# Biobased Packaging Catalogue

Karin Molenveld, Martien van den Oever, Harriëtte Bos

Wageningen UR
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**Foreword**

As part of the government's 'sustainable procurement' policy, the Ministry of Economic Affairs (EZ) commissioned Wageningen UR Food & Biobased Research to make a comprehensive overview of biobased materials that are suitable for and/or are already used in packaging applications. This catalogue was written for buyers, users and producers of packaging materials as well as for policy officers at the government and public organisations.

The purpose of the catalogue is to showcase biobased packaging products and provide an overview of commercially available biobased packaging in 2014. This catalogue is a translation of the Dutch version of the biobased packaging catalogue that was launched September 2014. The raw materials, products and services related to biobased packaging products are categorised wherever possible according to their application and described in brief. Some types of packaging consist partly of biobased materials and partly of non-biobased materials due to specific functional requirements. In such cases, the percentage of biobased content is stated. Wherever possible, references to producers and suppliers are given.

Various producers of biobased materials and packaging products assisted with the compilation of this catalogue. The result is a source document for renewable and sustainable packaging that can help buyers and policymakers to make responsible choices. Whilst we have aimed to be as comprehensive as possible, developments are advancing at such a rapid pace that some of the latest packaging innovations may not be mentioned here. Information on the composition and properties of packaging products was primarily obtained from reputable companies and websites. We assume that this information is correct, but cannot take any responsibility for the accuracy of information provided by these companies and websites.

**Reader's Guide**

The catalogue is subdivided into 3 sections.

Section 1 explains the background of biobased packaging and the reason for compiling this catalogue (Chapter 1). The sustainability aspects of biobased packaging are dealt with in Chapter 2. Chapters 3 and 4 introduce the various biobased materials with their specific characteristics and key properties.

Section 2 provides an overview of the currently available biobased packaging and future developments. The packaging products are subdivided into different categories based on the packaged products (Chapters 5 to 10).

Section 3 contains an explanation of the abbreviations and terms used in this document (Chapter 11) as well as an overview of suppliers of biobased materials and packaging (Chapter 12). Web addresses of relevant institutions and parties are mentioned in Chapter 13. This is followed by the reference list (Chapter 14) and an explanation of the pictograms in Chapter 15.

**A word of thanks**

Our thanks go to Ger Standhardt, Henk Vooijs, Caroli Buitenhuis and Christiaan Bolck for their contributions to the realisation of this publication, to Jenny van Driel for making the pictograms/illustrations, to the Netherlands Enterprise Agency (RVO.nl) for providing financial support for the research into the market for packaging and biobased alternatives (52802/NO), and to the Department of Green Growth and Biobased Economy of the Ministry of Economic Affairs for its financial support for this project (BO-20-12).

## Contents

# 1 Introduction

## 1.1 Sustainable packaging

Sustainable packaging is a topic that attracts a great deal of interest, both from government as well as industry and consumers. However, the term ‘sustainable packaging’ can refer to many different aspects, such as: the reduction of packaging materials, the use of recycled packaging and materials, or the use of materials with a lower ecological footprint. Two important new types of sustainable materials are biobased materials and compostable materials. The use of biobased materials reduces the depletion of finite fossil resources and $CO_2$ emissions. Compostable materials offer environmental benefits in the end-of-life phase. This catalogue focusses on biobased packaging, sometimes in combination with compostability.

## 1.2 Purpose of packaging

Packaging can be defined as materials used to (temporarily) contain, handle protect or transport articles. They are generally discarded as waste after usage. We can distinguish three main categories of packaging:

- Primary or sales packaging: the packaging in shops that is aimed at the consumer. A Primary packaging directly envelops the product and holds it, and cannot be removed without altering the product. Examples of primary packaging are tubes for toothpaste, boxes for rice, bottles for shampoo or soft drinks, bags for potatoes, and wrappings for bread or fresh chopped or whole vegetables.
- Secondary or grouped packaging: packaging which contains a number of packaged products and is used for distribution and in-store displays. A secondary packaging can be removed without damaging the product. Examples are multi-packs of soft drinks and boxes of candy bars.
- Tertiary or transport packaging: packaging for larger quantities of products that is specifically intended for transportation, such as pallets, cardboard boxes, plastic wrappings and containers that facilitate transport and handling.

The purpose of the packaging determines its shape and the applied material. Very often, a packaging is required to combine different functions, such as:

- protection of products
- prevention of product loss
- containment or agglomeration of products
- sharing product information
- marketing

Examples of the protective function are protection against dust, bacteria, dirt, humidity, oxygen, carbon dioxide and UV light. Another very different type of protection concerns protection against damage due to mechanical shock during transportation. The type of protection required for the specific product largely determines the choice of material and type of packaging.

A very important purpose of packaging is to prevent product losses. Depending on the packaged product (fluid, solid, coarse, fine), the packaging must be properly closed or sealed to protect the product and prevent losses.

Many products are not sold separately, but per weight with multiple units grouped together. Examples are potatoes, sweets or pasta bags. In this case, keeping the

*Figure 1. Board is the most commonly used material for secondary or transport packaging.*

multiple units together is one function of the packaging. Where heavier products are involved (such as potatoes), strength is a key criterion for selecting the material.

Product information is increasingly communicated on packaging. Examples are user instructions, expiry/best-before dates and ingredient declarations. This information is placed either on a label or directly on the packaging. Printability of materials is therefore an essential property for many packaging materials.

Other key functions of the packaging are to carry marketing messages and optimaly display the product. Alongside printability, shape and (sometimes) transparency, the look and feel of the packaging is also important.

Selection of the correct packaging offers the following advantages:

- extended product life
- minimisation of product losses during transport and distribution
- more attractive to buy for the consumer

Selection of the correct packaging helps to minimise the product's total environmental footprint. By helping to prevent product losses, the packaging can play a major role in making products more sustainable.

## 1.3 Current materials consumption

Acting on behalf of business and industry, Stichting Nedvang (Netherlands Packaging Waste Collection and Recycling Agency) collects specific data on the consumption, reuse and recycling of packaging materials (Nedvang, 2013a). In terms of volume, the total Netherlands packaging consumption is approx. 2750 ktonnes, 56% is already biobased in the form of wood, paper and board (Figure 2). In 2012 only 1 ktonne (i.e. 0.036%) of the packaging consumption consisted of bioplastics (biobased or biodegradable/compostable).

