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Biobased Plastics and the Sustainability Puzzle

Advancing sustainability with biobased food packaging

As consumer interest in sustainable alternatives to fossil fuel-based plastics continues to grow and food and beverage companies set goals to reduce their environmental footprint, the use of biobased plastics in food packaging is expanding. Revenue for the U.S. biobased plastics manufacturing sector was $177.9 million annually, according to a 2018 report prepared for the U.S. Department of Agriculture (USDA) titled, *An Economic Impact Analysis of the U.S. Biobased Products Industry*.[1] The report also estimates a 4.5 percent growth rate for the sector from 2018 through 2023.

The total production volume of biobased building blocks and polymers (worldwide) was 7.5 million tons in 2018, or about 2 percent of the production volume of petrochemical polymers, with a growth rate of 4 percent expected through 2023, according to a report by Nova-Institute GmbH.[2] The potential for significant growth is much higher, but low oil prices and a lack of political support are hampering growth, notes the report.

Examples of the use of biobased plastics in food packaging include Snickers candy bars with a biobased film wrapper made from potato starch by-products that were introduced by Mars in 2016 and the soon-to-be-available 20-ounce Dasani water bottles made with up to 50 percent renewable plant-based and recycled polyethylene terephthalate (PET) material beginning in mid-2020. The Coca-Cola Company first launched recyclable bottles made partially from plants (PlantBottle) in 2009 and expanded access to the PlantBottle IP in early 2019 to encourage industry-wide adoption. The new bottle, referred to as HybridBottle, includes recycled PET material in addition to the plant-based material.[3]

Other uses of biobased plastics in food contact articles include bags; containers for fruit, vegetables, eggs, and meat; bottles for soft drinks and dairy products; flexible packaging; and coffee pods. Biobased plastics also have been used in foodservice ware, such as bowls, cups, and straws.

Like most materials that are intended to be used to package or otherwise come in contact with food, biobased materials are also subject to the regulatory requirements imposed by several jurisdictions throughout the world. This article will focus on the requirements related to obtaining regulatory approval of biobased food contact materials (FCMs) in the U.S. and the European Union (EU), safety considerations, and future considerations.

We'll begin with some definitions. "Biobased" means related to or based on natural, renewable, or living sources. "Biodegradable" means capable of being broken down naturally into basic elemental components (water, biomass, and gas) with the aid of microorganisms. Compostable plastics are a subset of biodegradable plastics that biodegrade under specified conditions and time frames.

Several international standards are available to determine compostability of plastic packaging. The European Committee for Standardization standard EN 13432, "Requirements for packaging recoverable through composting and biodegradation," is a harmonized European standard and is linked to the EU Directive on Packaging and Packaging Waste (94/62/EC). In the U.S., American Society for Testing and Materials standard ASTM D6400, "Standard Specification for Labeling of Plastics Designed to be Aerobically Composted in Municipal or Industrial Facilities," is cited in various regulations. For example, California requires that food and beverage containers labeled as "compostable" must meet the ASTM D6400 standard.

Biobased Plastics versus Bioplastics

An important distinction exists between biobased plastics and bioplastics. European Bioplastics defines "bioplastics" as a plastic material that is either biobased or biodegradable or both. On the other hand, "biobased plastics" are plastics manufactured from renewable biomass, such as vegetable oil, cornstarch, pea starch, and microbiota. Accordingly, a product can be both biobased and biodegradable, but it can also be biobased and not biodegradable, or biodegradable and not biobased.

"'Bio-based food contact materials' (BBFCMs) are derived from biological renewable resources (animal or plant biomass) that consist of polymers directly extracted or removed from biomass, produced by chemical synthesis using renewable bio-based monomers, or produced by microorganisms or genetically modified bacteria," according to the 2019 report *Bio-Based Materials for Use in Food Contact Applications*.[4]

The first bioplastics were developed from traditional agricultural resources, such as sugarcane, soy protein, starch, and cellulose. Within this group are polymers directly extracted from biomass and polymers produced by chemical synthesis using renewable biobased monomers. For example, polylactic acid (PLA), which is commonly used as a base material or coating in food packaging, is produced through the polymerization of lactic acid, which can be derived from the fermentation of agri-food wastes such as sugar beets or sugarcane.

