A Guide to Bio-Based Materials

AdeptGroup

ENGINEERING EXCELLENCE

Sustainability Initiatives

Brands in all industries are pursuing aggressive initiatives to be more sustainable.

Packaging teams play a key role in these sustainability initiatives, as the United States Environmental Protection Agency (EPA) estimates that packaging comprised more than 28 percent of the waste sent to landfills in 2018, the latest year for which the agency has published numbers. Whether brands have signed on the Ellen MacArthur Foundation's Global Commitment or they're pursuing their own sustainability goals, they all face the challenge of designing to support the circular economy by focusing on elimination of waste, maintain circulation of products at their highest value, and regeneration.

Packaging departments that have not yet started a transition away from unsustainable packaging may soon have no choice. Pressure from consumers, regulators and retailers – from national brick and mortar chains to e-commerce giants – is growing. Those that aren't preparing for a more sustainable future now may soon find themselves playing catch up as their competitors race ahead of them.

When packaging teams evaluate their options, many may want to consider bio-based packaging materials. The umbrella term bio-based materials covers a wide range of options derived from renewable resources from traditional sources such as plants to recent developments in materials made from fungi and microorganisms. This white paper covers some of the promising types of bio-based materials, along with details about their advantages, limitations and common applications.

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A Diverse Subcategory

Bioplastics

Within the broad category of bio-based materials, bioplastics may be the most diverse subcategory.

In the relatively short amount of time that bioplastics have been available, suppliers have developed processes for deriving them from a wide range of sources. Bioplastics have been created from plant-based sources such as corn and sugar cane, and even more recent developments include bioplastics derived from seaweed and microorganisms such as algae, bacteria and others.

In addition to corn and sugar cane, plant-based sources of bioplastics include soybeans, hemp, starches from root vegetables such as potatoes and cassava, and cellulose extracted from wood pulp, cotton and other plants.

Non-plant sources of bioplastics are equally diverse:

MICROORGANISMS:

- Algae
- Bacteria
- Fungi

CELLULOSE EXTRACTED FROM:

- Bacterial cells

CHITIN (BIOPOLYMER):

- Exoskeletons of insects
- Exoskeletons of crustaceans
- Some fungi

The sources used to create bioplastics can vary greatly, but there are a common set of advantages they all hold over traditional, petroleum-based plastics. The most obvious advantages of bioplastics is their potential to break part of our dependency on fossil fuels. Many bioplastic materials are compostable, and they all require less energy to produce, meaning their carbon footprint is smaller than that of petroleum-based plastics. The sources used to create bioplastics are also renewable, a significant advantage over the finite quantity of petroleum available for the next few millennia.

A note on the meanings of "biodegradable" and "compostable":
These words are often used together, but it is important to understand their specific meanings and differences between them. A *biodegradable* material is one that can be consumed by living organisms such as bacteria. A *compostable* material is one that breaks down into non-toxic, natural elements at a rate similar to organic materials. All compostable materials are biodegradable, but not all biodegradable materials are compostable.

A key difference between the two is the role time plays in the process. Compostable materials break down over a defined duration and under a specific set of conditions. On a long enough timeline, all materials biodegrade when exposed to conditions such as sunlight, moisture and the presence of microorganisms. Paperboard may break down more quickly than plastic, but they'll both get there eventually.

For packaging, *compostable* is a much more meaningful designation. Because the necessary conditions are well-defined, organizations in many global territories issue certifications brands can use to market their product's packaging as compostable, but no such certifications exist for biodegradable materials.

It is also important to note that there are two different types of compostability: home and industrial. Items designated as home compostable can go to industrial composting facilities, but industrial compostable materials can not be home composted because they require specific conditions.

Suppliers' claims of biodegradability should be carefully scrutinized. While this can be meaningful for paper and other natural fiber-based materials, these claims are more dubious when it comes to plastics, even when they include additives meant to expediate the process. Additionally, *biodegradable* doesn't mean that there's no harm in sending the material to a landfill, as landfills act more as a time capsule for waste than a place for it to biodegrade and return nutrients to the environment. Items that biodegrade in a landfill are drivers of methane, a powerful greenhouse gas.