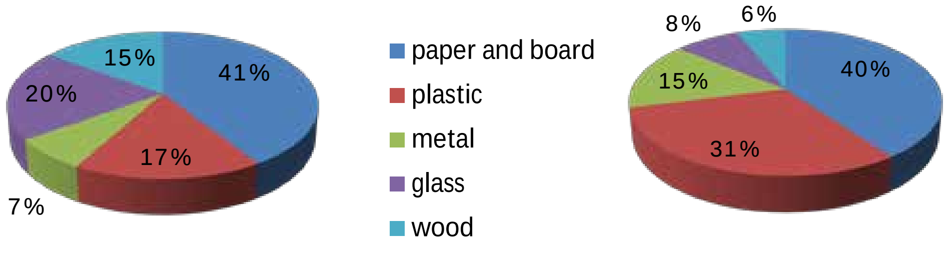



*Figure 2. Materials consumption in packaging based on weight in the Netherlands (left, Nedvang, 2013a) and on packed products in Europe (right, EuPC, 2009)*

The EuPC (trade association of plastics converters within Europe) publishes data on the consumption of materials (EuPC, 2009). According to the EuPC data, about one third of all goods are packaged in plastics, indicating that the use of plastics for packaging is still slightly smaller than the use of paper & board. As plastics and plastic packaging are much lighter than glass, metal and paper & board, there is a big difference between the share of plastic in the overall weight of packaging materials and the share of products packed in plastics of the total amount of packaged products, namely 17% versus 31% (see Figure 2).

The various categories of available packaging materials are briefly described below. A detailed description of the biobased materials follows in Chapter 3.

**Paper & board** are traditionally used in many packaging products and disposables. Examples are paper plates and cups, fruit trays and moulded fibre packaging, such as egg cartons. Solid board (is widely used for packaging deep-frozen foods, sometimes in combination with a plastic coating or plastic inner liner. Corrugated board is frequently applied in boxes used for grouped or transport packaging. Unless coated with plastic (like liquid packaging board), paper & board are very suitable for recycling.

**Wood** is mainly used as transport packaging in the form of e.g. pallets and crates. The key advantages of wood are good protection against damage, good strength and impact resistance, good rigidity and good stackability. Wooden crates are increasingly being replaced by cheaper plastic containers. For products such as wine and spirits, wooden barrels offer an additional function of assisting the maturation process by imparting flavours that enhance the quality of the product. Wooden packaging is also used to give products a more luxury or expensive image.

**Glass** is a traditional and popular packaging material because it is suitable for sterilisation and pasteurisation, has good rigidity, and does not react with food. It also offers good protection against external influences (humidity, gas, smells and micro-organisms) because it is impermeable. Furthermore, glass is suitable for reuse, (re-)sealing or reclosing and recycling. It is transparent but can also be coloured to protect products against light. Due to its excellent barrier properties ($CO_2$, oxygen, water), in some applications (such as beer bottles) glass is difficult to replace. Major drawbacks of glass are that it is heavy and therefore expensive to transport. It also breaks easily and splinters of glass can pose a food hazard.

The most frequently used **metals** are aluminium and steel, mainly for cans. The main advantages of cans are the complete protection of the contents against external influences, the sabotage-resistance and suitability for presentation (printing and shape). The main disadvantages are their weight (except compared with glass) and the resulting higher transportation costs and the high energy consumption during production, particularly for aluminium. Aluminium is also used as a thin layer on films and in laminates (in combination with plastic) when high barrier properties are required.

**Plastic** packaging is of more recent origin and also shows the highest growth in terms of applications. Examples of plastic packaging are flexible films (the biggest group with 55%), plastic trays and plastic bottles (EuPC, 2009). Packaging foams also belong to the plastics category. The main advantages of plastic packaging are the low price, low weight and versatility in terms of shape and appearance. Plastics also offer good product protection via barrier properties, heat sealing and insensitivity to humidity. Moreover, plastic packaging is practically unbreakable. Plastic bottles, like glass bottles, are very suitable for reuse (UU, 1999). A study commissioned by Plastics Europe published interesting conclusions regarding the environmental effects of plastic packaging (Denkstatt, 2012):

- The environmental impact of plastic packaging is often only 1% of the total environmental footprint of the packaged product whereas in case of glass packaging this is more than 30%.
- Plastic packaging saves 220 million tonnes of $CO_2$ emissions per year, mainly thanks to plastic bottles (97 million tonnes of $CO_2$ versus glass bottles) and plastic films (67 million tonnes of $CO_2$ versus alternatives such as cans and board).

On the downside, plastics are the most difficult packaging materials to recycle, partly because it is difficult and expensive to separate the broad variety of different plastic types, but also because plastics are often used in combination with other materials for instance in laminates. The most commonly used plastics in packaging applications are PolyEthylene (LDPE and HDPE), PolyPropylene (PP), PolyEthylene Terephthalate (PET), PolyStyrene (PS) and PolyVinyl Chloride (PVC). *Table 1* gives an overview of the most commonly used plastics according to data of the Association of Plastics Manufacturers Europe (APME).

*Table 1. Most commonly used plastics and their applications in packaging in Western Europe (APME, 2001).*

| Type of plastic | Share [%] | Application | Processing method |
|---|---|---|---|
| LDPE/LLDPE | 34 | Films, wraps, bags | Film blowing and extrusion |
| HDPE | 22 | Bottles, containers | Blow moulding |
| PP | 19 | Films, pots, crates | Film blowing, injection moulding |
| PET | 11 | Bottles | Blow moulding |
| PS + EPS | 8+2 | Trays | Thermoforming/foaming |
| PVC | 5 | Films | Film blowing |

Particularly noteworthy in this table is the high share of PE (LDPE + HDPE). Although it was not possible to find more recent data than these of 2001, the above picture can still be considered to be representative of the materials consumption in 2014, the main difference compared to 2001 being an increased use of PET.

## 1.4 Packaging Regulations and Guidelines

### *1.4.1 Introduction*

Packaging materials are required to meet various rules and guidelines, such as the European Parliament And Council Directive on Packaging and Packaging Waste (EU Packaging, 1994) and the Framework Regulation EC 1935/2004 that gives general requirements for all food-contact materials (Commodities Act, 2014)). These regulations focus on aspects such as the prevention of waste and the prevention of health damage. Standards are available to ascertain that packaging products and materials meet the set requirements and regulations. The sections below give an overview over the outlines of these regulations and guidelines, focusing mainly on biobased packaging materials and how these fit within the current regulations and guidelines. The most important labels for packaging and biopackaging as well as the (Dutch and European) government policy are also dealt with.

### *1.4.2 Framework Regulation EC 1935/2004- general requirements for all food contact materials*

Plastics that come into contact with food must comply with strict rules. Substances (such as additives) that are added to plastics can migrate from the packaging material and can be transfered into the foods. This may cause health damage or alter the composition, smell and/or flavour of the food. In Europe, the Framework Regulation 1935/2004 sets out general requirements for all materials that come into contact with food. These are elaborated in further detail for plastics (guidelines and regulations) in Plastics Regulation 10/2011/EC. Additional guidelines are in place for specific substances and groups of substances.

*Figure 3. Many plastics are suitable for contact with food.*

In practice these regulations demand that the supplier must demonstrate that no hazardous substances can migrate from the packaging into the packed food. Also, the migration of non-hazardous substances may not exceed a certain limit. The supplier must demonstrate that the packaging complies with the requirements via a Declaration of Compliance. More information about the mandatory guidelines for packaging and how these guidelines must be implemented can be found at e.g. the website of the Europian Commission (EU Food contact, 2012).

