Biodegradable Polymers – Inspired by Nature

Ecoflex®, Ecovio®
BASF has been producing biodegradable aliphatic-aromatic copolyesters under the tradename Ecoflex since 1998. Under certain environmental conditions, such as those found in compost, Ecoflex® degrades within a few weeks, leaving no harmful residues. In formulations based on thermoplastic starch and biodegradable synthetic polymers – known as starch blends – or on its own in the flexible films sector, with Ecoflex you can offer your customers a fully biodegradable packaging.

2006 heralded the arrival of a new biodegradable plastic, Ecovio®. This is composed of Ecoflex, BASF's biodegradable petrochemical-based plastic, and PLA (polylactic acid). PLA is produced from the renewable raw material, corn.
## ECOFLEX® AND ECIO® – FULLY BIODEGRADABLE PLASTICS

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Plastics – so the environment has a future

Plastics are making a significant contribution to protection of the environment and conservation of resources. In the future, they will continue to be used where they offer ecological advantages over other materials or where they open up new applications.

Versatile and eco-efficient

With efficient use of the natural resources available and a global proactive approach to environmental matters, plastics offer a potential that hardly any other material can match. Improved thermal insulation of buildings with plastic can save many millions of liters of fuel oil, and in a modern car the use of 100 kilograms (221 pounds) of plastic instead of heavier materials can reduce gasoline consumption by 0.3 to 0.5 liters per 100 kilometers (0.13 to 0.21 gallons per 100 miles).

With their special properties and the utility value based on them, plastics offer a number of options for environmental protection. Controversial discussions have been going on for some time on two quite different subjects: the raw material renewability and the question of what happens to plastic products when they have served their purpose.

Plastics can be produced from fossil or renewable raw materials, and irrespective of this they can be biodegradable in various disposal locations – or not. BASF does not consider that there are any general advantages or disadvantages of fossil or renewable raw materials. Only extensive analyses over the entire life cycle of a particular application can prove which raw material basis is best for the environment.
Renewable raw materials – a long tradition at BASF

Renewable raw materials have been an issue for BASF for many years and play an important role in new product developments. Examples are sugar as a raw material for the fermentation of vitamins, auxiliary products for paper produced on the basis of starch or surfactants and plasticizers based on oils and fats.

BASF’s first thermoplastic using renewable raw materials was Ecovio L BX 8145, introduced to the market in 2006, made with approximately 45% polylactic acid — 100% renewable plastic from corn sugar fermentation. 2007 saw the arrival of the plastic Lupranol® Balance — a polyol for the production of flexible polyurethane foams — and the polyamide Ultramid® Balance. Both are based in part on castor oil.

The same applies to recovery: biodegradable plastics are not generally any more environmentally friendly than other plastics, but they are the best solution for certain applications. For example, Ecoflex® and Ecovio® are suitable for mulch films in farming where they are ploughed in after use or for biowaste bags which are composted in industrial plants together with the organic waste they contain.

BASF favors the juxtaposition of different plastics. The application, the product properties required, the technical feasibility and not least the economic use should be the deciding factors in selecting the material. The Eco-Efficiency Analysis developed by BASF is a useful instrument for weighing the ecology and economy, cost and use of various materials for certain applications (see also www.basf.de/sustainability).
Nature is by far the largest producer of macromolecules. Apart from peptides and proteins, these are predominantly biodegradable polymers of vegetable origin such as starch and cellulose. Starch is found in all types of cereals and potatoes, while cellulose is a major component of wood and is used to manufacture paper.

How does biodegradation work?

From nature we can not only learn how macromolecules are formed — it has also developed methods for splitting the molecule chains of certain polymers. Microorganisms such as bacteria or fungi absorb the macromolecules as food and utilize them to fuel their metabolic processes, using for example enzymes in the digestion. The end products of this metabolism are then removed and incorporated into the natural product cycle.

