About Bioplastics

Bioplastics and Nanotechnology

Manufacturers add chemicals and additives to products and packaging on the market to improve performance capabilities and appearance. Bioplastic products are no different in this respect than conventional products. Because bioproducts are marketed as green and sustainable, however, this industry has a particular responsibility to ensure their products are indeed safe for the public and the environment. One trend in the bioplastic industry has been to improve bioplastic performance characteristics (such as barrier properties) by utilizing nanotechnology. We caution against the use of nanotechnology for several reasons that are discussed in the following.

What is Nanotechnology?

Nanotechnology utilizes the recently enhanced ability of researchers to manipulate things at the nanoscale, also called the atomic or molecular scale. This usually means a scale between 1 and 100 nanometers (a nanometer is one billionth of a meter). Working at the nanoscale enables the creation of products with unprecedented properties in terms of, for example, strength, thermal and electrical conductivity and mobility. Nanotechnology can be utilized to create more efficient and less obtrusive medicine such as cancer treatments that only target tumor cells and avoid healthy cells. Nanotechnology also has potential uses with more trivial applications such as the already existing stain-resistant tie that has a protective layer of nanomaterial. With all these possibilities and the increasing investments in research and development, nanotechnology is being called the next industrial revolution. Nanotechnology is not only a Western phenomenon but is also getting a lot of attention in countries like China. The exact number of products utilizing nanotechnology is unknown as they are currently not required to be labeled as such; however, to visit an extensive nanotechnology consumer products inventory, click here.

Nanotechnology and Bioplastics

One of the challenges in the development of bioplastics is that their mechanical properties, such as barrier properties, are not as good as those of petroplastics. One way companies are looking to solve this is to utilize nanotechnology. The increasing interest in nanotechnology and bioplastics is evident from the attention the topic is getting at conferences on bioplastics. At the 2007 Global Plastics Environmental Conference three of the twelve presentations comprising the bio-based and biodegradable materials track, and several of the student posters, discussed the potential of using nanotechnology to improve the properties of biodegradable plastics. Nanotechnology was also the topic of a number of presentations at the International Degradable Plastics Symposium held in Chicago 2006. As Andrew Myers of TDA Research stated in his presentation, "Nano is hot: lots of funding, lots of research, lots of patents."

An example of research and development within nanotechnology and biodegradable plastics is SustainPack, an EU-funded packaging research project. According to the SustainPack web site, the project aims to "establish fiber-based packaging as the dominant player in the packaging area within a decade. It will achieve this by applying nanotechnology solutions." They explain that nanotechnology will likely improve barrier properties and mechanical strength.

Nanotechnology is already being used in commercial bioplastics products. For example, Cereplast, the recipient of the 2007 Environmental Award for New Technology in Materials from the Society of Plastics Engineers, and the provider of cutlery for the Biodegradable Products Institute's Zero Waste Barbeque held at the US Composting Council's 2007 annual conference and exhibition, includes nanocomposites in their production of bioplastics. In addition to cutlery, Cereplast makes products such as drinking straws, plates and cups. Cereplast explains on their website that they use nanocomposites for surface optimization and further reinforcement of their products. Another bioplastics product that is made using nanotechnology is BioTRED, a Goodyear-Novamont tire partly made from Mater-Bi starches. The interesting thing about BioTRED is that instead of adding nanosized materials to the biomaterials comprising the product, the biomaterials are nanosized. According to Novamont, using nanotechnology increases some of the mechanical properties more than 100 fold.

Nanotechnology and Risk

The biggest problem with nanotechnology is that there is a lack of research into its potential risks. Furthermore, existing oversight systems are believed to be inappropriate at the nanoscale because of the drastic change in properties and behavior that materials experience when manipulated at the nanoscale. Particles smaller than 50nm stop following the laws of classical physics and start following the laws of quantum physics. An example of the inadequacies of the current oversight systems is the use of analogies to other materials with known risks as a basis for estimating the risks of new materials. However, one of the benefits of nanomaterials is their novel properties and behaviors. These have no analogy.

Nanotechnology covers a wide range of materials and techniques of which the risks and unknowns vary greatly. In fact, it has been argued that the number of new materials that can be created from nanotechnology may be as extensive as the number of existing known chemicals. Every nanomaterial should therefore be analyzed and treated separately. Due to the lack of comprehensive studies into nanotechnology and risks, results on risks are currently inconclusive, but fears include that some nanoparticles may be able to enter the body through inhalation, consumption or skin contact and further penetrate cells and tissues causing biochemical damage in humans or animals. Exposure could occur in the research lab, during production in the workplace, during use or after disposal. Disposal may be particularly problematic when the products are composted, as is the case with bioplastics, since the nanomaterials then become exposed to the environment during the process of degradation. Some nanoparticles may conglomerate and thus cease to be nanoparticles, but others may retain their size and react with the environment in harmful ways. Materials at the nanoscale have a large surface area compared to their mass making them less stable and more reactive.

