

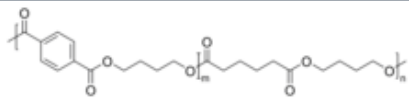


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Polybutylene adipate terephthalate

PBAT (short for polybutylene adipate terephthalate) is a biodegradable random copolymer, specifically a copolyester of adipic acid, 1,4-butanediol and terephthalic acid. PBAT is produced by many different manufacturers and may be known by the brand names **ecoflex**, **Wango**, **Ecoworld**, **Eastar Bio**, and **Origo-Bi**. It is also called poly(butylene adipate-co-terephthalate) and sometimes polybutyrate-adipate-terephthalate^[1] (a misnomer) or even just "polybutyrate".^[2] It is generally marketed as a fully biodegradable alternative to low-density polyethylene, having many similar properties including flexibility and resilience, allowing it to be used for many similar uses such as plastic bags and wraps.^[3] The structure is a random-block polymer consisting of butanediol–adipic acid and butanediol-terephthalic acid blocks.

Polybutylene adipate terephthalate

	
Identifiers	
CAS Number	130479-65-1 (https://commonchemistry.cas.org/detail?cas_rn=130479-65-1) 60961-73-1 (https://commonchemistry.cas.org/detail?cas_rn=60961-73-1)
Except where otherwise noted, data are given for materials in their <u>standard state</u> (at 25 °C [77 °F], 100 kPa).	
Infobox references	

History

Production of plastics for use in the industrial sector around the world makes up a very large market. PET (polyethylene terephthalate) is one of the dominant plastics within this market. It is commonly used for bottles because it makes a rigid container that is very lightweight. However, because of the stability of PET, it is also highly resistant to biodegradation, posing a significant environmental problem because of the amount of PET produced, sold, used and thrown away on a daily basis. An estimated 30% of the world production of PET goes into making these plastic bottles and only from 15% to 35% is recycled; the rest usually end up in a landfill.^[4] This has stimulated research into polymers that function comparably to PET, but are biodegradable.^[5]

As with all developments in the realm of materials there are several requirements for the 'ideal' material. For biodegradable plastics, they would be: cheap, renewable, easy to produce and eco-friendly. In addition to these, the polymer should be resistant enough to be functional, such as handling the strain of being put under pressure, and flexible so that it is easy to mold. There are no homopolymers that perfectly provide every one of these features. Therefore, researchers have turned their attention to copolymers: combinations of polymers that have chemical and mechanical properties that complement each other. This led to identifying poly(butylene adipate-co-terephthalate) (PBAT) as a potential copolymer for blending.

PBAT is a random copolymer known for being flexible and tough. This makes it ideal for combination with other biodegradable polymers that have high elastic modulus and strength, but are very brittle.^[6] This allows for the production of blended copolymers that can replace industry-standard plastics with

environmentally safe and biodegradable plastics that will harmlessly disappear in a short period of time.

Properties

PBAT is classified as a random copolymer due to its random structure. This also means that it cannot crystallize to any significant degree due to the absence of any kind of structural order. This leads to several physical properties: wide melting point, low elastic modulus and stiffness, but high flexibility and toughness. The flexibility and toughness of this polymer makes it ideal for blending with another biodegradable polymer that is strong and rigid for bottle production.^[5]

The drawback of this polymer is that if it has high flexibility and toughness, then it will not be strong and rigid. This makes it non-ideal for any situation in which a strong, rigid container is desired. An example of this would be transparent barriers, such as those made of plexiglass (Poly(methyl methacrylate)), a transparent glass substitute.^[5]

PBAT is fully biodegradable when composted due to the presence of butylene adipate groups. The high stability and mechanical properties come from the terephthalate portions.^[5]

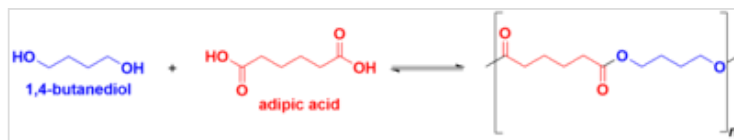
Does not degrade in marine and fresh water.^[7]

Preparation

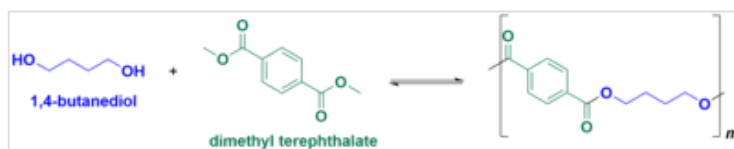
PBAT is synthesized from the polymer of 1,4-butanediol and adipic acid and the polymer of dimethyl terephthalate (DMT) with 1,4-butanediol.

