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Compostable Packaging

A Greener Approach to Packaging Materials

An Adept Packaging White Paper

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More than ever, the environmental impact of plastics is making headlines. From garbage patches twice the size of Texas, to the staggering statistic that the amount of plastic will outnumber fish in the ocean by 2050, the problem is front and center.

In 1980, the production of plastic was around 70 million tons, with 100% of it being discarded. But by 2015, production reached 381 million tons from which 55% was discarded, 25% incinerated, and 20% recycled; still leaving over 200 million tons of plastic being thrown away each year.

From the article Plastic Pollution, Hannah Ritchie and Max Roser outline the current situation on global usage and wastage of plastic. In 2010, the global primary production of plastic reached 270 million tons and the global wastage of plastic reached 275 tons; from which 31.9 million tons were mismanaged and had a high risk of leaking into the environment (8 million directly into the ocean).

In an effort to manage the problem, the disposal methods have changed, but the problem doesn't stop at waste management. The plastic that finds its way into the environment has a significant impact on wildlife through entanglement, ingestion and general interaction.

Given these detrimental statistics, companies are looking to alternatives to combat this global problem through sustainable sourcing, design, production and disposal of packaging through the following approaches:

- Design for recycling
- Design for reuse
- Replace plastics with bioplastics (some of them compostable)
- Replace plastics with paper
- Reduce and remove packaging
- Shift to mono-materials
- Increase recycled content

Specifically, this white paper will focus on the pros, cons, capabilities and alternatives of the compostable packaging solution.

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When companies begin to explore compostable packaging solutions for their products, some questions come up:

- ✓ What is compostable packaging?
- ✓ What is the difference between biodegradable and compostable?
- ✓ What makes a material compostable according to regulatory requirements?
- ✓ What types of compostable materials exist and what are the advantages and disadvantages of those materials?
- ✓ How are companies currently using compostable materials in the market?

With the market demanding a more sustainable approach to packaging, answering the above questions will offer your company a framework to decide if compostable packaging is a realistic approach for your products.

What Do We Consider as Compostable Packaging?

Compostable packaging or more specifically compostable plastic is defined by the ASTM (American Society for Testing & Materials) as "capable of undergoing biological decomposition in a compost site as part of an available program, such that the plastic is not visually distinguishable and breaks down to carbon dioxide, water, inorganic compounds, and biomass, at a rate consistent with known compostable materials (e.g. cellulose) and leaves no toxic residue."

According to World Centric, to be considered compostable plastic, there are three characteristics that must exist: it must be biodegrade, disintegrable and free of ecotoxicity.

1. Biodegradable – in order for a material to be considered biodegradable, it must break down into carbon dioxide, water, biomass at the same rate as cellulose (paper).
2. Disintegrable - the material is disintegrable if it is indistinguishable in compost; it must not be visible or needed to be screened out
3. Free of Eco-toxicity – a material is considered free of eco-toxicity if the biodegradation does not produce any toxic material and the compost can support plant growth.

Differences Between Biodegradable and Compostable

One common confusion when dealing with compostable packaging is the ability to discern between biodegradable and compostable, which mean similar things but, practically, have significant differences.

- ✓ What is the difference between bioplastics, biobased plastics, biodegradable plastic and compostable plastics?