Jim Guest, President of *Consumer Reports*, in his October 2006 monthly letter to subscribers states: "We seem to have missed a few steps: manufacturing standards, labeling regulations, safety guidelines... Before these products show up en masse in stores and doctors' offices, a worldwide effort is needed to understand what nanoparticles can do to our health and to the environment." Joseph Mendelson, legal director of the Washington-based International Center for Technology Assessment, comments to the Washington Post, "Every day, consumers are being asked to be a test market for some of those risks." Some argue that it is not uncommon for a new technology to take off without proper risk research until after an accident happens or risks become evident. Nevertheless, a wide array of stakeholders is calling for more research into risks, including those stakeholders supporting the current rapid growth of nanotechnology. They are worried that an accident, or even merely public fear of an accident, will impede the economic benefits of the current nanotechnology boom. As Kristen Kulinowski, of Rice University, says to the Washington Post, "No nanotech company... wants to be the next Monsanto."

The UK House of Lord's Report on Nanotechnologies in the Food Industry

In February 2009, the U.K. House of Lords Science and Technology Committee launched an inquiry into the use of nanotechnologies in the food sector. Part of its scope was to investigate whether effective systems are in place to ensure that consumers are aware of and protected against any potential risks. The Committee released its 112-page report, Nanotechnologies and Food, January 2010. [Click here for report: http://www.publications.parliament.uk/pa/ld/ldsctech.htm.]

The report acknowledged the limited amount of research looking at the toxicological impact of nanomaterials, particularly in areas relating to the risks posed by ingested nanomaterials. The committee noted that this research is needed in order to ensure that regulatory agencies can effectively assess the safety of products before they are allowed onto the market and further concluded that research into these areas was not being afforded a high enough priority by Government or its Research Councils, considering the timescale within which products containing nanomaterials may be developed.

The report's summary notes, "It is equally important to ensure that the regulatory framework governing food is adequate to deal with the novel challenges posed by nanomaterials. While, in principle, existing legislation should ensure that all nanomaterials used in the food sector undergo a safety assessment before they are allowed on to the market, there are certain 'grey areas' where products containing nanomaterials may slip through the regulatory net. We make recommendations to fill these gaps; in particular, we recommend that a definition of nanomaterials be added to food legislation to ensure that all nanoscale materials that interact differently with the body as a result of their small size are assessed for risk before they are allowed on to the market."

- "Given the uncertainty about the potential risks of nanomaterials, it is essential that any nanomaterial used in a food product [except those naturally occurring] should be subject to a formal risk assessment process through the European Food Safety Authority. We recommend, therefore, that the Government should work within the European Union to promote the amendment of current legislation to ensure that all nanomaterials used in food products, additives or supplements fall within the scope of current legislation."
- "We endorse the case-by-case approach taken by the European Food Safety Authority in assessing the safety of products. It allows the responsible development of low-risk products where safety data are available and is, in effect, a selective moratorium on products where safety data are not available. It provides consumers with the greatest security and ensures that unless a product can be fully safety assessed, on its own merits, it will not be allowed on to the market."
- "We recommend therefore that the Food Standards Agency create and maintain an accessible list of publicly-available food and food packaging products containing nanomaterials that have been approved by the European Food Safety Authority."

Dealing with Risks and Nanotechnology

Bioproducts are marketed as green and sustainable, and therefore this industry, in particular, has a responsibility to ensure its products are indeed safe for the public and the environment. Following the precautionary principle nanotechnology should be avoided since there is not yet enough information to ensure that products utilizing nanotechnology are completely safe for human health and the environment throughout their lifecycle. Nevertheless, nanotechnology is a genie that can be hard to put back into the bottle and it is already being used extensively. All stakeholders need to collaborate to enable a comprehensive investigation into risks and ensure the responsible development of nanotechnology. US Congress is not, however, appropriating adequate funds into risk research and nanotechnology. Companies can therefore play a huge role in determining what are the risks involved with nanotechnology by carrying out independent investigations. Companies that do carry out such research should thus be acknowledged and if companies can provide documented evidence that the nanotechnology they use is safe throughout the product lifecycle the product should be supported.