Adipic acid and 1,4-butanediol are polymerized to create their polyester (plus water). DMT and 1,4-butanediol are also reacted to form their polyester (plus methanol). This polyester is then added to the butylene adipic acid polyester by using tetrabutoxytitanium (TBOT) as a transesterification catalyst; an overabundance of 1,4-butanediol influences chain lengths. The result is a copolymer of the two previously prepared polymers.

This is a random copolymer, because there is no control on the dispersity of the polymer chain lengths or block structuring in the copolymerization reactions; repeat positions are not controlled. If A = polyester of adipic acid and B = polyester of DMT, each with 1,4-butanediol, then the chain structuring



The polyester of adipic acid is synthesized using 1,4-butanediol. The chain lengths are kept low by using an excess of diol in the reaction.



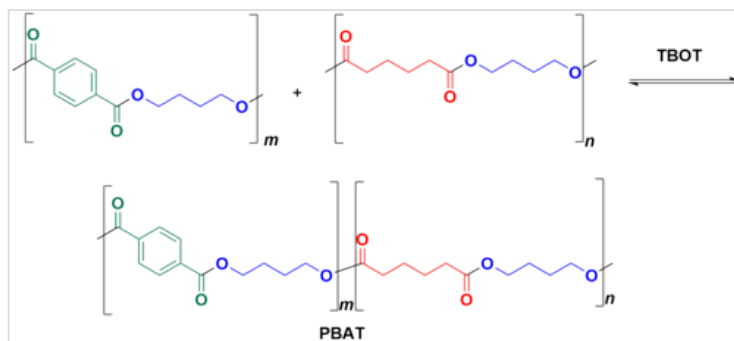
The polyester of DMT is generated using 1,4-butanediol. This is the second polymer used with the step 1 product to create the copolymer PBAT.

could look like any of these: AABABBABA or ABABAAAABB or ABABABBBBA; there is no selectivity for A and B reacting with themselves or each other.^[8]

Commercial sources

PBAT is produced commercially by **BASF** under the trademark **ecoflex**^[3] and in a blend with poly(lactic acid) called **ecovio**,^[9] by Novamont as

Origo-Bi and in a blend with starch called **Mater-Bi**,^[10] by Zhuhai Wango Chemical Co Ltd under the name **Wango**, by JinHui Zhaolong as **Ecoworld** and in a blend with starch called **Ecowill**, and by Eastman Chemical as **Eastar Bio**.^[11] Furthermore, suppliers in China and other nations now produce PBAT. These companies include Zhejiang Biodegradable Advanced Material Co. Ltd, Dongguan Xinhai Environmental Protection Material Co., Ltd.,^[12] Hangzhou Ruijiang Chemical Co., Ltd.,^[13] and Jiangsu Torise Biomaterials Co., Ltd.^[14] in China as well as Green Chemical Co., Ltd.^[15] and WILLEAP^[16] in South Korea.



TBOT is used to catalyze the transesterification of the polyesters of adipic acid and DMT to generate the random, copolymer PBAT.

Current and future uses

PBAT is marketed commercially as a fully biodegradable plastic, with BASF's **ecoflex** showing 90% degradation after 80 days in testing.^[17] Particular applications that are highlighted by the manufacturers include cling wrap for food packaging, compostable plastic bags for gardening and agricultural use, and as water resistant coatings for other materials, as in paper cups.^[18] Due to its high flexibility and biodegradable nature, PBAT is also marketed as an additive for more rigid biodegradable plastics to impart flexibility while maintaining full biodegradability of the final blend.