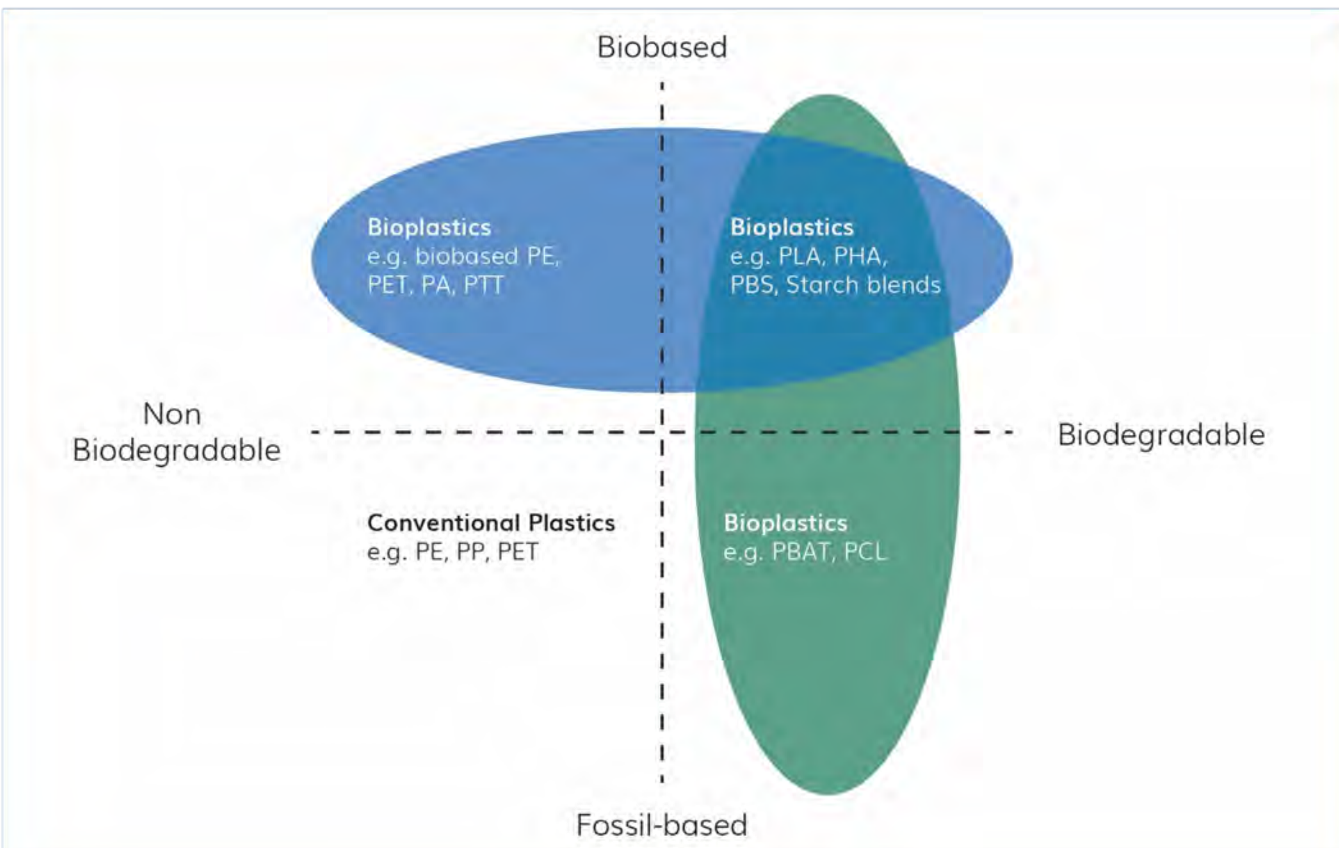
As per the European Bioplastics organization, a bioplastic refers to a broad family of materials that can be either biobased, biodegradable or both. (see graphic below)

Biobased refers to the spectrum of materials that are wholly or partially derived from biomass (plants) such as corn, sugarcane or cellulose.

Biodegradable means that the material is capable of being decomposed by a chemical process in which microorganisms (disposables in the environment) convert those materials in natural substances as water, CO_2 or compost. This process depends not only on the material itself, but on some environmental conditions such as location, temperature etc.

Compostable, as indicated in the above paragraph, refers to materials that can be decomposed in natural sub products in a compost environment (compostable specific conditions) within a limited period of time and with no toxic impact on the soil.

In the graphic below, we can see the relationship between these defined terms. The materials are divided according to the two axes; Biodegradable vs Non-Biodegradable and Biobased vs Fossil-based. In this white paper, we will focus on materials that are specifically biodegradable or biobased (adding PCL), which have better compostable behavior.



Reference: https://www.european-bioplastics.org/bioplastics/

What Makes a Material Compostable According to Regulations?

In order to determine that a material is compostable, there are certain tests that the material must pass. Some institutions that exist have defined either the standards or the methods to perform these tests, such as:

Region	Standard
Europe	European Standardization Committee (CEN) **EN13432** German Institute for Standardization (DIN) **DIN V49000** British Standard Institution **BS EN 13432**
America	American Society for Testing and Materials **ASTM-6400-99**
Canada	Standards Council of Canada (SCC) **BNQ 9011-911**
Japan	Japan BioPlastics Association **JBPA**
International	International Standards Organization (ISO) **ISO14855** (only for biodegradation)

The main characteristics that the compostable packaging has to achieve are biodegradability, disintegrability, no negative output within the process of composting, and very little existence of heavy metals or a bad effect on the quality of the compost.