It is generally a good idea to avoid marketing as product's packaging a biodegradable to avoid confusing consumers with claims that can be viewed as greenwashing.

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A Diverse Subcategory

Bioplastics

Though this factor may not be on par with traditional plastics, bioplastics are highly versatile.

They can be used to create bags, films, wraps and some more rigid packaging components such as trays, and they can be molded into the same sizes and shapes as traditional plastics. Microorganisms can be tailored and engineered to enhance strength, flexibility and other properties that make the bioplastics derived from them suitable for a broad range of applications.

While bioplastics hold many sustainability advantages over their more traditional counterparts, they do have some limitations. Advances in material science may overcome these challenges in the future, but bioplastics generally do not possess equivalent barrier properties and heat resistance to petroleum-based plastics.

Currently, bioplastics tend to be more expensive than traditional plastics due to the higher costs of raw materials and manufacturing processes. Economies of scale should mitigate this difference if supply increases, but that depends on many factors that are difficult to predict at the present moment. On a related note, the limited supply of most bioplastic materials means it may not be a viable option for brands whose production quantities require large runs of packaging materials.

Thorough review of the advantages and limitations of bioplastics can help brands determine if they're a viable option for a product and its distribution environment. There are, however, a handful of common applications that may help speed up the decision-making processes. Composability and biodegradability may make bioplastics a strong choice for the bags, wraps and other packaging types used by food brands. Those same factors, combined with biocompatibility and ease of disposal, may also make bioplastics a strong option for medical devices and some medical packaging. CPG brands that don't require strong barrier properties for their packaging may find the strong case for using bioplastics for packaging of products such as electronics, toys and others.

Sustainable Advantages

Fiber-based Materials

Fiber-based packaging materials span from traditional paperboard and corrugate derived from wood pulp to natural fibers from cotton, hemp, bamboo, eucalyptis and other sources.

The most familiar types are corrugated cardboard, paperboard, molded pulp and kraft paper.

Corrugate is generally comprised of three layers of paper – a fluted layer contained between two flat layers. The strength and durability of corrugate can be tailored to meet packaging requirements by increasing or decreasing the thickness of the paper, changing the size of the fluting and adding additional layers. The size of fluting is the most common way to alter the strength of corrugate, ranging from A-Flute, with a heigh of 5mm, to F-Flute with a height of just 1mm.

Corrugate has a number of factors that make it an excellent packaging material for sustainability-minded brands. It is strong and durable, making it suitable for many packaging applications. It is also recyclable and compostable, unless contaminated by coatings, certain dyes and inks, food waste, or a handful of other materials.

Paperboard is a thick, stiff, lightweight material that can be used with or without coatings that add strength and moisture barrier properties. Much of its popularity is owed to its inexpensive price point and the ease of printing on paperboard. It is also recyclable unless contaminated by certain coatings, dyes and inks.

Like the process of making paper, molded pulp is created by pulping the source material and mixing it with water to create a slurry. Commonly used materials include virgin or recycled paper, wheat grass, bamboo, and bagasse. It is best suited for interior packaging components such as trays but can also be used in food service applications. For specialized applications, additives may be added to the mix to improve certain properties and performance characteristics. A vacuum then draws this slurry water onto a screen that holds the matted cellulose fiber in place as it travels through a drying oven to evaporate the water, leaving behind a lightweight tray of material. For applications that require a more precise shape, an additional drying process can press the tray between match-molded tooling surfaces.

Because of the materials used, molded pulp is both biodegradable and fully recyclable. It provides excellent cushioning and vibration dampening properties, along with low-static properties, which makes it a great fit for a wide variety of products, including electronics. It is also a low-cost packaging material because its base materials are inexpensive and readily available.

Fiber-based Materials

Kraft paper is a sturdy, tear-resistant material made from wood pulp. It differs from other paper materials in its production process, which involves cooking wood chips in an alkaline solution to loosen the fibers and remove impurities. The resulting material is then washed, bleached and processed into paper. Kraft paper can also be created from a combination of virgin and recycled fibers.

Common uses for kraft paper include bags, wraps, shipping envelopes and dunnage. Like other paper materials, it is both recyclable and biodegradable, making it highly sustainable.