Polymers just like in nature: Ecoflex® and Ecovio®

Both Ecoflex® and Ecovio® molecules have a similar structure to naturally occurring polymers and are also degraded by microorganisms and their enzymes. The important factor in this degradation process is simply the structure of the macromolecule and not the source of the raw materials (Fig. 2).

Microorganisms therefore process Ecoflex and Ecovio molecules just like the macromolecules present in nature, leaving behind carbon dioxide, water, energy and biomass.

Ecoflex and Ecovio do not need any additives for their decomposition, and both are certified globally to be compostable in industrial composting facilities. Unlike oxo-degradable plastics, they are free from regulated metal compounds and don’t leave any toxic residues behind.

Putting degradability to the test

Extensive series of tests have shown that Ecoflex complies with the stringent requirements of the binding European standard for biodegradable plastics (EN 13432), US ASTM D 6400 specifications and the Japanese standard GreenPla, i.e. with regard to complete biodegradability, compostability, compost quality, toxicity and soil compatibility (Fig. 3).

Tests show whether a polymer material can be biodegraded under the framework conditions of controlled composting or converted to compost constituents. Further tests examine whether the composting process and quality of the compost are affected by the material or its degradation products. Synthetic plastics, irrespective of whether they are composed of fossil naphtha or renewable raw materials, can be fully biodegradable if enzymes split their molecule chains and all the fragments can be used by microorganisms as food.

Ecovio is composed of Ecoflex that has all the certifications for compostability, and the annually renewable raw material PLA which is also compostable.

These compostability logos are an important mark of quality worldwide. Only products made of fully biodegradable materials, such as Ecoflex or Ecovio, can be given this mark. In special certification procedures, independent institutes check the suitability for composting.
based on strict criteria. Ecoflex® complies with European standard EN 13432 on the compostability of materials and the Japanese GreenPla standard and with the American standard ASTM D 6400.

Oxo-fragmentable PE sheet (sometimes also wrongly termed “oxo-biodegradable”) is material decomposed by special additives based mainly on the elements cobalt, manganese, iron etc. Triggered by exposure to UV or heat, they oxidize the polymer chains and break them up into smaller fragments.

However: It has not to date been possible to scientifically prove any biodegradability of these PE fragments remaining after decomposition that meets the standards, whether or not the materials were pre-treated with UV radiation or heat. Added to this is the fact that, even if stabilizers are added, the PE sheet loses its mechanical properties comparatively quickly, particularly if it is exposed to sunlight. Different storage conditions would therefore be needed to avoid premature ageing and the premature loss of the mechanical properties.
Ecoflex® – the highest quality in harmony with nature

BASF has been producing biodegradable aliphatic-aromatic copolyesters under the tradename Ecoflex® since 1998.

Under certain environmental conditions, such as those found in compost, Ecoflex degrades within a few weeks, leaving no residues.

Properties of Ecoflex®

- compostable
- complies with food safety requirements
- can be processed on conventional blown film plants for polyethylene
- water- and tear-resistant
- elastic
- printable and weldable

Ecoflex – attractive to microorganisms and a winner with consumers

Pure Ecoflex, in other words the product on its own, is particularly suitable for films, above all for the packaging sector and for agriculture mulch films.

Packaging benefits from Ecoflex as a protective film or as a component of laminated paper. Its properties guarantee a high wet strength and grease resistance, so it is ideal for packaging which becomes highly contaminated with food residues after use – wrapping paper, drinks cartons, fast-food packaging and drink cups. The combination of paper with the fully biodegradable Ecoflex can be completely composted.

Ecoflex film can be used in farming as a mulch film for cotton, corn, lettuce and cucumbers. The films are simply ploughed in with the remains of the plants after harvest and biodegrade afterwards.

Ecoflex – the alternative for the retail trade

Ecoflex can be processed in a number of ways: as tubular film, extrusion coating or cast film. Ecoflex also offers the possibility of manufacturing transparent film and complies with food safety requirements of 2002/72/EC and the FDA Under Food Contact Notifications 372 and 780.