In the European market, a Declaration of Compliance is obligatory for packaging that comes into contact with food. US FDA approval is not sufficient in Europe. The underlying systems of the European and US guidelines differ: the FDA is based on 'no objection', while in Europe the safety of a product must be actively demonstrated via e.g. migration tests.

*Biobased*

Various biobased materials such as polylactic acid (PLA), bio-PE, cellophane and some polyhydroxyalkanoates (PHA) have been approved for food packaging and are also frequently used in such applications. As with conventional plastics, recyclates are not permitted. Paper & board can also be made suitable for food packaging, in which case the raw materials must also exist of virgin paper pulp. Due to the addition of plasticisers such as glycerol and sorbitol, many starch blends fail to meet the migration requirements, but there are some exceptions: some starch-based materials such as various Mater-bi grades (Novamont), Solanyl grades (Rodenburg) and Bioplast grades (Biotec) do pass the food contact test.

### *1.4.3 Packaging guidelines and standards*

The European Directive for Packaging and Packaging Waste 94/62/EC was conceived to harmonise the packaging and packaging waste rules for all EU member states (EU Packaging, 1994). This directive is elaborated in the umbrella standard EN13427. Within this umbrella standard, reference is made to the various standards for the production, composition, reuse and recovery of packaging and packaging waste (Figure 4). The ISO standards for packaging and the environment were also published in early 2013. These are largely based on the EN standards.

> European standard (EN)
> A European EN standard is valid for all European member states. National Standardisation institutes are obliged to adopt the European standards (implementation duty). Each country has its own code to refer to these standards, e.g. NEN-EN for the Dutch market or DIN-EN for the German market.
>
> International standard (ISO or IEC)
> International standards are developed in the international context at ISO or IEC. No implementation duty applies to these global standards. The standards that the Netherlands chooses to accept carry the code NEN-ISO or NEN-IEC (NEN, 2014).

The standards specify that prevention and reduction of packaging waste is the preferred option (EN13428 and ISO18602). If this is not possible, reuse is a good alternative (EN13429 and ISO18603). Packaging that is not suitable for reuse can be recycled (EN13430 and ISO18604), composted (EN13432 and ISO18606) or incinerated with energy recovery (EN13431 and ISO18605). Landfilling must be avoided as much as possible.

Unfortunately, instead of achieving the envisaged harmonisation of waste systems, the EU Directive has given rise to very different waste systems within the various EU countries.

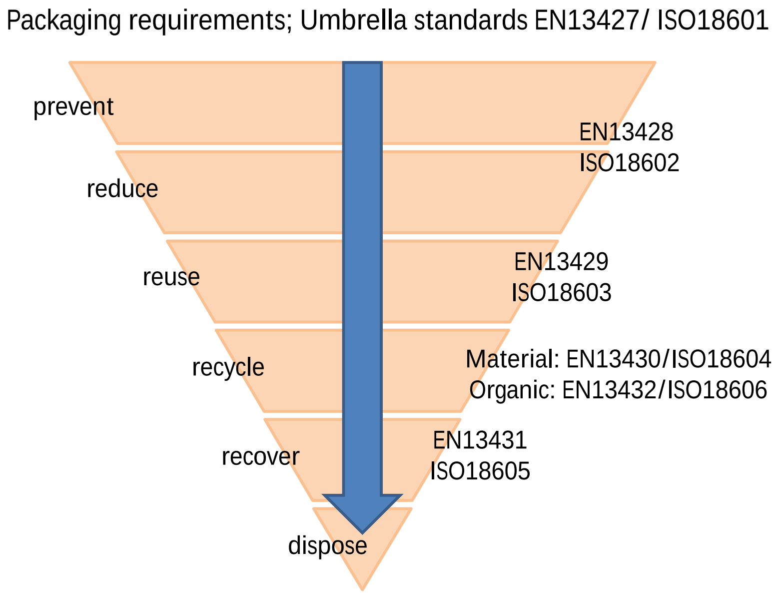



*Figure 4. Schematic representation of the applied packaging and packaging waste standards.*

### *1.4.4 Prevention and reduction*

The biggest environmental gain can be achieved by preventing or reducing the consumption of packaging materials. However, it is important to bear in mind that environmental gains are only realised if the omission or reduction of packaging materials does not result in more product losses. One key incentive for seeking to prevent and reduce the use of packaging materials is that this almost always leads to cost savings. As plastic is thinner and lighter, the use of plastics instead of glass, metal cans and paper & board usually also reduces the volume of packaging materials. Thanks to improvements in the quality of plastics and production technologies, packaging (including PET bottles and plastic carrier bags) is becoming steadily thinner while retaining the same functionality. In the past 30 years, for instance, the weight of PET bottles has decreased by 35% (PET-fles, 2006). Regarding plastic carrier bags, the EU has introduced a directive obliging the member states to take steps to limit the use of thin carrier bags (PPW Directive, 2013).

### *1.4.5 Reuse and recycling*

The reuse and recycling of packaging materials has already been a focus of attention in the Netherlands for many years. Nedvang monitors the packaging recycling results for all producers and importers of packaged products in the Netherlands. *Table 2* provides a summary of the recent reuse percentages for each category of packaging material (Nedvang, 2013a). Reuse means that the packaging *product* is used again, such as is the case with bottles with a deposit. Recycling means that the packaging *material* is recovered and used again for a specific application. Recovery in this context notably refers to use as bioenergy (Nedvang, 2013b). Small differences in the recycling percentage can occur over the years due to monitoring constraints (Nedvang, 2013a).

*Table 2. Weights and percentages of recycled or recovered packaging in the Netherlands in 2012 (Nedvang, 2013a).*

| **Material** | **2012** | | | **2011** | **2010** |
|---|---|---|---|---|---|
| | On the market (ktonnes) | Recycling (ktonnes) | Recycling (%) | Recycling (%) | Recycling (%) |
| Glass | 536 | 382 | 71 | 83 | 91 |
| Metal | 193 | 175 | 91 | 91 | 88 |
| Paper & board | 1129 | 1004 | 89 | 89 | 90 |
| Wood | 423 | 124 | 29 | 30 | 32 |
| Wood, recovery | | 147 | 35 | 44 | 50 |
| Plastic | 459 | 219 | 48 | 51 | 48 |
| Plastic, recovery | | 24 | 5 | 5 | |

*Glass*

The recycling percentages for glass, metal and paper & board are traditionally high. Glass bottles (with deposit) can be refilled several times. Refilled bottles are not included in the above table. The largest share of single-use glass is imported and mainly concerns bottled waters in the hospitality sector (Nedvang, 2014). Glass packaging waste can be reprocessed into new glass products without loss of quality (recycling as presented in table 2). Glass collection takes place through separation at the source: consumers (and businesses) take glass to special glass collection points. Glass that finds its way into the environment is not toxic in so far as known. The apparently strong decrease in the reuse of glass between 2010 and 2012 was partly caused by an adjustment of the measurement method in 2011.

*Metals*

Metal packaging (both tinplate and aluminium) are mainly used for food. Though reuse as packaging is virtually impossible, metal can basically be endlessly recycled without loss of quality. Some municipalities collect metal packaging (cans) via separation at the source, but separation can also take place in the post-collection stage using magnets and eddy-current separators (Blik, 2014; Nedvang, 2014). Metals can also be reclaimed by upgrading bottom ash from furnaces or incinerators.