Less traditional, natural fiber-based materials include bamboo, hemp, cotton, jute and coir. Though these materials may be less familiar than paper options, some are growing in popularity as demand for sustainable packaging increases.

Cotton is popular for its reusability, both in behind-the-scenes manufacturing applications and consumer-facing applications such as shopping bags. It is soft, absorbent and biodegradable at the end of its reuse cycle.

Hemp fibers are strong and durable and provide antimicrobial properties to packaging. Like most fiber-based materials, it is recyclable, biodegradable and renewable, making it a strong option for sustainability-minded brands.

Bamboo is one quickly growing packaging material due to properties such as strength, lightweight, biodegradability and renewability. With thoughtful design, bamboo can provide a premium appearance as an internal component of e-commerce packaging in addition to applications across food service and retail packaging for CPG products.

Jute is a strong, durable fiber that can be woven into a sturdy material well suited for bags used to carry agricultural products such as coffee beans, potatoes, seeds and nuts. It is both compostable and biodegradable, which gives it high sustainability scores for end-of-life scenarios.

Coir is a natural fiber sourced from the husks of coconuts. It shares similar durability to other natural fiber-based materials, with the added advantage of water-resistant properties. On the sustainability side, it is biodegradable and highly renewable.

Eucalyptus can also be a natural source. Its fibers are strong and durable, with high tear resistance properties. Its light weight helps to save on costs and emissions during shipping, and it can be regrown quickly, making it highly renewable. Depending on how the fibers are processed, they can also be designed for recyclability.

Fiber-based Materials

A common advantage shared by all fiber-based packaging materials is sustainability.

The paper-based options are nearly all recyclable, compostable and biodegradable in addition to the renewability of their sources. According to the EPA, more than 66 percent of paper materials are recycled, which puts it above other materials such as plastic, glass and aluminum. Less traditional natural fiber materials are also both renewable and biodegradable, though there is variance across the different materials when it comes to recycling and composting.

Paper-based packaging materials share the advantage of high availability and the relatively inexpensive price points to match. This is a limitation for the less traditional fiber materials, as their lower supply generally leads to higher prices.

A common limitation of fiber-based packaging materials is that they're not well suited to supporting heavy loads. Most of them also do not hold up well when exposed to moisture unless used with a coating, which often limits sustainability advantages.

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Mycelium Packaging

Mushroom-based Materials

A growing trend in bio-based packaging materials are ones derived from mushrooms, also commonly referred to as mycelium packaging.

These materials are commonly made by sterilizing agricultural waste such as stems, corn stalks, sawdust and others to serve as a nutrient-rich base for growing mushrooms. As the mushrooms grow, they bind the waste into a sturdy material that can be molded in various sizes and shapes with pressure and heat before drying and hardening into sturdy packaging materials.

These mushroom-based materials are both compostable and biodegradable in addition to being highly renewable. The use of agricultural waste in the growth process also helps to keep material out of landfills. The resulting material is lightweight, which helps save on fuel consumption – as well as fuel costs – during shipping. Because it can be molded into a variety of sizes and shapes, it is highly customizable to fit unique shapes of electronics, other CPG products and even some food products.

Mycelium packaging does have a few limitations that brands should consider when evaluating it as an option. While it has better moisture barrier properties than non-coated paper, it still has limits to its durability when exposed to moisture, especially when compared to plastics. It has a limited shelf life and durability when compared to more traditional options, limit its utility for long-term storage applications. Its novel nature also means its currently limited in availability, and the production process can be slow and resource-intensive, meaning it's not a great option for brands that require large runs and those with tight margins that need to keep per-unit costs down.

Contact Us

The wide range of options and the unique properties of each bio-based material mean packaging departments should evaluate them carefully when looking for more sustainable alternatives.

The unique needs of a product and its distribution environment will help brands narrow their options, and cost savings and sustainability goals also play an important role in determining which materials are a good fit for a packaging project. Insights from an experienced sustainable packaging professional, including life cycle assessment of current packaging and potential alternatives, can help packaging departments make more informed decisions.

If your team could benefit from expert help in evaluating bio-based material options to determine which are viable for your brand and its products, get in touch with the Adept team.

Our highly experienced sustainability team can thoroughly vet each material's features and limitations against product requirements and brand priorities to help you determine which are the best to fit your needs.