Ecoflex is therefore ideal for packaging ecologically produced premium foods; frozen food and vegetables or fruit can be presented to the customer in fully biodegradable packaging. Ecoflex gives the retailer an additional argument for sale: he is seen to be environmentally conscious and sets himself apart from competition.
Ecoflex® – improves the properties of products made from renewable raw materials

In a biodegradable composite with Ecoflex®, the properties of packaging based on corn or potato starch and polylactic acid (PLA) are improved even further. Ecoflex-coated food packaging made from renewable raw materials such as corn starch, PLA or potato starch (known as starch blends) simply migrate on to the compost where they are completely biodegraded just like other materials (food, paper residues, etc.).

Clamshells, drink cups, packaging for meat, fish, fruit or vegetables, food trays and fast-food containers – Ecoflex improves starch foam packaging in terms of their serviceability. They benefit for example from an Ecoflex coating because they are then better protected against damage from breakage and liquids.

Thanks to the wet strength and tear resistance of Ecoflex, foam packaging can withstand grease, moisture and fluctuations in temperature. The result for the end consumer is that the food keeps fresh and retains its flavor.

Ecoflex® – improves the properties of starch foam packaging
Ecovio®, biodegradable and renewable!

Ecovio® is the blend of the petrochemical-based Ecoflex® and polylactic acid (PLA) produced from maize starch. Ecovio can be supplied to the client as a finished product, i.e. directly and without further blending and suitable for the extrusion of biodegradable films.

Properties of Ecovio®

- highly tear-resistant
- water-tight
- weldable
- printable
- high melt strength
- processable on conventional blown film plants for polyethylene

First a shopping bag – then a compost bag

Ecovio makes waste a clean issue

With Ecovio rubbish bags, food waste can be collected hygienically in the kitchen and composted together with the bag, preventing undesirable odor and pest infestation. There is no more laborious scrubbing of the waste bin in the kitchen; because liquid from tea-bags or fruit residues does not leak through Ecovio L, thus the bag remains stable.

Carrier bags from “alternative” to “luxurious”

Manufacturers can, without pre-treatment or further blending, make carrier bags from Ecovio that appeal both to very environmentally-conscious consumers and to fashion-conscious trendsetters, because Ecovio and its property profile provide a number of options for applications where previously high density PE was used.
Ecovio® L Foam for foam applications

The interest in plastic products made from renewable raw materials is growing and BASF is working on further development of its biodegradable and biobased plastic Ecovio® L BX 8145.

The new material will be called Ecovio L Foam and is designed so that an extrusion foam manufacturer can convert it to a foam without any changes to the process on its XPS machine (XPS = extruded rigid polystyrene foam). The foam is thermoformable into many different applications, such as plates, bowls, trays and clamshells.
Ecoflex® – ecologically tested and toxicologically safe

The ecological properties of Ecoflex® have been investigated in extensive tests, with the verdict that Ecoflex has no negative consequences for nature or the environment. Scientifically recognized ecotoxicological tests proven in practice for soils are for example the plant growth test with summer barley and the daphnia test. The series of tests on toxicological effects based on OECD directives again did not produce any negative consequences for human health (Tab. 1). Another advantage is that Ecoflex does not contain additives for decomposition. Unlike oxo-degradable plastics, Ecoflex does not contain regulated metal compounds and leaves no toxic residues behind.

The plant growth test

This test looks at the effect of the test substance on the growth of summer barley (Fig. 7). The following samples were prepared and used for testing:

- Mixture of reference soil and 25% compost with addition of Ecoflex after 12 weeks composting.
- Mixture of reference soil and 50% compost with addition of Ecoflex after 12 weeks composting.