*Paper & board*

Collection of paper & board takes place through separation at the source. Paper & board can be recycled about seven times before the fibres become so small that they disappear from the paper cycle into the process water. To obtain the required quality, mixtures of recycled and virgin raw materials are used.

*Wood*

Wooden packaging consist mainly of pallets. These can be used several times and even repaired. It is mainly businesses that reuse and discard wood. Households take wooden packaging to their municipality's domestic waste collection point where it is separated from other waste. Other forms of waste wood recovery include incineration in biomass energy plants. This latter application showed strong growth in 2009, a trend that was sustained in 2010 and 2011 (Nedvang, 2012). Subsidies to promote bioenergy generation impede the reuse of materials (Nedvang, 2012). The falling trend in the percentage of reuse and recovery of wooden packaging may be due to the accumulation of stocks, the repeated use of pallets without companies recognising this as reuse, or the domestic burning of wood (Nedvang, 2013b).

*Plastics*

Plastic crates and PET bottles have for many years been systematically collected and reused or recycled via the deposit system. The abolition of the deposit system for PET bottles (larger than 0.5 litre) is under consideration in the Netherlands, but the decision has been postponed until April 2015. Plastic pots and trays made of PP and PS are collected and recycled in the agricultural sector. In addition, plastic waste streams from the plastics processing industry and the distribution sector are collected and recycled. The overall percentage of plastics reuse and recycling was traditionally low because virtually no consumer packaging was recycled. In the past few years,

campaigns to encourage the separation at source of plastic consumer packaging (Plastic Heroes) has raised the recycling percentage of plastic packaging to approx. 50% (Nedvang, 2013a; Plastic Heroes, 2014).
About 90% of the collection of domestic plastic packaging waste takes place through separation at source while about 10% concerns post-collection separation (Nedvang, 2013a). Businesses predominantly separate plastic packaging at source. The quality of this industrial packaging waste (and distribution waste) is much higher than the waste separated post-collection or at source.

Collected plastic can be separated into pure plastic streams with the aid of a near-infrared (NIR) scanner. An NIR scanner can identify all plastics and greatly improves the recycling of plastics and the quality (purity) of plastic recyclates. One exception is black and dark-coloured plastic that escapes detection by the scanner and ends up with the residual waste. Another limitation of NIR is that composite plastic products cannot be effectively separated. At present, the most frequently occurring types of plastic are separated via NIR, namely: PE, PP and PET. For the year 2012 Nedvang reported a sorting rate of 76% for materials reuse from collected source-separated domestic plastic packaging waste (Nedvang, 2013a). The rest of the plastic can be incinerated to reclaim (recover) energy. Other plastics can also be separated, provided that the supplied quantities are large enough to make this commercially viable. Polystyrene (PS) can be effectively separated with the aid of NIR and can be recycled, but this does not happen so that polystyrene ends up in the residual waste. The advice on what should be done with polystyrene is unclear. On the one hand, Plastic Heroes says that EPS packaging (e.g. styrofoam) are not allowed to be placed in refuse sacks (Plastic Heroes, 2014). On the other hand, Stybenex, the umbrella organisation of EPS producers in the Netherlands, advises that hard PS can be placed in refuse sacks (Stybenex, 2013). Equally confusing are the reports about applications of compostable plastics, which allegedly have a negative effect on the recycling of plastic. However, these plastics too can be separated via NIR from the other plastics. At present, NIR technology is mainly used for ‘hard’ packaging from the ‘Plastic Heroes’ streams (HDPE, PP, PET). Films are separated in advance (blown off) and recycled as a single film fraction. Thanks to a new NIR technology developed in France, it is now also possible to separate the films into pure streams.
At the end of 2012, the packaging industry, central government and the municipalities entered into a new ‘Packaging Framework Agreement’. This agreement contains commitments for the collection, reuse and recycling of packaging until the end of 2022. One of the commitments is that 52% of all plastics will be reused in 2020, as opposed to just over 42% in 2012. For comparison: Europe required member states to

collect a total of 22.5% of their plastic waste in 2012, so the Netherlands is doing a considerably better job than most of its European partners. Other important arrangements from the agreement with regard to recycling and reuse are:

- Increase of the recycling of domestic plastic waste to 90 ktonnes (82 ktonnes in 2012)
- Place waste collection containers at all supermarkets
- Use at least 25% recyclates in new PET soft drinks bottles
- Set up, implement and complete a pilot for the collection of beverage cartons

*Beverage cartons*

Beverage cartons are increasingly used for fruit-based lemonades and non-carbonated waters (FWS, 2014). Their composition is approx. 75% board, 21% LDPE (for


*Figure 5. Beverage cartons are frequently applied for dairy drinks and fruit juices.*

waterproofing) and 4% aluminium (protection against light and oxygen). Most European countries have organised separate waste collection and recycling at national level. Germany and Belgium already collect, respectively, 71% and 81% of the marketed beverage cartons (Hedra, 2013). A pilot is currently being carried out in 36 Dutch municipalities to establish how beverage cartons can best be collected in the Netherlands (KIDV, 2013). After separation, the board fibres can be reused for diverse paper applications. The LDPE and aluminium can be used for the production of e.g. consumer products (FWS, 2014).

### *1.4.6 Composting*

Within the EU Directive, composting is regarded as a specific recycling method: organic recycling. Biodegradable materials are materials that can be broken down by microorganisms (bacteria or fungi) into water and naturally occurring gases such as carbon dioxide ($CO_2$) and methane ($CH_4$). Compostable packaging materials are materials that comply with EN13432. This standard defines how quickly and to what extent a biodegradable plastic must degrade under industrial composting conditions. According to the EN13432 standard, plastic packaging can only be called compostable if it is demonstrated that:

- The packaging material and its relevant organic components are naturally biodegradable;
- Disintegration of the packaging material takes place in a composting process for organic waste;
- The packaging material has no negative effect on the composting process;
- The quality of the compost is not negatively influenced by the packaging material.

EN13432-certified packaging is allowed to carry the seedling logo. Every certified packaging also has its own P number. Alongside the seedling logo, there are also other

*Figure 6. Logos showing that products are compostable according to EN13432: Vinçotte (left), Seedling logo (right).*

certification programmes, such as the Vinçotte 'OK compost' programme. The seedling logo is the most commonly used logo in the Netherlands, Germany and the UK, while the OK compost logo is more widespread in Belgium, France and Italy. It is of course crucial that the underlying tests to qualify as compostable are based on equivalent requirements.

Composting is well-regulated, but unfortunately the same does not apply to all biodegradation routes. The term 'biodegradable' is not protected in the Netherlands and is also used for non-biological degradation routes (UV, oxo-degradables, disintegration). As composting is well regulated for packaging, this catalogue only refers to compostable products that are EN13432-compliant and avoids the term 'biodegradable'.