Preferably extensive research into risks should be done before a product ends up on the market. This has not been the case with nanotechnology. An interesting new development in nanotechnology is what is called "green" nanotechnology. This comprises:

1. Advancing the development of clean technologies that use nanotechnology,
2. Minimizing potential environmental and human health risks associated with the manufacture and use of nanotechnology products, and
3. Encouraging replacement of existing products with new nanoproducts that are more environmentally friendly throughout their life cycles.

Although these are laudable goals, those pushing for green nanotechnology are not pushing for the precautionary principle. They argue that by looking into risks before a disaster happens they are ahead of the curve. However, introducing the products without first assessing the risks may end up being disastrous.

Whether products that contain nanomaterials should be labeled as such is currently debated. If nanotechnology proves to be completely safe then labeling would not be needed, but since risks are unknown it should be up to the consumer to decide whether or not they want to take the risks exposure may involve. The Toronto-based ETC (erosion, technology, concentration) Group has, in reaction to the lack of labeling for products produced using nanotechnology, launched a design contest to create a label that can be put on products to indicate that they contain nanoparticles. People from around the world have sent in suggestions, several of which were rather morbid with symbols such as skulls included in the design. This contest gives an impression of the fear of nanotechnology among some in the general public. To see the signs and read more about the contest click here.

The Sustainable Biomaterials Collaborative's Sustainable Purchasing Guidelines recommends the following:

"Avoid nanomaterials: Use only nanomaterials that have been subjected to thorough testing and environmental health and safety impact assessment across their life cycle. Follow the Precautionary Principle, substituting safer alternatives in preference to nanomaterials that may have serious adverse effects. Utilize nanomaterials only in a manner that protects against human exposures or environmental releases. Label all uses of nanomaterials and include toxicity information on nanomaterials for worker protection on material safety data sheets."

The World of Bioplastics

- The use of bioplastics is steadily increasing in many countries, especially in Europe
- Bioplastics can be non-biodegradable
- ASTM D6866 measures the exact percentage in bioplastics that came from renewable sources

Bioplastics may not have the exact properties of their fossil fuel-based counterparts and their production is not easy, but their use in the market has been steadily increasing, especially in Europe.

Bioplastics or “organic plastics” are commonly used as packaging materials, disposable catering products, compostable waste bags, and biodegradable mulch films. Reabsorbing organic plastics are also used in the medical sector. Bioplastics are water vapor permeable but they are waterproof, hence they make good materials for sanitary products. Consumer electronics, leisure goods, and even the automobile industry are starting to use bioplastics due to their low electrostatic charging properties.

ASTM D6866 for Bioplastics

The exact percentage in bioplastics that came from renewable sources (e.g. plant derivatives) can be known via ASTM D6866 – an industrial application of radiocarbon dating. ASTM D6866 measures the Carbon 14 content of biobased materials; and since fossil-based materials no longer have Carbon 14, ASTM D6866 can effectively dispel inaccurate claims of biobased content.

Examples of ASTM D6866 results:

Product A – plastic bag manufactured from petroleum-derived polyethylene

Product A biobased content = 0%

Product B – plastic bag manufactured from biomass-derived polyethylene

Product B biobased content = 100%

Bioplastics vs Petroleum-based Plastics

According to European Bioplastics, direct comparison of petroleum-based plastics with bioplastics may lead to an inappropriate image because the former are now commodities while the latter are still in early stages of development.

But are bioplastics truly more environmentally and economically advantageous than fossil fuel-based ones? Although several life cycle assessment studies have documented that bioplastic production consumes less fossil energy and have less carbon dioxide emissions, these findings would still not support that “bioplastics are the more environmentally friendly solutions.”

In terms of economics, bioplastics production in Europe can help reduce dependence on imports and may create jobs and export opportunities.

What are Bioplastics?

According to European Bioplastics, there are two underlying concepts that determine whether a “plastic” is a bioplastic or not – compostability and raw materials.

Bioplastics are (1) certified compostable plastics that are based on renewable and/or fossil resources, or (2) those that are made from renewable sources.

For plastics to be considered compostable, they must be certified according to the legally binding standards EN 13432 or EN 14995 in Europe, ASTM D-6400 in the US, or ISO 17088 in other countries. In Europe, products made of compostable plastics usually carry the trademarked "seedling" logo.

Plastics made from renewable resources such as sugar, starch, vegetable oils, or cellulose are bioplastics. Most of the ones available in the market nowadays use corn, potatoes, cereals, sugar cane, and wood as feedstocks.

Are Bioplastics Biodegradable?

NOT all bioplastics/biopolymers are biodegradable. The degree of a material’s biodegradability depends on its molecular structure and not on its source.

