to have numerous companies buy a large sum of biodegradable materials. Laws of supply and demand state that increasing demand will drive costs down.

Like conventional plastics, biodegradable plastics must have the same structural and functional qualities, in addition to reacting the same as conventional plastics when used by the consumer. The biodegradable plastics also must be inclined to, "microbial and environmental degradation upon disposal, without any adverse environmental impact" (Mohanty, 2004).

Purpose and Needs of Biodegradable Materials

"Annual expenditure on packaging increased by more than 4% between 1994 and 1996", according to a report from Pira, the UK packaging consultancy. "Plastic's share of the total packaging expenditure remained constant over the same period, at 29%". Since there is an abundant amount of waste in the world, there has been a lot of interest in research devoted to the creating of biodegradable materials.

There are many advantages to creating the biodegradable plastics. Starch-based plastics have been proved to be more environmentally friendly. Starch-based biodegradable plastics have been shown to degrade 10 to 20 times faster than traditional plastics (“Plastic’s”, 1998). When traditional plastics are burned, they create toxic fumes which can be damaging to people’s health and the environment. If any biodegradable films are burned, there is little, if any, toxic chemicals or fumes released into the air. Biodegradable plastics have been proved to improve soil quality. This process is performed as the microorganisms and bacteria in the soil decompose the material, and it actually makes the ground more fertile (“Plastic’s”, 1998).

With all of the advantages of biodegradable plastics, there are a number of disadvantages. Recycling helps the environment and it works well for many plastic containers such as bottles.

Figure 1.7 Bottles are still wasted with recycling

Eventually there is a limit to how many times a piece of plastic can be recycled, so there will in the end there will be waste produced. The cost of recycling plastics, in terms of energy, can be significantly higher than virgin resin. Toxic gases can be releasing from burning waste plastics in order to harness the energy for production. Many plastics that appear to be biodegradable in reality break down into miniscule bits that can affect both the soil and animals. Unfortunately, as researchers try to improve the environment with these new plastics, in essence they may be creating risks, as well.

The Future

The future of biodegradable plastics shows great potential. Many countries around the world have already begun to integrate these materials into their markets. The Australian Government has paid $1 million dollars to research and develop starch-based plastics. Japan has created a biodegradable plastic that is made of vegetable oil and has the same strength as traditional plastics. The mayor of Lombardy, Italy recently announced that merchants must make biodegradable bags available to all of their customers. In America, McDonald's is now working on making biodegradable containers to use for their fast food ("Plastics", 1998). Other companies such as Bayer, DuPont, and Dow Cargill are also showing interest in biodegradable packaging. According to Dr. Mohanty, "demands for biodegradables are forecast to grow nearly 16% per annum." This increasing interest will allow the technology needed to produce biodegradable plastics became more affordable and the falling production costs will eventually lead to an increase in producers ("Plastics", 1998). America and Japan show the greatest potentials for the biodegradable markets. The estimated amount of biodegradable plastics produced per year is about 30,000-40,000 tons over the next five years (Mohanty, 2004).

Conclusion

Biodegradable plastics are one of the most innovative materials being developed in the packaging industry. Companies cannot work fast enough to produce this highly valuable technology. How widespread biodegradable plastics will be used all depends on how strongly society embraces and believes in environmental preservation. There certainly are an abundant amount of materials and resources to create and fund more uses for biodegradable plastics. The advancement of biodegradable technology has skyrocketed in recent years and there are growing signs that the public shows a high amount of curiosity in the product. With the variety of biodegradable plastics available in the near future, there will be a place for them current Age of Plastics.

Work Cited

1. Biodegradeable plastics “could replace landfills with compost heaps”
Vol. 43, Iss. 12; pg. 6. BioCycle. Emmaus: Dec 2002. 16 Feb. 2004
(Replace Landfills, 2002).

2. Making packaging greener—Biodegradable Plastics. 22 Feb. 2004
<http://www.science.org.au/nova/061/061print.htm>
(Packaging Greener, 2004).

3. The Research foundation: *The State University of New York.* Biodegradable Plastics.
22 Feb. 2004 <http://www.rfsuny.org/tto/chem/r1345-210.htm>

4. P. Hernandez-Munoz, A. Kanavouras. Development and characterization of biodegradable films made from wheat gluten protein.
J. Agric. Food Chem., vol. 51, no. 26, Dec. 2003, pp 7647-7654
(Wheat Gluten, 2003)

5. P. Halley. Biodegradable packaging for the food industry.
Packag. Bottling Int., vol.4, no. 4, Sept, 2002, pp 56-57
(“Food Industry”, 2002)

6. Zero Waste New Zealand Trust: Biodegradable Plastics
<http://www.zerowaste.co.nz>
(“Zero Waste”, 2004)

7. Anon. Commercial production of **biodegradable materials** scheduled to begin next year. Med. Text., Nov. 2003, p. 2 (P) IS:ISSN 0266-2078
(“Scheduled”, 2003)

8. A. K. Mohantya, b, M. Misraa, b, G. Hinrichsen, Biofibres, biodegradable polymers and biocomposites. Technical University of Berlin, Institute of Nonmetallic Materials, Polymer Physics, Englische Str. 20, D-10587 Berlin, Germany
(Received: September 27, 1999; revised: March 2, 2000)
(Mohanty, 2004)

9. E.S. Stevens <http://www.greenplastics.com> 2001-2004 (“Green Plastics”, 2004)

10. Dirtworks <http://www.dirtworks.net/Bio-Bag1.html> (“Bio Bag”, 2004) (Figure 1.2)

11. Emily Kinser. <http://www.eng.iastate.edu/explorer/topics/plastics/bio.htm> 1998
(“Plastics”, 1998)

12. Kathy Sykes. <http://www.firstscience.com/site/articles/sykes.asp> 2004 (Picture from Figure 1.7)

13. < http://www.ftns.wau.nl/agridata/TablePropBioPlast.htm> 26 Jan. 1999(Table 1)

14. H. Kaastra, L. Muilwijk, A. Janssen, S. Hartmans, H. Gruppen
<http://www.designinsite.dk/htmsider/m0956.htm> (Figure 1.3)