There are still no European standards for 'home compostable' and 'soil degradable' packaging. Within the EU, the European Commission for Standardization (CEN) is working on European standards for these end-of-life routes. Research for this purpose is being carried out in the EU Open-Bio KP7 Project. Ahead of European regulations, the originally Belgian certification company Vinçotte issues certificates in Europe for 'home compostable' and 'soil degradable' products and materials. In the certification procedure, compliance with the composting standard is tested under adjusted conditions (e.g. lower temperature).

### *1.4.7 Positioning of biobased materials within the Packaging Directive*

Biobased materials are dealt with in the EU Directive under the manufacturing and composition heading and, more specifically, under EN13428 (prevention, reduction). The manufacture of biobased materials requires less energy (in the form of fossil feedstock) and usually results in lower $CO_2$ emissions.

One commonly used term is 'biobased content', which is the percentage of a product's weight that is based on renewable raw materials. In the 'BioPreferred Program', the US applies ASTM D6866 which is based on the amount of recently stored carbon in a product: this is tested using the C14 carbon dating method. Within the EU, CEN is

*Figure 7. Logos of Vinçotte, Din Certco and the USDA to indicate that a material has biobased content.*

currently developing a European standard. This includes assessing whether the ASTM standard can be followed or whether improvements are necessary, for instance by also taking on board other components such as oxygen, nitrogen and minerals. This research is being carried out in two EU KP7 projects – KBBPPS and Open-Bio – with the participation of the Dutch research institutes ECN and Wageningen UR Food & Biobased Research. Ahead of European regulations, Vinçotte is issuing certificates in Europe for the biobased content of materials: 1 star denotes a biobased content of more than 20%, 2 stars more than 40%, 3 stars more than 60% and 4 stars more than 80%. The German certification company DIN CERTO mentions the biobased content in the logo. Both companies base their tests on ASTM D6866.

#### *1.4.8 Policy*

In conformity with the European Packaging Directive, the Dutch policy is aimed at the reduction and reuse of packaging. In the 1991–2005 period, the packaging policy was regulated via three successive covenants (agreements between government and businesses). On January 1st 2006 the government replaced the packaging covenants with a single Act: the Packaging Decree. The covenants and the Packaging Decree set out commitments and targets aimed at, among other things, the reduction of the amount of packaging waste, reuse, recycling and prevention of litter. The packaging tax was introduced on January 1st 2008 as part of the Tax Plan 2008. Besides bringing together the various levies that businesses already paid, this tax has also led to an increase in the total payable amount. The packaging tax consisted of different rates, depending on the type of packaging material. Biobased materials such as wood and paper were taxed at a lower rate than aluminium and petrochemical plastics. Bioplastics (both biobased and biodegradable) thus received more favourable tax treatment than traditional petrochemical plastics. The packaging tax was abolished on January 1st 2013 and replaced with a framework agreement between the government and importers and sellers of packaged products. Under this agreement, the importers and sellers have undertaken to pay the costs for the collection and reuse of plastic packaging materials in the coming ten years. The companies have also promised to reuse more packaging materials in the coming years, and to make the entire packaging chain more sustainable. In this connection, the Sustainable Packaging Knowledge Institute (KIDV, 2014) has been set up to promote structural efforts to improve the sustainability of the entire packaging chain.

Alongside the sustainability objectives, no specific arrangements have been made regarding the use of biobased materials and plastics. The government policy on sustainable procurement also appears to have had no effect so far on the application of biobased materials. This catalogue is intended to give easy access to knowledge about the potential of biobased materials.

#### *1.4.9 Labels*

The purpose of a label is to provide clear at-a-glance information about a packaging. Labels concerning compostability and biobased content have already been introduced (sections 1.4.6 and 1.4.7). Other labels on packaging relate to:

- Collection: Plastic Heroes, deposit bottles, recycling (Figure 8);
- Material type (type of plastic);
- Compliance with certification standards (such as FSC, Figure 9);
- Contents: gluten free, lactose free, organic, fair trade.

Unfortunately, there are now so many labels that these may merely confuse rather than inform consumers.

*Figure 8. Various end-of-life labels, from left to right: Plastic Hero, bottle bank, litter and paper bank.*

*Figure 9. Various certification marks, from left to right: FSC logo, 'milieukeurmerk', cradle to cradle, CE marking.*

## 1.5 Why biobased packaging?

Packaging has a short life and therefore give rise to large quantities of waste. Accordingly, it is vital to use the most suitable raw materials and implement good 'end-of-life' solutions. Biobased and compostable materials have a key role to play in this respect.
In section 1.3 we already noted that 56% (based on material weight) of the packaging is of biobased origin in the form of wood, paper and board. These materials are increasingly being replaced by plastics, so that plastics now account for a large share of the packaging, particularly in terms of the number of packaged products (Figure 2).

Plastics are still chiefly made of petrochemical raw materials. However, oil and gas are scarce resources that are expected to become steadily more expensive in the future. Industry must therefore lose no time in exploring innovative applications of biobased plastics and developing new technologies to facilitate a smooth transition to a biobased economy. With packaging accounting for no less than 40% of the market applications for plastics, it is imperative for the plastics industry to study the potential of biobased plastic packaging. Apart from slowing down the depletion of fossil resources, this will also benefit the environment by reducing the volume of $CO_2$ emissions.

The temporary use of plastic packaging is often associated with waste issues such as litter, landfill and plastic soup. In the 1980s, biodegradable and compostable materials were hailed as the magic cure-all for our waste problems. This euphoria has made way for a more balanced view. Compostable materials are now seen as one of the solutions to the waste problem, particularly for packaging products that are difficult to recycle (film laminates) and/or strongly contaminated (with green waste or sand). Many (but by no means all!) biobased materials are compostable. It is therefore important to make a clear distinction between 'biodegradable'/'compostable' and 'biobased'. Compostability is a property relating to the end-of-life phase. Biobased refers to the origin of the raw materials. This distinction is explained in more detail in section 1.6.

Alongside compostability, biobased plastics also offer other functionalities that are extremely interesting and environmentally beneficial. Examples are:

- The breathing capability of various biobased plastic packaging materials, which extends the life of perishable products like lettuce and keeps bread fresh for longer;
- The inherent antistatic properties of various biobased plastics, which reduces the need for additives;
- The absence of toxic substances in some biobased plastics, which is an advantage in certain cases.

Due to the risk of migration of phthalate plasticisers, flexible PVC packaging has virtually disappeared. Various other plastics are also associated with the presence of potentially toxic substances. Examples are:

- The bisphenol-A debate in relation to PolyCarbonate (PC) bottles for baby food
- The antimony catalyst remnants in PET (this also applies to bio-PET)
- Small quantities of styrene monomer in PS

The health risks of exposure to these substances due to migration from packaging materials have not been conclusively proven, but the discussion alone is sufficient to influence consumers, and therefore also producers, in their choice of materials.

One reason why large producers such as Heinz, Danone, Procter & Gamble and Coca-Cola are extremely interested in biobased plastics (and other biobased packaging materials such as paper & board) is the positive image that these materials help to


*Figure 10. Coca-Cola uses the 'PlantBottle$^{TM}$' to advertise its green credentials.*

communicate to the consumer. One example is Coca-Cola's innovative PlantBottle, a PET bottle made partly from biobased PET.