Testing plant compatibility in the barley test is a key parameter for compost quality. The higher the plant compatibility, the higher the amount of a compost used and the better its recovery in a number of applications in gardening and farming. A compost is recognized as plant-compatible if in a mixture of 25% compost with 75% reference soil a 90% barley yield is achieved. A variant with 50% compost is also used.

In the variants, the test with Ecoflex showed no negative consequences on the barley yield.

Fig. 7: Result of the plant growth test: Compost with Ecoflex® shows no negative impact on the growth of barley.

<table>
<thead>
<tr>
<th>Test</th>
<th>Result</th>
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<tbody>
<tr>
<td>Acute toxicity to fish OECD 203</td>
<td>Not harmful</td>
</tr>
<tr>
<td>Acute toxicity to daphnia EEC 84/449 C.2</td>
<td>+</td>
</tr>
<tr>
<td>Acute toxicity to algae OECD 201</td>
<td>+</td>
</tr>
<tr>
<td>Earth worm toxicity EC50 OECD 207</td>
<td>+</td>
</tr>
<tr>
<td>Terrestrial plant toxicity OECD 208</td>
<td>+</td>
</tr>
<tr>
<td>Mutagenicity test (Ames test) OECD 471</td>
<td>The substance was not mutagenic</td>
</tr>
<tr>
<td>Acute oral toxicity to rats LD₅₀ OECD 423</td>
<td>+</td>
</tr>
<tr>
<td>Primary skin irritation rabbit OECD 404</td>
<td>+</td>
</tr>
<tr>
<td>Primary skin irritations of the mucus membrane rabbit OECD 405</td>
<td>+</td>
</tr>
<tr>
<td>Guinea pig OECD 406 (modified Buehler test)</td>
<td>+</td>
</tr>
</tbody>
</table>

Tab. 1: Ecotoxicity and toxicity tests on Ecoflex®
In the barley test, the quality of the compost to which Ecoflex® had been added was tested. Result: the barley developed very well as with reference soil.

Testing of water-soluble intermediates – daphnia test

In the toxicity tests, the toxicity of the water-soluble intermediates is particularly important because they can easily enter groundwater or be more readily absorbed by the organism.

Testing was carried out in accordance with DIN 38412 Part 30. In this test, the pollutant-dependant immobilization of the daphnia in solutions of different concentrations (series of dilutions) is used. The control solution contains microorganisms that biodegrade Ecoflex® enzymatically. The stock solution at the end of the test also contains the degradation intermediates of Ecoflex.

It is successively diluted and for each concentration ten daphnia 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 (stage 2), as in the control solution, there are still nine daphnia swimming. The test is therefore passed.

<table>
<thead>
<tr>
<th>Result</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC₅₀ (96 h) &gt; 100 mg/l</td>
<td>+</td>
</tr>
<tr>
<td>Not harmful to aquatic organisms</td>
<td></td>
</tr>
<tr>
<td>EC₅₀ (48 h) &gt; 100 mg/l</td>
<td>+</td>
</tr>
<tr>
<td>EC₅₀ (48 h) &gt; 100 mg/l</td>
<td>+</td>
</tr>
<tr>
<td>No effects at the highest concentration</td>
<td>+</td>
</tr>
<tr>
<td>No effects at the highest concentration</td>
<td>+</td>
</tr>
<tr>
<td>The substance was not mutagenic</td>
<td>+</td>
</tr>
<tr>
<td>&gt;4000 mg/kg virtually non-toxic after a single ingestion</td>
<td>+</td>
</tr>
<tr>
<td>Non-irritant</td>
<td>+</td>
</tr>
<tr>
<td>Non-irritant</td>
<td>+</td>
</tr>
<tr>
<td>Non-sensitizing</td>
<td>+</td>
</tr>
</tbody>
</table>

The common water flea (Daphnia pulex) is a popular model organism for the effect of environmental factors on certain individuals and their progeny due to their rapid reproduction and straightforward rearing conditions.
The property profile of Ecoflex® compared to low density polyethylene

Ecoflex® F BX 7011 (abbreviated by “Ecoflex”) is a soft plastic designed for film extrusion and extrusion coating where polyolefins, particularly polyethylene (PE), are mainly used. A conventional commercial LDPE – a product used to manufacture e.g. plastic bags, carrier bags, diaper and laminating films – was therefore used to compare products (Tab. 2).