PLA exhibits barrier properties comparable to fossil fuel-based plastics, such as low-density polyethylene and polyethylene, and has been used as a replacement for them, although it has the disadvantage of being more expensive to produce. The first generation of bioplastics also includes polymers produced by microorganisms or microbial fermentation, such as polyhydroxyalkanoate (PHA) and poly-3-hydroxybutyrate.

The second generation of bioplastics that are beginning to be introduced are made from raw materials such as food by-products, wood, and sawdust, explained Patrick Krieger, Plastics Industry Association, in an interview for the 2018 USDA report mentioned above. He added that the next or third generation of bioplastics, many of which currently are in the laboratory stage, will come from algae and other organisms that are not associated with the production of food. Another area of research is the production of strains of microbes through genetic engineering that can improve yields of biobased polymers.

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While biobased plastics offer myriad benefits related to sustainability, there are some concerns related to end-of-life issues. A potential disadvantage arising from the use of BBFCMs is the need to ensure effective segregation from fossil fuel-based materials to enable their effective recycling, suggests Fera Science in the UK report. For example, the presence of small quantities of PLA can prevent recycling of PET into a transparent product suitable for reuse in food and drink applications. Also, bioplastics produced from polymer blends that include biobased fillers may be difficult to recycle or may adversely affect the existing recycling stream.

Legislation for Plastic FCMs

Generally speaking, biobased plastics are required to comply with the same regulations with respect to food safety as fossil fuel-based plastics.

In the U.S., the Federal Food, Drug, and Cosmetic Act of 1938, 21 U.S.C. Section 301, et seq., provides that any substance, the intended use of which is reasonably expected to become a component of food (e.g., migrates from packaging into food), must be authorized for such use by the U.S. Food and Drug Administration (FDA) through a food additive regulation or in the case of packaging and other FCMs, a Food Contact Notification (FCN), or the substance must be generally recognized as safe (GRAS) or used in accordance with a sanction or approval issued prior to 1958 by either FDA or USDA, among other potentially available exemptions and exclusions.

Polymers cleared for food-contact use through food additive petitions are listed in Title 21 of the *Code of Federal Regulations* (C.F.R.), Part 177, "Indirect Food Additives: Polymers." This part is further divided by types of polymers. Polymers and other food contact substances can also be cleared through an FCN. FCNs are proprietary and may be relied on only by the notifier/manufacturer and its customers.

For plastic packaging materials, FDA regulations generally clear the final polymer, not unreacted starting materials. There are, however, some exceptions where FDA permits certain starting reactants to be used to make a finished polymer. For example, in Part 175.300, "Resinous and polymeric coatings," FDA lists cleared precursor materials since these substances are typically complex and often cross-linked compounds.

In addition, any food packaging material intended to come in contact with food must comply with FDA's Good Manufacturing Practices (GMP) regulation, found in Title 21 C.F.R. Section 174.5. GMP requirements apply to both the use level of an additive and its purity. This means that additives may only be used in an amount necessary to achieve their function or purpose and may not contain impurities at levels sufficiently high as to result in the adulteration of food.

In the EU, the Plastics Regulation, (EU) No. 10/2011, governs the use of plastic materials and articles intended to contact food. It applies to the plastic layers in all multi-layer food contact articles. This regulation includes a positive list of permissible monomers and other starting substances, additives (other than colorants), and some polymer production aids. In contrast to U.S. regulations, the EU Plastics Regulation does not include limits on co-reactants or use levels for starting materials, temperature restrictions, specification of single versus repeated use, and food types for specific substances.

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Anyone can petition to add a new monomer or additive to the Plastics Regulation's positive list. These petitions are first reviewed by the European Food Safety Authority (EFSA), which will issue a formal opinion on the safety of the substance when intended for use with food and any limitations that should be observed. Once EFSA has issued an opinion, finding a proposed use of a substance to be safe, the European Commission (EC), provided it concurs with the opinion, will add the substance to the list through an amendment to the regulation.