In Europe, the CEN in the norm EN13432 determine that:

- 60% of the carbon in CO_2 must be biodegraded within 180 days (6 months) for monopolymers and 90% for copolymers or mixed polymers. Disintegration is measured with less than 10% of the biodegraded elements with 2 mm of size after 120 days (4 months).
- Eco-toxicity is evaluated by testing plant growth in a compost that is mixed with soil and a limit of heavy metals (set from standards) and is compared to the growth in a controlled compost.
- Upper limits of heavy metals are (BS EN13432) in mg/kg of dry sample, are:
    - zinc 150, copper 50, nickel 25, cadmium 0.5, lead 50, mercury 0.5, chromium 50, molybdenum 1, selenium 0.75, arsenic 5 and fluoride 100.
- It is also noted in the BS EN13432 that the compostable packaging must not negatively alter variables of the compost: nitrogen, phosphorus, magnesium, potassium and bulk density, salinity, volatile solid and pH.

Commonly, to receive the assessment and certification there are independent certification bodies that help on this process such as:

- DIN Certco (German Institute of Standardization, Germany)
- AFOR (Association for Organics Recycling, UK)
- Keurmerkinstituut (Certification Institute, Netherlands)
- COBRO (Packaging Research Institute, Poland)
- ABA (Australasian Bioplastics Association, Australia)
- Vinçotte (Accredited Inspection and Certification Organization, Belgium)
- Jätelaito-syhdistys (Solid Waste Association, Finland)
- Certiquality/CIC (Composting and Biogas Association, Italy)
- Avfall Norge (Waste Management and Recycling Association, Norway)
- BPI (Biodegradable Products Institute, USA)
- BNQ (Bureau de Normalisation du Québec, Canada)
- JBPA (Japan BioPlastics Association, Japan).

Once all tests have been passed, a certification is awarded and then the compostable logo can be displayed on the packaging.

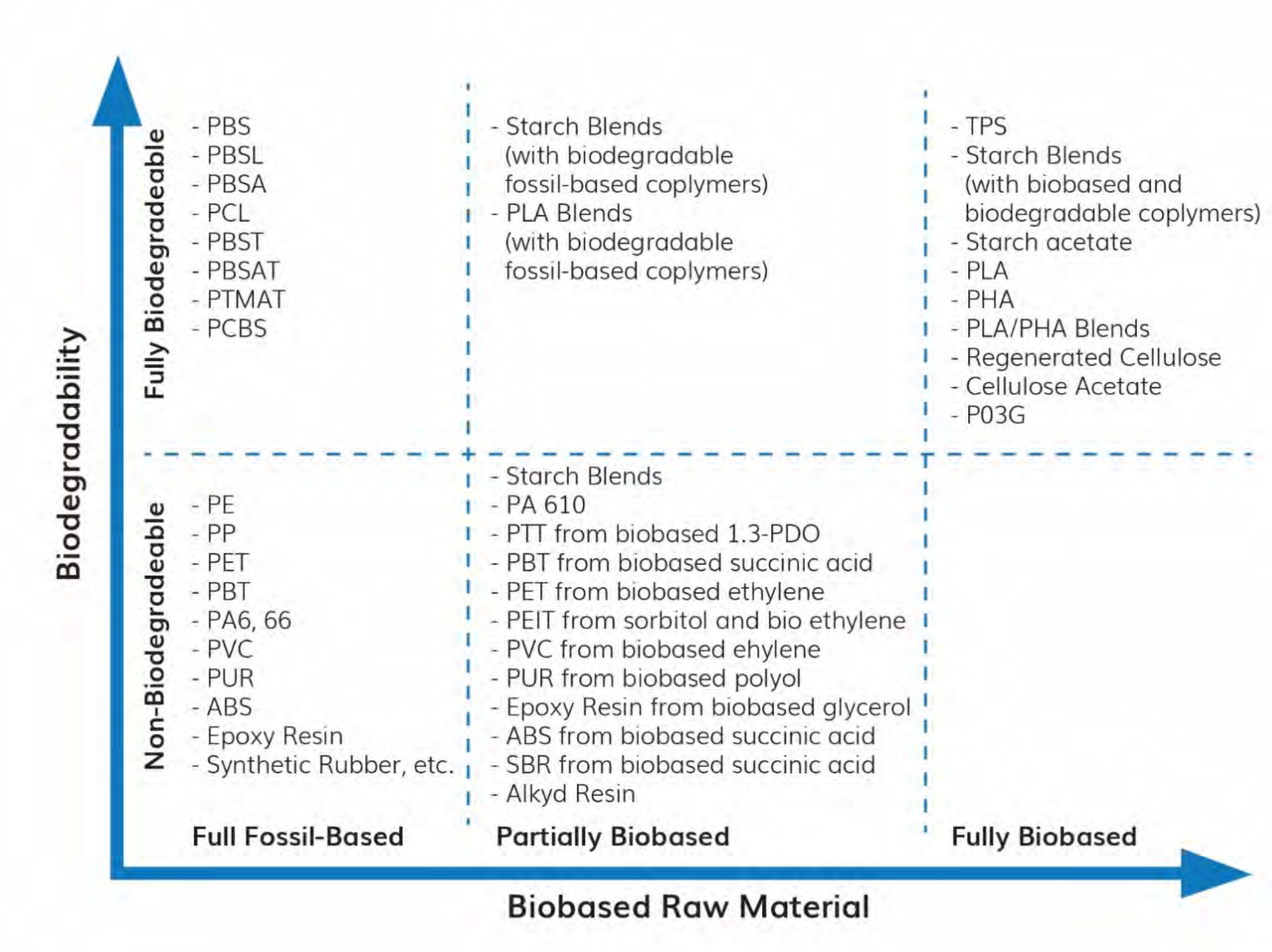
The certification has to be renewed every 3 years. Within this period, samples can be collected from the market for further testing. (e.g. Association of Organics Recycling in UK)