In contrast to the majority of polyester grades, Ecoflex does not require pre-drying because the hydrolysis stability at conventional processing temperatures is adequate.

Ecoflex has a typical copolyester density of 1.25 g/cm³ which exceeds the density of LDPE by 35%. The MVR is 2.5 - 4.5 ml/10 min and therefore significantly higher than for LDPE (0.8 - 1.2 ml/10 min). Since Ecoflex is processed at much lower melt temperatures (140 - 170 °C) than for LDPE (190 - 220 °C), the difference in viscosities at the processing temperature is low. The Shore D hardness and Vicat temperature of Ecoflex F are significantly lower than LDPE. Both products have a crystalline melting point in the same range of 110 - 120 °C. Shrinkage measurements should be taken at temperatures above 100 °C.

In contrast to LDPE, Ecoflex at the same time achieves a high ultimate elongation and a high puncture resistance. With LDPE, it is normal to achieve a high puncture resistance or high elongations at break depending on the processing conditions.

The tensile and tear strengths of Ecoflex are significantly higher than the reference values for LDPE. The oxygen permeability of LDPE is approximately double that of Ecoflex, but conversely the water vapor permeability of Ecoflex is many times higher than the level for LDPE (Tab. 3). One reason for this is the greater polarity of Ecoflex compared to LDPE. Ecoflex is somewhat less transparent than typical LDPE grades. The addition of approximately 5% Ecoflex Batch NA1 (nucleation agent) produces about 50% improvement in the transparency of the film.

Product data sheets for Ecoflex® are available at www.plasticsportal.eu/ecoflex

Product data sheets for Ecovio® are available at www.ecovio.de
Like Ecoflex F BX 7011, Ecovio L BX 8145 has a density of 1.25 g/cm³ because the densities of PLA and Ecoflex are similar. The MVR at 190 °C, 2.16 kg, however, is significantly reduced to values of < 2.0 ml /10 min. compared to Ecoflex F BX 7011. Because of the high viscosity, the MVR at 190 °C in Ecovio L BX 8145 is measured at 5 kg load.

Because of the PLA content, Ecovio L BX 8145 has two crystalline melting ranges: 110 -120 °C for Ecoflex F BX 7011 and 140 - 155 °C for PLA. This means that Ecovio can usually be processed at approx. 165 -190 °C. With regard to better bubble stability, melt temperatures of around 170 °C should be targeted.

The mechanical resistance of Ecovio L BX 8145 significantly exceeds the comparative values for LDPE. The elongations at break in the extrusion direction are comparable to LDPE, while in transverse direction they are significantly lower. The puncture resistance of Ecovio L BX 8145, however, is much higher than LDPE.

Interestingly, the barrier properties of Ecovio L BX 8145 also increase compared to Ecoflex F BX 7011 by approx. 100 %. The water vapor barrier is well below that of LDPE. The oxygen permeability of Ecovio L BX 8145 is approx. 80 % lower than for LDPE.

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**Functionality**

Ecovio® L BX 8145 – the innovation in biodegradable film materials

Ecovio® is the product for film materials containing renewable raw materials. Ecovio L BX 8145 for example contains 45 % polylactic acid (PLA) produced from corn starch.

Ecovio L BX 8145 is a relatively rigid film material which, like high density PE, was designed for the extrusion of stiff films. The Shore D hardness of Ecovio L BX 8145 is 85 % higher than for Ecoflex® F BX 7011; the stiffness of Ecovio L BX 8145 is approx. 400 to 700 % higher than Ecoflex F BX 7011.