Finally, all FCMs in the EU must comply with the safety criteria set forth in Framework Regulation (EC) No. 1935/2004, which specifies that FCMs and articles may not transfer their constituents to food in quantities that could endanger human health, bring about an unacceptable change in the composition of the food, or bring about a deterioration in the organoleptic characteristic of the food. All FCMs must also comply with the GMP Regulation, (EC) No. 2023/2006.

While certain biobased polymers have been cleared in the U.S. and the EU, such as PHA, a number of regulatory issues need to be considered for new materials or new applications for existing materials. For example, when preparing a submission to obtain clearance of the material, what are the appropriate food simulants to be used to estimate the potential for migration? Likewise, how do you prove to authorities (and to customers) that the substance is stable for an intended application that involves a specific type of food or temperature range?

Also, in some instances, it may be necessary to demonstrate the suitable purity of a product with respect to the potential presence of organic matter, such as cellular debris. Possible contamination with naturally produced contaminants (e.g., mycotoxins and algal biotoxins) may also need to be considered. In addition, possible contamination with organic compounds (e.g., dioxins and polychlorinated biphenyls) or inorganic compounds (e.g., lead and arsenic), nitrates, pesticide and veterinary medicine residues, and plant toxins may need to be evaluated. In addition, depending on the feedstock and processing conditions, process contaminants such as acrylamide could be formed due to Maillard reactions occurring when complex biomaterials such as food are heated.

Additional questions could result from the inclusion of nanoscale materials—to improve barrier function and to achieve similar or better shelf life—in biobased packaging. There could also be questions about the genetically modified microbial strains, if they are used, to produce the biobased plastic. The UK Food Standards Agency (FSA) report points out that, to date, there have not been any studies that address the presence of genetically modified materials present in the biomass used for the production of BBFCMs.

Another regulatory consideration concerns the use of alternative fiber sources in biobased food packaging—an area that is being investigated in both the U.S. and the EU. A potential application for fiber is the addition of bamboo to a polymer backbone for products such as reusable cups. Regulators in the EU are considering the use of bamboo in contact with food. With respect to other fiber sources, in the U.S., pulp is listed as GRAS under 21 C.F.R. Section 186.1673 for food packaging uses, including paper production. It is defined as "soft, spongy pith inside the stem of a plant such as wood, straw, sugarcane, or other natural plant sources" and therefore gives wide latitude in the potential candidates that could be available for use as alternative pulp sources. In the EU, untreated wood flour and fibers are cleared as additives in the Plastics Regulation. However, in all these cases, the suitable purity/safety demand of the regulations is still applicable.

Conclusion

The report *Bio-Based Materials for Use in Food Contact Applications* was the result of a review commissioned by FSA on potential risks and other unintended consequences of replacing fossil fuel-based plastic FCMs with BBFCMs. The key findings from the study are summarized below.

1. Limited research has been conducted on BBFCMs derived from agri-food by-products.
2. BBFCMs can exhibit barrier properties similar to traditional fossil fuel-based plastics, enabling comparable shelf life performance and consumer protection.
3. Information on the presence of inorganic contaminants such as heavy metals, persistent organic contaminants, and natural toxins in BBFCMs, and their capacity to transfer from biomass-derived BBFCMs into food, is required.
4. Polypeptide-based materials used for packaging may include substances that are known or suspected allergens or are extracted from matrices that contain allergens. More information is needed on the allergenicity of BBFCMs, as well as on the potential for transfer of allergens to food.

5. Current analytical methods and risk assessment processes for establishing contaminant chemical transfer from fossil fuel-based plastics to food are expected to be appropriate for or adaptable to BBFCMs.

While the current use of BBFCMs is low, the UK report predicts that their use will grow significantly in response to consumer pressures, manufacturer demand, and increased levels of industrial production. Also contributing to the growth of biobased plastics are new regulations that encourage movement toward sustainable products, especially in the EU, and the development of biobased polymers with increased performance benefits, such as ones that can be used in lighter-weight bottles that can hold carbonated pressure longer. Finally, increased demand for biobased products is likely to drive down production costs. ■

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