### 1.6 'Biobased' versus 'biodegradable'

*Biobased* plastics are not all biodegradable and compostable, whereas some *petrochemical* plastics are biodegradable and compostable, so biobased ≠ biodegradable. The term 'bioplastic' can therefore be confusing and it is better to use the terms 'biobased' and 'biodegradable' (or, in the case of packaging, 'compostable') plastics. This makes it clear what the prefix 'bio' actually refers to. The trend in the use of biopolymers in packaging is very strongly focused on biobased plastics (such as bio-PE and bio-PET). Compostability is regarded as an additional property that offers end-of-life advantages in some applications, such as fruit and vegetable packaging.

A growing number of products is appearing on the market based on conventional petrochemical plastics (such as polyethylene) which have been made degradable by

| | Fossil based | Partly biobased | Biobased |
|---|---|---|---|
| Not biodegradable | PE, PP, PET, PS, PVC | Bio-PET | Bio-PE |
| Biodegradable | PBAT, PBS(A) | Starch blends | PLA, PHA, cellophane |

*Figure 11. Scheme indicating positioning of biobased versus petrochemical plastics and biodegradable versus non-biodegradable plastics.*

**What is biobased?**
Biobased materials are made of raw materials that are of direct or indirect natural origin. Examples are paper and wood, but also plastics such as PLA which is produced from sugars. Biobased materials can be subdivided into 3 categories:

1. Materials originating directly from biomass, such as wood, paper pulp, cellulose, starch and proteins;
2. Materials that can be made from building blocks originating (e.g. via fermentation) from biomass, such as polylactic acid;
3. Materials that are produced by microorganisms, such as PHA.

**What is biodegradable?**
Biodegradable materials are materials that can be broken down by microorganisms (bacteria or fungi) into water and carbon dioxide ($CO_2$). Biodegradability depends strongly on the ambient conditions: temperature, presence of microorganisms, presence of oxygen and water. Compostability is important for packaging. Compostable materials are materials that meet the international EN13432 standard for compostable plastics. EN13432-compliant packaging is allowed to carry the seedling logo and can be placed in the green waste container.

**What is petrochemical or fossil?**
Petrochemical or fossil plastics are made of fossil oil. About 6% of all fossil oil is used for the production of plastics.

means of additives. These materials are called oxo-degradables and are sold as biodegradable, but do not meet the standards for biodegradable products (such as EN13432 for industrial composting). The materials fragment under the influence of UV and/or heat, but there is no evidence that the fragments break down entirely into $CO_2$ and water as required in EN13432. Examples are films for wrapping magazines and miniature soap and shampoo bottles in hotels. The use of oxo-degradables is controversial and the Netherlands is currently working on regulations similar to those already introduced in Belgium where oxo-degradables are banned.

More information on biobased plastics can be found in the publication 'Biobased Plastics 2012' of Wageningen UR Food & Biobased Research (Bolck *et al.*, 2011).

# 2 Sustainability aspects of biobased packaging

## 2.1 Introduction

Biobased packaging can be regarded as a sustainable alternative for petrochemical plastics because it reduces the use of scarce fossil resources and also lowers $CO_2$ emissions. However, many other aspects that determine whether a material or packaging is sustainable must also be taken into account in the overall assessment. Apart from *biobased* packaging, other options for making packaging more sustainable include the reduction of materials consumption (thinner films and bottles), reuse of packaging, recycling of packaging and even the avoidance of packaging altogether (see section 1.4).

## 2.2 Reduction

The reduction of the consumption of packaging materials has been high on the environmental agenda since the 1970s (see also section 1.4.3). This has resulted in a trend towards thinner packaging products (Haffmans, 2013) which, in practice, translates into a growing use of plastics. Plastic bottles can be much thinner than glass bottles, while retaining sufficient rigidity. Owing to their lower thickness and lower density, plastic bottles are much lighter than glass ones, which leads to fuel savings during transportation. Another trend that can spur the use of plastic packaging is that food is being packaged in smaller portions to reduce spoilage and waste. This also promotes sustainability as smaller portions lead to less food being thrown away. Moreover, the environmental impact of the packaging materials relative to the contents is very small.

The reduction of materials and energy consumption achieved by using biobased packaging varies strongly, depending on the functionality of the selected biobased material. For instance, the replacement of plastic with paper or board makes the packaging heavier. Various biobased plastics such as starch blends and PLA also have a greater specific weight than e.g. PE and PP, which means more packaging kilograms for a film of equal thickness. To calculate the actual savings per type of packaging, it is necessary to carry out a Life Cycle Analysis (LCA).

## 2.3 Functionality

When deciding whether a switch to biobased packaging is beneficial, it is important to consider the functionality of the packaging. Choosing a non-functional biobased packaging can entirely cancel out any sustainability benefits derived from the use of biobased materials – for instance, because it is necessary to use a combination of materials or a composite instead of easy-to-recycle mono-materials. On the other hand, various biobased plastics also offer functional advantages. The good breathing properties of PLA packaging, for instance, help lettuce to stay fresh longer. Another functional benefit concerns the use of compostable (and biobased) packaging in applications where recycling is too difficult or costly, e.g. because the packaging is too contaminated with organic residues. Compostable bags or bin liners offer a functional advantage for the collection of green waste. Various studies show that the use of these or bin liners leads to improved separation of green waste and that green waste containers need to be cleaned less often. The result of better separation is that the processing of green waste is energetically more efficient via composting than via incineration.

## 2.4 Litter, plastic soup and behaviour

Some companies and organisations see biodegradable/compostable plastic packaging as a solution for preventing plastic litter. However, biodegradability depends strongly on the ambient conditions of the environment where the plastic packaging ends up. The temperature and presence of humidity, oxygen, bacteria and fungi determine the speed of the process. For instance, the rate of degradability in the soil is much slower than in an industrial composting installation, so plastic litter can remain in the soil for more than a year – and plastic litter lying on the surface takes even longer to break down (Rudnik, 2010). Unfortunately, 'biodegradable' is not a protected term and is regularly abused to make misleading and false claims. Biodegradable materials do not break down fast enough to solve the litter problem. In fact, some argue that biodegradable/compostable materials could pose an increased risk in encouraging consumers to discard litter on the roadside or in the woods in the mistaken assumption that it will soon break down anyway. The priority must therefore be to prevent plastic waste ending up in the environment in the first place by setting up an effective and uniform waste system supported by clear and correct communication on the packaging, explaining to consumers that packaging must either be handed in at Plastic Heroes (see under 'Plastics' in section 1.4.5) or discarded in the green waste container (packaging carrying a seedling logo). In both cases, the packaging will be put to good use in the end-of-life stage via recycling, energy recovery or composting. Another option for reducing litter is to minimise the use of easily detachable parts (such as aluminium can closures) and to impose a ban on plastic packaging where litter is likely to occur (e.g. beaches, festivals, events and schools). Encouragingly, many festivals and events are greening up their act by using compostable cups.