In Ecovio L BX 8145, PLA is made compatible with Ecoflex and is finely distributed in Ecoflex to achieve a structure suitable for film applications. Ecoflex in this compound gives good mechanical strength and good processability, while PLA significantly improves the stiffness, puncture resistance and gloss of the film material.

Ecovio L BX 8145 can typically be processed from the container without pre-drying because it has a low level of moisture at the time of manufacture and packaging. If during processing dwell times in a standard climate are prolonged, pre-drying can – if necessary – be carried out at 60 -70 °C over approx. 2-6 hours depending on the type of dryer.

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**Property** | **Unit** | **Test method** | **Ecoflex® F BX 7011** | **Ecovio® L BX 8145** | **LDPE***
---|---|---|---|---|---
Transparency | % | ASTM D 1003 | 82 | 58 | 89
Modulus of elasticity | N/mm² | ISO 527 | 95/80 | 750/520 | 240/200
Tensile strength | N/mm² | ISO 527 | 35/44 | 35/27 | 26/20
Tear strength | N/mm² | ISO 527 | 36/45 | 36/27 | –
Elongation at break | % | ISO 527 | 560/710 | 320/250 | 300/600

Failure energy (Dyna test) | J/mm | DIN 53373 | 24 | 38 | 5.5

Permeation rates:
Oxygen | ml/(m² d bar) | ASTM D 3985 | 140 | 600 | 2900
Water vapor | g/(m² d) | ASTM F 1249 | 170 | 92 | 1.7

*Lupolen 2420 F

Tab. 3: Typical film properties of Ecoflex®, Ecovio® and LDPE at a thickness of 50 µm
Tailor-made blends can also be produced from Ecovio®. Both more flexible and more rigid formulations are possible, depending on the mix ratio of Ecovio, Ecoflex® or PLA.

In addition, Ecovio can be combined predominantly with other biodegradable polymers such as PCL (polycaprolactone), PHA (polyhydroxyalkanoates) or PBS (polybutyl succinate).

Mixing gives – Ecovio® blends

On our lab line for blown film extrusion with an extruder (diameter D: 60 mm, screw length: 30 D) equipped with a grooved feed section and a 160 mm die (die gap: 1 mm), a 30 µm thick film was produced with different dryblends of Ecoflex F BX 7011 and Ecovio L BX 8145, from 0/100 to 100/0 percent ratio. The melt temperature was set to 185-190 °C to simulate normal production conditions.

Adding Ecoflex F BX 7011 to Ecovio L BX 8145 by some 10-20% dramatically reduces the stiffness of the product to the typical level of HDPE bags from the market at 30 µm thickness. By further addition of Ecoflex F BX 7011 from 30-50% to Ecovio L BX 8145, the typical stiffness of LDPE bags from the market in 30 µm thickness is obtained (Fig. 9).

The typical range of tensile strength of 25-30 MPa for LDPE is measured at all dryblend ratios. Tensile strength level of > 35 MPa for HDPE is obtained at less than 90% Ecovio L BX 8145 (Fig. 10).

The ultimate elongation is typically very high for both LDPE and HDPE. Ultimate elongations for LDPE are typically registered up to a level of 70% of Ecovio L BX 8145.

In contrast to the ultimate elongation, a high level of performance of the Ecovio + Ecoflex modular system is noted in the Dyna-Test (puncture resistance test), which has been shown in Fig. 11. The level of LDPE of some 10 to 20 J/mm is obtained for all blend ratios. But the high level of HDPE, e.g. 40 J/mm, is only measured at high orientation levels of the film – e.g. by the HDPE-process or by an LDPE-process with intensive cooling.
Fig. 9: Stiffness of blown films, 30 μm, from dryblends of Ecoflex® and Ecovio®

Fig. 10: Tensile strength of blown films, 30 μm, from dryblends of Ecoflex® and Ecovio®

Fig. 11: Puncture resistance of blown films, 30 μm, from dryblends of Ecoflex® and Ecovio®
Processing of Ecoflex® and Ecovio®

Extrusion of Blown Film

- Processing of Ecoflex® F BX 7011 and Ecoflex® L BX 8145 starts with the cleaning procedure of the line.

