More on Biopolymers

Editor's Note: In the February issue of SJ, we examined the importance of biopolymers and their growing use as a replacement for petroleum based products. According to the USDA, biopolymers currently use about 0.1% of the US corn crop and as more plastic films are replaced by biobased products, conversion of other starch and sugar sources to biopolymers will ensue.

Biopolymers are a class of polymers produced by living organisms. Starch, proteins and peptides, DNA, and RNA are all examples of biopolymers, in which the monomer units, respectively, are sugars, amino acids, and nucleic acids.

Biopolymers (also called renewable polymers) are produced from biomass for use in the packaging industry. Biomass comes from crops such as sugar beet, potatoes or wheat: when used to produce biopolymers, these are classified as non food crops. These can be converted in the following pathways:

Sugar beet > Glyconic acid > Polyglonic acid
Starch > (fermentation) > Lactic acid > Polylactic acid (PLA)
Biomass > (fermentation) > Bioethanol > Ethene > Polyethylene

Biopolymers versus Polymers

A major but defining difference between polymers and biopolymers can be found in their structures. Polymers, including biopolymers, are made of repetitive units called monomers. Biopolymers inherently have a well defined structure: The exact chemical composition and the sequence in which these units are arranged is called the primary structure. Many biopolymers spontaneously fold into characteristic compact shapes which determine their biological functions. In contrast most synthetic polymers have much simpler and more random (or stochastic) structures. This fact leads to a molecular mass distribution that is missing in biopolymers. In fact, as their synthesis is controlled by a template directed process in most in vivo systems all biopolymers of a type (say one specific protein) are all alike: they all contain the same sequence and number of monomers and thus all have the same mass. This phenomenon is called monodispersity in contrast to the polydispersity encountered in synthetic polymers.

Biopolymers are renewable, because they are made from plant materials which can be grown year on year indefinitely. These plant materials can come from agricultural non food crops. Therefore, the use of biopolymers stands to create a sustainable industry. In contrast, the feedstocks for polymers derived from petrochemicals will eventually run out. In addition, biopolymers have the potential to cut carbon emissions and reduce CO_2 quantities in the atmosphere: this is because the CO_2 released when they degrade can be reabsorbed by crops grown to replace them: this makes them close to carbon neutral.

Sugars

Sugar-based biopolymers are often difficult with regards to conversion. Sugar polymers can be linear or branched and are typically joined with glycosidic bonds. However, the exact placement of the linkage can vary and the orientation of the linking functional groups is also important, resulting in α- and β-glycosidic bonds with numbering definitive of the linking carbons' location in the ring. In addition, many saccharide units can undergo various chemical modification, such as amination, and can even form parts of other molecules, such as glycoproteins.

Biopolymers as Packaging

Many types of packaging can be made from biopolymers: food trays, blown starch pellets for shipping fragile goods, thin films for wrapping. More than 15,000 grocery stores are selling products in packaging made from the corn based polymer.

Biodegradability and Compostablility

Some biopolymers are biodegradable: they are broken down into CO_2 and water by microorganisms. In addition, some of these biodegradable biopolymers are compostable: they can be put into an industrial composting process and will break down by 90% within 6 months. Biopolymers that do this can be marked with a 'compostable' symbol, under European Standard EN 13432 (2000). Packaging marked with this symbol can be put into industrial composting processes and will break down within 6 months (or less). An example of a compostable polymer is PLA film under 20Ìm thick: films which are thicker than that do not qualify as compostable, even though they are biodegradable. A home composting logo may soon be established: this will enable consumers to dispose of packaging directly onto their own compost heap. The standards for such a home composting logo have not yet been developed.

The importance of the expanding use of biopolymers is exemplified by the fact that the production of conventional plastics, dependent upon petroleum, is currently using 180 million barrels of oil per year.

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