As part of a larger project to convert certain waste plastics to fuel oil, DOE and the Procedyne Corporation developed an innovative combination of separation processes for recycling PET (polyethylene terephthalate) beverage bottles. At a demonstration plant set up to use the processes, approximately 20 million pounds of bottles and cans were sorted for recycling according to those made of PET, high-density polyethylene, or aluminum. The separator is currently being used at a Pepsi plant, where it is recycling 12 to 18 million pounds of PET annually. The energy savings associated with the recycling of waste plastics using the new separation technology are expected to reach 13.8 trillion Btus annually by 2010.

Biodegradable Plastics

The use of plastics has become a significant ecological problem as landfills become overwhelmed and plastic debris continues to pollute the environment. DOE-supported research shows that conventional materials can be used to make plastics that break down in a few years through biochemical mechanisms after exposure to soil and water. The new technology grafts polystyrene onto starch or cellulose. The process may provide the means to recycle items such as garbage bags, styrofoam cups, and milk containers, which currently end up as nondegradable trash.

Emulsifiers are used to allow the polystyrene to attach as a sidechain to the starch or cellulose backbone. The resulting copolymer has as much as 40% to 50% cornstarch or cellulose distributed throughout the plastic, compared with less than 10% in current commercial products. Microorganisms naturally present in the environment feed on the starches, degrading the polymer within a few years. The approach offers some versatility because different types of plastic polymers can be grafted to the starch or cellulose backbone.

The manufacturing rights are expected to be sold soon for applications of the new biodegradable materials to fast-food packaging and garbage bags.

Bioreactions in Nonaqueous Media

The efficient use of protein biocatalysts (enzymes) generally requires an aqueous environment, which is a poor medium for most industrial chemical processes. Many viable enzyme catalysts are only slightly soluble in water, creating mass-transfer limitations and low-productivity processes. In addition, the end products of many enzyme-catalyzed reactions polymerize in water, causing a decrease in biocatalyst activity, which results in low product concentrations. Furthermore, these processes often require the use of aqueous separation systems that are capital- and energy-intensive.

DOE is currently supporting research to overcome these problems and enhance the potential of biocatalysts to produce commodity chemicals. One such effort is the development of new methods for enzymatic oxidative catalysis in organic solvents. Such methods are needed for a variety of chemical processes, including the selective oxidation of aromatic compounds to form hydroxylated products and the peroxidase-catalyzed depolymerization of lignins.

The enzyme polyphenol oxidase has great potential for selective hydroxylation but cannot be used in an aqueous medium because of its low water solubility and the tendency of its products to spontaneously polymerize in water, which causes the catalyst to be modified and deactivated. Research shows that polyphenol oxidase in a p-cresol/chloroform solvent successfully catalyzes the formulation of hydroxylated quinone at yields of 80%. The same reaction in an aqueous medium produces a yield of only 3% because of the formation of intractable polymers.

Scientists have also carried out peroxidase-catalyzed depolymerization of synthetic lignin in organic solvents. This process could potentially produce useful chemicals of low molecular weight from lignin or lignin waste products economically.

Two inventions developed from this work have been licensed for use in the commercial sector. Both use the enzymes as sensors.

Dew-Point Hygrometer

Drying operations represent approximately 5% of the total energy requirements for the U.S. industrial sector, and this energy is lost mainly through dryer exhaust gas. If optimum conditions are maintained in the exhaust gas systems through the use of sensors and controls that continuously monitor the humidity and temperature of the exhaust gas, dryer energy consumption can be minimized. However, existing sensors are often unsuitable for continuous use in many common industrial drying processes because of the high temperatures and contamination encountered.