In the United States, this assessment is performed by the Biodegradable Products Institute (BPI). To receive the proper certification means that the product has been tested by a well-known lab and has met the standard of ASTM D6400 or ASTM D6868.

Once certified, the packaging will receive the BPI compostable logo.

Types of Compostable Materials

In addition to understanding what makes a material certified as compostable, having an overview of the different kinds of materials is also relevant to choosing the best compostable packaging design. The graphic below depicts common materials shown on a biodegradability/bio-based raw material scale.



These materials, which correspond to the graph above as being fully biobased and biodegradable, are the most common in the industry:

- PLA
- PLA-PCL
- TPS
- PHA(PHB)

As they are the ones with biodegradable capabilities and better material solutions for home and/or industrial composting.

Understanding the benefits and drawbacks of each of these materials allows packaging engineers to make an informed decision on which material would be best for each product.

PLA (Polylactic acid or polylactide)

"PLA is a polyester (polymer containing the ester group) made with two possible monomers or building blocks: lactic acid and lactide. Lactic acid can be produced by the bacterial fermentation of a carbohydrate source under controlled conditions. In the industrial scale production of lactic acid, the carbohydrate source of choice can be corn starch, cassava roots, or sugarcane, making the process sustainable and renewable." (Joseph Flynt, 2017).

This material can replace fossil-based thermoplastics and has been introduced into the market as a renewable alternative that can be used as a fertilizer (after composting) once the packaging lifecycle has ended.

Although this is one of the bestselling biodegradable plastics on the market, it requires high temperatures for breakdown and is not home compostable. However, when blended with PCL (polycrolactone), it is degraded completely to carbon dioxide, biomass and water under typical home-composting conditions. (American Chemical Society, 2018).

PLA has the following benefits:

- It is Eco-friendly because it is renewably sourced, biodegradable and compostable
- It is considered biocompatible because if it is disposed of correctly in a compostable facility, it is considered not toxic.
- It is considered more processable than other materials as PHA or PCL.