PBAT is already widely marketed and used for all of the above applications, but is also being investigated as a component in antimicrobial films. In such films, PBAT serves as the bulk of the film with the antimicrobial agent being incorporated during processing. The antimicrobial films would be used in food packaging to inhibit bacterial growth, helping to preserve food products safely.^[19]

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Retrieved from "https://en.wikipedia.org/w/index.php?title=Polybutylene_adipate_terephthalate&oldid=1232501009"



**ecoflex[®] –
the original since 1998**

Certified compostable plastic



Original ●

The certified compostable polymer **ecoflex®**

ECOFLEX® IS THE FIRST CERTIFIED COMPOSTABLE POLYMER BY BASF ON A FOSSIL BASIS. IT IS ON THE MARKET FOR MORE THAN TWO DECADES.

Compared to conventional plastics, **ecoflex®** offers a decisive benefit: certified compostability. **ecoflex®** is an innovative pioneer in the field of biodegradable polymers, being an important raw material for many compostable and biobased plastics.

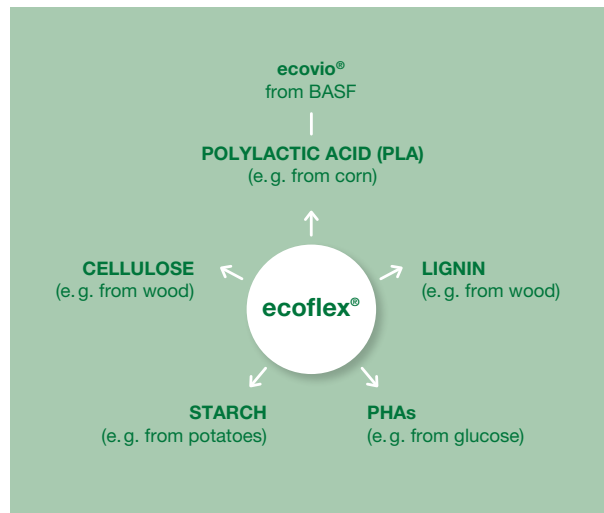
ecoflex® is:

- the ideal blend component for bioplastics
- certified compostable
- elastic as well as water and tear-resistant
- processable on conventional blown film machines for polyethylene
- printable and weldable
- suitable for food contact

ecoflex® – the optimal compound partner

ecoflex® is an ideal blend component for the production of plastics from renewable raw materials making many applications actually possible in the first place. Thus way **ecoflex®** provides the biobased and compostable BASF polymer **ecovio®** with special product properties such as flexibility and toughness.

Next to polylactic acid (PLA), other compound partners such as starch can be used in order to achieve a specific, characteristic profile for the application. A high content of **ecoflex®** is particularly suited for the production of flexible film products in the packaging area. Mechanical characteristics, such as stiffness or puncture resistance, can be varied and specifically adjusted.



Proven

The certified compostability of ecoflex®

THANKS TO A SPECIAL CHEMICAL STRUCTURE, ECOFLEX® CAN BE BIODEGRADED BY MICROORGANISMS AND THEIR CORRESPONDING ENZYMES.

Under the circumstances given in an industrial composting plant, the ecoflex® molecules are biodegraded within a few weeks.

in terms of biodegradability, compostability, compost quality, and plant compatibility.

In special certification procedures, independent institutes verify the suitability of bioplastics

ecoflex® offers various product grades that meet the following, international and national standards and regulations for industrial composting, among others:



European standard EN 13432,
Australian standard AS 4736



European standard
EN 13432



American standard
ASTM 6400



Japanese standard
GreenPla

Certification criteria

Chemical test	Compost quality	Disintegration and biodegradability
<ul style="list-style-type: none"> ■ Publication of all ingredients ■ Adherence to limit values for regulated metals and certain elements, e.g. fluor 	<ul style="list-style-type: none"> ■ Plant growth test ■ Ecotoxicity test ■ No negative impacts on the quality of the compost 	<ul style="list-style-type: none"> ■ Disintegration in particles smaller than two millimeters within 84 days ■ Biological biodegradation to water, CO₂ and biomass to 90% of the sample within 180 days