  - One method is to purge with a LDPE-grade MFI 4-5 g/10 min. for at least 4 hours at the minimum melt temperature for the LDPE grade being used.

  - As an alternative, cleaning batches with sufficiently high melt flow rates and suitable for thermoplastic polyesters should be chosen to clean the extruder of low melt flow rates – e.g. MFR 190 °C, 2.16 kg of < 2 g/10 min.

- The adequate melt temperature for Ecoflex/Ecovio (<190 °C) should be used introducing the formulation of Ecoflex/Ecovio on the line. Purging has to continue until all deposits forming stripes and gels are eliminated. Deposits from PE on the die can occur during purging. They will disappear after about 1 hour of continuous purging.

- The grooved feed section of the extruder should be kept as cold as possible. The temperature of the first extruder zone will be reduced to about 140 °C. All other zone temperatures along the extruder line including the die should be set to achieve a melt temperature in the range of 165 to 190 °C.

- Because of the typically high specific output rate of Ecoflex L BX 8145 on regular extruders with a grooved feed section, we suggest to reduce the screw speed by 35% from normal conditions for LDPE. As a precaution for a break down of the bubble we suggest a high film thickness during start-up. Because of the high elasticity of the bubble it is advisable to position the sizing basket at a low height above the die – depending on film thickness and output rate.

- Sharp blades – if possible hardened with Titanium Nitrite – should be used in the cutting processes. It is always more flexible to trim the edges. At amounts of Ecoflex F BX 7011 below 50% in the Ecoflex/Ecovio formulation trimless cutting equipment can be used.

- Ecovio L BX 8145 prefers to run on machines equipped with a long A-frame (collapsing boards) and long gusset folders with wooden bars or cloth for HDPE to avoid the formation of wrinkles. The film bubble needs to be fixed precisely using a sizing basket, collapsing boards and gusset folders. Stretch rolls and/or guiding rolls with spiral grooves have to be installed after the very precise haul off rolls in an adequate horizontal reversing system for Ecovio L BX 8145 to prevent wrinkles.

- Corona treatment for low amounts of Ecovio L BX 8145 in the formulation is recommended if a slip batch such as Ecoflex Batch SL 2 is being used.

- We need stretching rolls to avoid creasing of the web. The contact winder needs a very fine control of web tension.

- After the trial return to processing conditions as necessary for LDPE and HDPE. When temperatures have reached PE-level, the PE-type for the next production run can be employed to purge the machine of Ecoflex F BX 7011 and Ecovio L BX 8145.

Printing

In general, Ecoflex F BX 7011 and Ecovio L BX 8145 can be printed and welded on standard equipment for LDPE-films. Both alcohol or water based inks can be used after testing. Prior to printing the material should be corona treated for achievement of the proper surface energy. The drying temperatures should be kept below LDPE conditions depending on the content of Ecoflex L BX 8145. As drying conditions depend very much on the machine design they need to be determined during the trial.
The welding temperature should be lowered to an actual surface temperature of 90-100 °C. Welding pressure and welding time are also of high importance. As the crystallization process is slower than LDPE we have to allow for higher crystallization times. During crystallization the welding line can stick to the welding surface, if direct surface contact is employed. Therefore the welding machine has to allow for extra cooling of the weld lines.

Ecoflex® F BX 7011 has a better welding performance than Ecovio® L BX 8145. We recommend to use at least 30% of Ecoflex F BX 7011 for films thicker than 20 µm to improve the welding performance.
Storage and ageing of Ecoflex® and Ecovio®

Biodegradable plastics should perform their function during application use like traditional plastics and be biodegradable after use under specified environmental conditions like composting. Because of their specific molecular structure, certified biodegradable plastics such as Ecoflex® and Ecovio® can meet these demanding requirements, but there are often doubts about the functionality and ageing of biodegradable plastics in the use phase.