Biodegradable materials may be the best solution in agriculture, where products such as land cover materials, clips and pots often vanish in the soil and are impossible to recover. In such cases, it is obviously good if they break down naturally. However, standards for soil degradable products are still under development.

*Figure 12. Corn is a raw material for many industrial applications, including bioplastics such as PLA.*

## 2.5 Regional

The transition from a fossil oil-based economy to a circular biobased economy will involve the replacement of petrochemical plastics by biobased plastics. Though some regions are more suitable for growing biobased raw materials than others, and will therefore receive a stronger economic impulse from this industry, a wide variety of biobased raw materials can be cultivated in many regions around the world. PLA, for instance, can be produced from diverse crops grown on different continents:

- Corn in North America
- Sugar beet and corn in Europe
- Sugarcane in South America
- Sugarcane and cassava in Asia and Africa

The advantage of this is that more economies can source raw materials regionally. However, it is also important to make sure that the production process is sustainable.

## 2.6 Food versus packaging

The available biomass in the world amounts to about 13 billion tonnes, of which only 15% is used for direct food consumption (Raschka & Carus, 2012). Feed accounts for the largest share of biomass: 58%. The bulk of non-food biomass consumption (about 27% of the total) is wood destined for energy, paper, furniture and construction. Only a small portion of the available biomass is used for the production of chemicals and plastics. However, due to the growing use of biomass for the manufacture of biofuels, biobased plastics and chemicals, the need for efficient production (high yield per hectare) and optimal utilisation of biomass is becoming increasingly pressing. Optimal utilisation entails that all components of the biomass are used. The woody parts of a plant that are not suitable for food consumption, for instance, can be used for non-food applications such as second-generation biofuels and plastics and paper. The knowledge necessary to make optimal use of plants (biocascading) and the technologies for isolating the different plant components (biorefining) must be developed further in the coming years. Thanks to rising feedstock prices, products such as second-generation biofuels and plastics will become steadily more competitive with fossil fuels and first-generation biofuels and bioplastics. In addition, biobased materials retain their energy content, so that they can be used as bioenergy after their useful life.

## 2.7 GMO biomass

Genetic modification can be employed to alter the composition and size of plants, improve their yield or enhance their resistance to e.g. pesticides. However, genetic modification has run into fierce resistance from environmental groups who are concerned about the possible health risks arising from the consumption of genetically modified vegetable material and the unintentional spreading of genetically modified organisms (GMO) to conventional crops. It is not yet clear to what extent disturbances may be caused to the natural balance of ecosystems in the near or distant future.

Genetically modified microorganisms such as bacteria, yeasts and fungi can produce monomers or polymers (via fermentation in closed systems). GMOs are not necessary for the production of many biobased plastics, but are needed for the manufacture of some chemicals and second-generation polymers. PHAs can be produced both with and without GMOs. NatureWorks produces PLA based both on GMO corn and non-GMO corn.

## 2.8 Green washing

'Green washing' is a form of propaganda where a product or material is misrepresented as being 'greener' or more sustainable than it actually is. Typical examples of this are: presentation of over-optimistic LCA data, the disclosure of only some product or material properties (and the deliberate omission of others), and the use of logos and texts using letter fonts and colours that evoke associations with nature. Greenwashing takes place at all levels, from global A-brand owners to humble sellers of water in PET bottles. Apart from misleading the customer, greenwashing can


*Figure 13. Frequently occurring claims on packaging.*

cast sustainability in a less positive, and even negative, light. One example of greenwashing concerns oxo-degradables. These materials are sold as being biodegradable, but there is no evidence to back up the claims that these materials cause no bioaccumulation and really break down completely into water and naturally occurring gases. To fight greenwashing, European Bioplastics has drawn up the following guidelines for communications about bioplastics.

- Make sure that environmental claims are specific, accurate, relevant and truthful.
- Avoid vague, general claims that fail to meet these criteria, such as ‘green’, ‘sustainable’, ‘environmentally friendly’ and ‘climate friendly’.
- Justify claims with methodologies and data in accordance with the applicable international standards and verified by independent parties.
- Make the data available to all parties involved.

# 3 Biobased materials

## 3.1 Introduction

This chapter introduces the most commonly used biobased materials and their possible packaging applications. These include both relatively old materials such as paper, board and wood as well as the much newer biobased plastics.

## 3.2 Paper and board

Paper and board-based packaging is very popular, particularly among consumers. This is one reason why paper and board are among the most widely used packaging materials in the world, including in Europe and the Netherlands. Paper and board are biobased (in Europe from sustainably managed woods, with PEFC or FSC mark), recyclable, biodegradable *and* suitable for thermal recycling (incineration). In the Netherlands and wider Europe, paper and board are made from mixtures of recycled paper and virgin (new) fibres. Almost all paper and board packaging can be collected as waste paper and about 72% of all paper and board in Europe is recycled (European Recovered Paper Council, 2014).

Not all paper packaging is suitable for paper recycling. Packaging material that contains food or other organic residues, for instance, cannot be recycled but can be composted. All sorts of processes during the manufacture of the paper or the packaging can render paper unsuitable for recycling. Examples are the addition of barrier layers made of plastic and aluminium. However, options for also reusing these types of material are currently being explored, such as in the pilots for the recycling of beverage cartons (section 1.4.5).

Paper has a strongly sustainable image. This perception is justified regarding the recycling aspect. In general, more raw materials, water and energy are consumed during the manufacture of paper than, for example, the production of plastic. However, the fact that paper can be recycled means that less virgin materials are required. Paper packaging that is not suitable for recycling (paper/plastic combinations) is less sustainable. Paper and board packaging also has the disadvantage of being heavier than plastic packaging, so that more fuel is necessary for transportation (Papier en Karton, 2014).

A material resembling paper or board can also be made from residual side streams from the agri-food and horticulture sectors. Examples are cups and trays based on fibre side streams e from sugarcane plantations. The Roots products of Moonen are a case in point. The products have the look and feel of paper/board and are also recyclable as waste paper. Another example concerns tomato trays made from tomato plant residues. Large quantities of residual leaves and stalks are produced during the cultivation of tomatoes. Until now, these were routinely thrown onto the compost heap. However, researchers from Wageningen UR have now discovered that this tomato fibre pulp can be put to more profitable use for the production of packaging (Groen Kennisnet, 2013). Growers produce more than enough leaves and stalks to package their own tomatoes. Trays are currently also being made of grass. The use of various alternative raw fibre materials for paper and board applications is currently under development.

*Figure 14. A tomato tray made from a residual stream from the tomato plant.*

## 3.3 Wood

Apart from its application in paper and board, wood is mainly used for transportation in the form of pallets and crates. In 2012 a total of 423 ktonnes of wooden packaging was brought onto the market in the Netherlands (Nedvang, 2013a). The big advantage of wooden pallets is that they are sturdy, easy to repair and have a long life. The percentage of sustainably produced PEFC or FSC-certified wood is high. Wood is increasingly being replaced by cheaper plastic containers, meaning that a biobased material is making way for non-biobased materials.