Properties of PLA:

- Similar properties such as PET, PVC
- High performance, comparable with PS, PP and ABS
- High mechanical strength
- Low toxic level
- Good barrier for moisture and heat
- UV resistant
- Resistant to chemicals
- Low flammability & smoke formation

Some suppliers of PLA:

- Bioware (Huhtamaki, Finland)
- NaturalBox (Coopbox, Italy)
- Earthfirts (Plastics Supplier Inc, US)
- Leoplast (Italy)
- Naturpackaging
- BioTak (Berkshirelabels, UK)

Disadvantages of PLA usage:

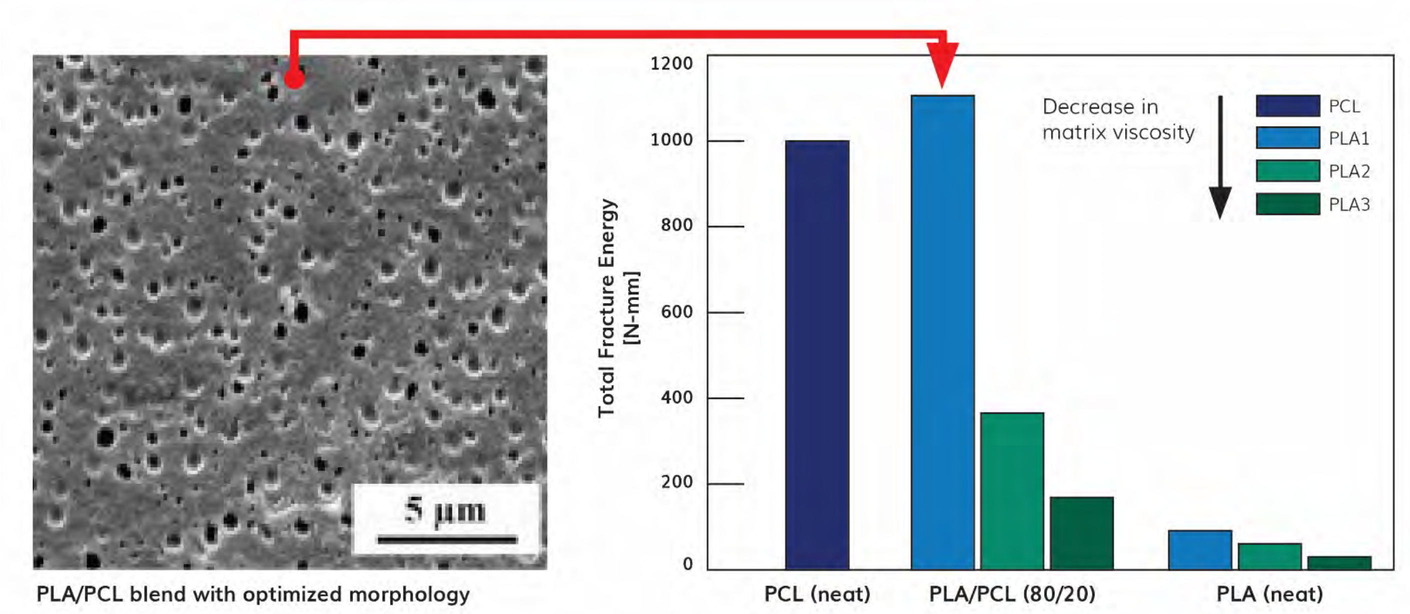
- Breaks down in a specific environment at 58ºC
- Difficult to dispose of because there are not enough appropriated composting facilities
- If not disposed of properly, toxicity takes place due to the emission of methane
- PLA is less suitable for high temperature areas due to the low glass transition at approximately 55°C
- Low Ductility
- Poor impact strength
- Low crystallization rate that usually lead to amorphous products
- More susceptible to chemical and biological hydrolysis
- Poor gas barrier capabilities
- Less flexibility that leads of higher mold cycles
- Heat can cause deformities
- Limited shelf life

Typical uses of PLA:

- Usually divided into three forms: Rigid thermoform, biaxial oriented films and bottles
- Food contact polymer for plastics (FDA approval for short shelf life products)
- Healthcare and Medical Industry: due to its biocompatibility, biodegradability and versatility, there is a wide variety of application in this industry, such as: bioabsorbable medical implants, tissue engineering, delivery system materials, covering membranes, medical devices, dermatological treatments etc. See graphic below:
- Fibers and fabrics: this is a good solution for carpets, mattress, sportswear due to the low moisture absorption and good resistance to UV light.
- PLA filaments for 3D printing
- End segment applications: packaging, building, agriculture, transport, furniture, electronic appliances, household products etc.