The terms biobased and biodegradability may be related, but they are not synonymous nor are they interchangeable. If a material is biobased, it comes from plants or animals, but it does not necessarily follow that it is biodegradable. A material is biodegradable only if microbes in the environment can break it down and use it as a food source.

Some forms of cellulose are, in fact, non-biodegradable while some that are derived from petroleum do biodegrade contrary to popular opinion. Nowadays there are synthetic plastic resins that will biodegrade and compost just like paper. There are also bioplastic materials, such as Braskem’s bio-polyethylene, that do not biodegrade.

Bioplastics vs Biofuels vs Food

The European Bioplastics claims that bioplastics have no impact on food supply or availability and should not be regarded as a threat to sustainable development. Unlike biofuels, bioplastic volumes are relatively low and the cultivation area needed to supply the bioplastics industry is very small.

Moreover, the bioplastics industry is making a strong effort to use agricultural residues (cellulosics), other waste streams, and feedstocks that do not compete with food markets. There are bioplastic materials in production that use non-edible, non-food wastes like potato skins.

ASTM D6866 for Biobased Content Testing

- ASTM D6866 was developed originally for biobased content determination of products for the USDA BioPreferred Program
- ASTM D6866 biobased content computation only considers Total Organic Carbon Content, not product weight
- The standard does not measure product biodegradability

ASTM D6866 was developed in the United States as a standardized analytical method for determining the biobased content of solid, liquid, and gaseous samples using radiocarbon dating. Specifically, ASTM D6866 was developed at the request of the United States Department of Agriculture to satisfy legislation requiring federal agencies to give preference in procurement to manufacturers using the greatest amount of biomass in their products (per the Farm Security and Rural Investment Act of 2002).

It was quickly established that radiocarbon dating was the only viable and accurate technique to use for the determination of a product's biobased content. A working standard of radiocarbon dating for industrial use was completed in 2004 and is now cited in US Federal Law (7 CFR part 2902).

ASTM D6866 is a widely used method in the bioplastics industry. Braskem, a leading Brazilian petrochemical company, is one of the many bioplastics companies that use ASTM D6866 to certify the biobased content of their products.

ASTM D6866 was first published in 2004. There have been several versions released since then. The current active version of the standard is ASTM D6866-10 effective August 6, 2010.

ASTM D6866 Measures Renewable Carbon

ASTM D6866 distinguishes carbon resulting from contemporary biomass-based inputs from those derived from fossil-based inputs. Biomass contains a well-characterized amount of carbon 14 that is easily differentiated from other materials such as fossil fuels that do not contain any carbon 14. Since the amount of carbon 14 in biomass is known, a percentage of carbon from renewable sources can be calculated easily from the TOTAL organic carbon in the sample.

ASTM D6866 quantifies the biobased content relative to the material's total organic content and does not consider the inorganic carbon and other non-carbon containing substances present. To illustrate, here are some hypothetical formulations and their ASTM D6866 results:

Product 1 – liquid with 50% starch-based material and 50% water

Biobased Content = 100% (product 1 has 50% organic content and 100% of that fraction is biobased)

Product 2 – liquid with 50% starch-based material, 25% petroleum-based, 25% water

Biobased Content = 66.7% (product 2 has 75% organic content but only 50% of that fraction is biobased)

Product 3 – solid that is 50% glass and 50% polyethylene from petroleum

Biobased Content = 0% (product 3 has 50% organic carbon but from fossil sources; glass is not carbon-containing)

Product 4 – solid that is 50% glass and 50% polyethylene from biomass

Biobased Content = 100% (product 4 has 50% organic carbon and 100% of it is renewable)

Product 5 – liquid with 50% soy-based material, 30% petroleum-based, 10% water, and 10% inorganic substances

Biobased Content = 62.5% (product 5 has 80% organic carbon but only 50% of it is renewable)

ASTM D6866 Does Not Measure Biodegradability

It must be noted that ASTM D6866 only quantifies the biobased content of a material but results do not have any implication on the material's biodegradability.

The terms biobased and biodegradability may be related, but they are not synonymous nor are they interchangeable. If a material is biobased, it comes from plants or animals, but it does not necessarily follow that it is biodegradable. A material is biodegradable only if microbes in the environment can break it down and use it as a food source.

Some forms of cellulose are, in fact, non-biodegradable while some that are derived from petroleum do biodegrade contrary to popular opinion. Nowadays there are synthetic plastic resins that will biodegrade and compost just like paper. There are also bioplastic materials, such as Braskem's bio-polyethylene, that do not biodegrade.