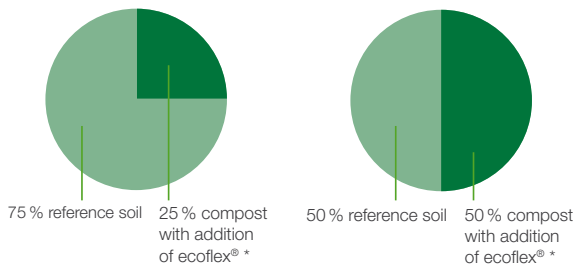
Safe

Ecologically tested and toxicologically safe

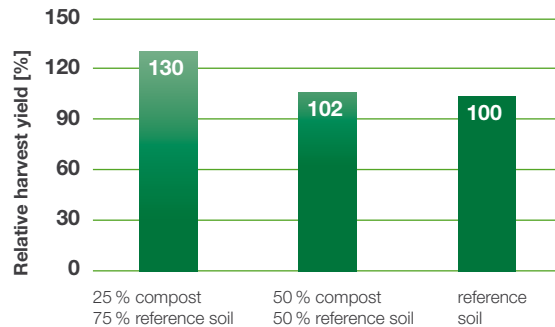
The plant growth test

The plant compatibility in the barley test is a key parameter for compost quality. This test looks at the effect of the test substance on the growth of summer barley. The following samples are prepared and used for testing:

A compost is recognized as plant-compatible, if in a mixture of 25% compost with 75% reference soil a 90% barley yield is achieved. In both variants, the test with ecoflex® shows no negative consequences on the barley yield.



* after 12 weeks composting



The Daphnia test

In this test, the pollutant-dependant immobilization of the Daphnia in solutions of different concentrations (series of dilutions) is used. Testing was carried out in accordance with DIN 38412 Part 30.

The control solution contains microorganisms that biodegrade ecoflex® enzymatically.

The stock solution to be tested also contains the degradation intermediates of ecoflex®. It is diluted step by step. For each concentration stage ten Daphnia are placed in the test solution (20 °C, pH 7.0 ± 0.2). After 24 hours, the number of Daphnia still swimming is counted. Even with a low dilution, as in the control solution, there are still at least nine Daphnia swimming. The test is therefore passed.

Quality ●

You can rely on it.

ECOFLEX® GUARANTEES VERIFIED QUALITY. ITS ECOLOGICAL PROPERTIES HAVE BEEN INVESTIGATED IN EXTENSIVE TESTS.

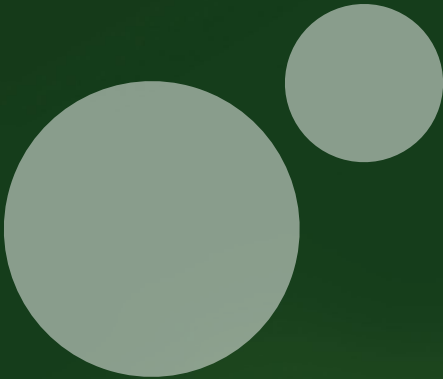
Scientifically recognized tests (plant growth test, Daphnia test, toxicological tests according to OECD directives) have proven in practice that ecoflex® has no negative consequences for nature or the environment.

Furthermore, ecoflex® is in its composition one of the few compostable polymers complying with the requirements of the European food contact regulation¹ as well as the requirements of the US Food Contact Substance Notification².

¹ Commission Regulation (EU) No. 10/2011 of January 14, 2011 on materials and objects of plastic, designed to be in contact with food

² According to Food Contact Substance Notification No. 907 of FDA





Note

The data contained in this publication are based on our current knowledge and experience. In view of the many factors that may affect processing and application of our product, these data do not relieve processors from carrying out own investigations and tests; neither do these data imply any guarantee of certain properties, nor the suitability of the product for a specific purpose. Any descriptions, drawings, photographs, data, proportions, weights etc. given herein may change without prior information and do not constitute the agreed contractual quality of the product. It is the responsibility of the recipient of our products to ensure that any proprietary rights and existing laws and legislation are observed. (July 2019)

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can be found on the internet:**

www.ecoflex.basf.com

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