For this reason, the effect of storage and ageing of films made of Ecoflex F BX 7011 and Ecovio L BX 8145 in a standard climate (23 °C, 50% relative atmospheric humidity) was investigated more closely*.

Ecoflex® F BX 7011

Biodegradable films from Ecoflex F BX 7011 show a favorable ageing performance. Deterioration of mechanical properties (tensile strength, puncture resistance) is not observed before 18 months of storage time at standard room conditions (23 °C, 50% relative humidity). Stiffness and ultimate elongation stay at a similar level for 3 years.

After 3 years of storage, tensile strength and ultimate elongation still achieve or exceed the level of LDPE carrier bags. The puncture resistance achieves more than 70% of the values for LDPE carrier bags. Stiffness increases above the level of the Ecoflex-reference film.

* Extracts of the results are given here. The complete documentation is available on request.
If blown films from Ecovio® BX 8145 are stored at standard room conditions (23 °C, 50% relative humidity) mechanical film properties can change in the course of 2 years storage time:

- Stiffness increases by 50% in machine direction and 25% in cross direction.
- Tensile strength is reduced by less than 10% in machine direction and about 20% in cross direction.

The ultimate elongation is reduced by 25% in machine direction and after 21 months to more than 130% in cross direction.

But: The property level of LDPE carrier bags can be achieved or exceeded for stiffness, tensile strength and puncture resistance. The equivalent initial level of the ultimate elongation at break can be obtained using about 50% Ecoflex® F BX 7011 in formulations with Ecovio L BX 8145.
Form supplied and storage

Ecoflex® F BX 7011 is supplied as eggshell colored pellets in 1 ton supersacks (big bags). Bulk delivery is available on demand. Ecovio® L BX 8415 is supplied as white pellets in 1.2 tons octabins.

Temperatures during transportation and storage may not exceed 70 °C at any time. Storage time in an unopened bag should not surpass 12 months at room temperature (23 °C).

Quality control

Ecoflex and Ecovio are produced as a standard material in a continuous production process according to DIN EN ISO 9001:2000. The melt volume rate, MVR, at 190 °C, according to ISO 1133 has been defined as a specified parameter for quality control. A certificate of the MVR value can be provided with each lot number upon request. Other data given in our literature are typical values, which are not part of our product specification for Ecovio or Ecoflex.
Glossary

**Biobased**
Refers to the origin of the raw materials. Only significant if the plastic content for annually renewable raw materials is given.

**Renewable**
Refers to (annually) renewable raw materials such as maize, wheat, paper, wood, etc.

**Non-renewable**
Refers to raw materials not classed as renewable, such as oil, natural gas and coal.

**Fragmentable**
Certain materials containing special metal additives as decomposition aids decompose under the effect of sun, water, different temperatures, etc. Not completely biodegradable.

**“Oxo-degradable”**
Are plastics that break down into plastic fragments due to the addition of additives on exposure to strong light. Complete biodegradation does not take place.

**Biodegradable**
Microorganisms such as bacteria, fungi, mold or algae metabolize these materials completely, giving off CO₂, water, energy and biomass.

**Compostable**
Completely biodegradable material (certified to European standard EN 13432, Japanese standard GreenPla and American standard ASTM 6400) is processed to compost in industrial composting plants.

References

**Product data sheets**

Ecovio®: www.ecovio.de
- Ecovio L BX 8145 – Product Information

Ecoplex®: www.plasticsportal.eu/ecoflex
- Ecoplex Batch AB – Product Information
- Ecoplex Batch C Black – Product Information
- Ecoplex Batch C White – Product Information
- Ecoplex Batch SL – Product Information
- Ecoplex F BX 7011 – Product Information
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. (December 2009)