PLA-PLC (Polylactic acid or polylactide)

As mentioned above, neat PLA is not home compostable. Various studies have demonstrated that blends of PLA with PCL (Polycaprolactone) shows a better degradation under home conditions, as well as an improvement of other parameters as a percentage of elongation and impact strength.



Resource: https://www.sciencedirect.com/science/article/pii/S175161611730022X

TPS (Thermoplastic Starch)

Starch is a very abundant, plant-based material which is biodegradable and presents physical and chemical properties that make it an interesting material to be developed. Typical sources of starches are corn, potatoes, rice, green peas etc.

In a more chemical description, starch is a crystalline material that under some conditions, when mixed with a certain amount of water, a homogenous melt known as thermoplastic starch (TPS) appears with thermoplastic features.

TPS is a biodegradable material that can be incorporated into the soil as fertilizer. Apart from that, TPS can be transformed in several thermoplastification processes just like injection molding, extrusion blow molding, injection compression molding and extrusion. (Itene, 2011)

Properties of TPS:

- Second biopolymer more abundant
- Good mechanical properties similar to LDPE and PS
- Sealable and printable with no superficial treatment
- Can be a barrier against gases such as CO2 and O2 and aromas
- Antistatic properties
- Water soluble
- Can be modified chemically

Typical uses of TPS:

- Flexible films
- Household items
- Damping materials
- Thermoformed trays
- Bags
- Some closing systems
- Bottles

Disadvantages of TPS:

- High sensibility to humidity
- High Water Vapor Transmission Rate
- High Density
- Fragility
- Difficulties on extrusion process

Some suppliers of TPS:

- Mater-BI (Novamont)
- Biplast (Biotec)
- Biocaps (Wiedmer AG)
- Gaialene (Roquette Laisa S.A)

PHA (Polyhydroxyalkanoate)

PHA is a unique bio-based and biodegradable material that comes from bacteria (such as *Pseudomonas putida* and *Cupriavidus necator.*) It is obtained from either microbial or sugar fermentation and can be decomposed if it is exposed to soil, compost, or marine sediments.

Properties of PHA: (Itene, 2011)

- Variety of properties depending on the composition
- Similar mechanical properties as other polyolefins (e.g. LDPE)
- Resistant to fats and solvents
- Good elongation ratio for blowing processes
- Stability in front of hydrolysis
- No scrap from catalysts

Typical uses of PHA (Creativemechanism staff, 2017)

- Single use packaging for foods, beverages, consumer products, etc.
- Medical applications like sutures, bone marrow scaffolds, bone plates, etc.
- Agricultural foils and films

Disadvantages of PHA: (Itene, 2011)

- Sensitive to thermic degradation
- Brittle
- Very low viscosity within melting

Some suppliers of PHA (Itene, 2011)

- Mirel (Metabolix-Telles, US)

By reviewing the properties of the compostable materials mentioned above, companies can make an educated decision to determine which, if any, would work for their products.

Examples of Compostable Packaging in the Markets

As compared previously, it is evident that biodegradable materials and particular compostable materials can offer opportunities to reduce waste, CO_2 emission and general dependence of fossil sources. Below are examples of companies currently applying these materials to their packaging.

TIPA provides packaging for their specific application, ranging from fresh produce and snacks to magazines and apparel. They operate on a global scale and their compostable polymer technology is applicable worldwide.

Careli developed a complete range of household products that are completely biodegradable and compostable.

Level Ground Trading offers 100% compostable, BPI certified packaging for coffee.

Eco Products offers rectangular deli cold food containers made from PLA and meet the ASTM standards for compostability.

Adept Packaging Compostable Recommendations

The decision to use or not to use compostable packaging (or any other sustainable option) depends on several factors that must be evaluated.

First, there are clear demands from the market to change to a more sustainable packaging, which minimizes pollution and impact on the environment.

Next, companies need to evaluate the impact that they want to have, both on the customer experience with their products, as well as on their environmental footprint.

If compostable packaging seems like an avenue you want to explore for your products, consider the advantages and disadvantages of the materials discussed in this paper. If you need assistance, Adept Packaging engineers can be leveraged to evaluate options and make suggestions for the materials, components and design that would be best suitable for your products.

If you have questions about compostable packaging or other sustainable options, our experts would be happy to assist. Contact us for assistance with your sustainable packaging.

www.adeptackaging.com

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