## 3.4 Biobased plastic materials

At present, about 99% of all plastic packaging is of petrochemical origin. The small share of bioplastic packaging is of an extremely diverse nature. *Table 3* shows which biobased plastics (or blends) can serve as alternatives for the various petrochemical plastics. The overview is not complete, but provides a useful indication.

*Table 3. Overview of packaging applications made of fossil plastics and biobased alternatives.*

| **Petrochemical plastic** | **Application** | **Biobased alternatives** |
|---|---|---|
| PE (polyethylene) | Films and bottles | Bio-PE<br>Starch blends<br>Starch hybrids<br>PLA blends<br>PHA and PHA blends |
| PP (polypropylene) | Films, bottles and thermoformed products | Bio-PBS<br>PHA (blends)<br>PLA blends<br>Bio-PP (under development) |
| PS (polystyrene) | Hard plastic packaging (thermoformed) and foam | PLA (foam, films and hard packaging)<br>Cellulose (pulp trays)<br>Starch blends |
| PET (polyethylene terephthalate) | Particularly bottles (and trays and blisters) | Bio-PET<br>PLA<br>PEF (under development) |

### *3.4.1 Conventional plastics from renewables*

Renewables can be used to make biobased plastics that are identical to petrochemical plastics. Well-known examples are bio-PE and bio-PET. These biobased plastics are also referred to as ‘drop-in’ plastics. The advantage of both bio-PE and bio-PET is that these materials can be processed via the conventional recycling routes. The strong surge in the use of biobased packaging is largely attributable to bio-PE and bio-PET. One very recent innovation is the application of biobased nylon in packaging.

#### 3.4.1.1 Bio-PET

Bio-PET is a ‘drop-in’ bioplastic that currently has a maximum biobased content of about 30% and is mainly used in ‘PlantBottle™’ bottles for soft drinks (Coca-Cola) and tomato ketchup (Heinz). Bio-PET is about 30% biobased because only one of the bio-

PET building blocks, ethylene glycol, is of renewable origin. The biobased raw material for ethylene glycol is sugar (from sugarcane) that is converted via bioethanol into biobased ethylene glycol. The biggest bio-PET supplier is Indorama, while the leading bio-PET production countries are Indonesia and the US. The production volume of bio-PET ran to about 450 ktonnes in 2012 and is growing rapidly (European Bioplastics, 2014). Researchers are currently working on 100% biobased PET (see also Chapter 10.1), but this is not expected to be commercially available before 2020 (Plastics Engineering, 2012). The environmental gains of bio-PET have not yet been conclusively demonstrated via a publicly available peer-reviewed LCA. A non-peer-reviewed study by Imperial College indicates a reduction in $CO_2$ emissions of 25% and a 10% reduction in the use of fossil resources (Robertson, 2012). One positive aspect of bio-PET is that it has no effect whatsoever on the PET recycling process.

#### 3.4.1.2 Bio-PE

Bio-PE is another 'drop-in' bioplastic, but with a biobased content of 100%. Bio-PE is currently used for such applications as packaging film, dairy packaging (Actimel bottles) and cosmetics and soap packaging (Ecover, Pantène). The Braskem company operates a bio-PE production facility in Brazil with an output capacity of 200 ktonnes per year. Based on bioethanol, bio-PE is produced via a few chemical conversions.

*Figure 15. Sugarcane is widely used for the production of biobased building blocks for plastics in countries such as Brazil and Thailand.*

Braskem makes use of the existing infrastructure for the production of bioethanol from sugarcane. LCA data from Braskem show that $CO_2$ is now captured instead of emitted on a net basis (Braskem, 2014).

### *3.4.2 New biobased plastics*

The 1970s and 1980s witnessed the emergence of a number of new compostable materials based on renewables. Examples are PLA, starch blends and PHAs. Driving this trend was the fact that natural materials could be more easily made biodegradable. Moreover, many of these materials are (bio)polyesters which are by nature easily degradable.

In this same period, various multinationals also developed 100% petrochemical plastics that are biodegradable. Now that attention has turned to renewable plastics, only some of these new petrochemical plastics currently remain in commercial production.

#### 3.4.2.1 PLA

PLA is a 100% biobased plastic that also complies with the EN13432 standard for compostable products. Transparent and approved for food contact applications, PLA is extremely suitable for packaging. PLA is applied in transparent thermoformed trays and films, notably for fresh organic produce such as bell peppers and strawberries. Its good breathing properties make PLA ideal for packaging chopped lettuce (film) and bread (windows in bread bags). As PLA is relatively permeable to water, its use in bottles is limited. PLA fibres are applied in non-wovens for e.g. teabags. PLA is also regularly combined with paper, in the form of e.g. coatings for compostable paper cups and plates. One novel development is a plastic coffee cup for coffee vending machines based on heat-stable PLA. Biofoam™ is a new PLA-based foam and can replace EPS (polystyrene foam) packaging (see also section 3.4.4.2). The biggest PLA manufacturer is the US company NatureWorks LCC (Ingeo™), which has a production capacity in the US of 140 ktonnes per year (NatureWorks, 2014) while a comparable facility is currently being set up in Thailand. NatureWorks has a sales office in the Netherlands and is also represented by Resinex. Smaller-scale PLA producers are Corbion (focus on high-grade applications), Futerro (joint venture of Total and Galactic) and various Chinese companies. Detailed studies on the environmental gains of PLA have appeared in peer-reviewed journals. These data show that, compared to conventional plastics such as PET and PS, the production of PLA (NatureWorks manufacturing facility in Nebraska, US) reduces $CO_2$ emissions by 60% and fossil feedstock consumption by 50% (NatureWorks LCA, 2014). However, definite statements about the environmental gains can only be made after LCAs have been performed at product level (i.e. on a complete packaging). Moreover, other environmental impact categories also need to be investigated.

*Figure 16. PLA is transparent, strong and approved for food contact applications.*

3.4.2.2 PHA

PHAs are 100% biobased and display excellent biodegradability in various environments including cold soil and seawater. Production is still limited in volume terms and scattered widely across diverse manufacturing facilities. However, various types of PHAs are available, offering a broad spectrum of different properties. For instance, PHBV with a high percentage of valerate (one building block of PHBV) is flexible and suitable for film applications. PHB and PHBV with a low valerate content are rigid and more suitable for injection moulding applications. PHAs are currently mainly applied in films for carrier bags and in applications where biodegradability is crucial (e.g. mulch films). PHAs are relatively expensive and the processing of pure PHAs is still subject to technical limitations. For these reasons, this material is often combined with e.g. Ecoflex and PLA. One disadvantage of PHAs in packaging applications is that they are not transparent. Producers of PHAs include Metabolix (Mirel$^{TM}$), Tianan (ENMAT$^{TM}$), TGBM (Sogreen$^{TM}$), Kaneka (Aonilex$^{TM}$), Ecomann (Ecomann®) and Biomer (Biomer®). The US company Meredian is building a PHA manufacturing facility with an initial output capacity of 30 ktonnes per year, with plans for further expansion to 90 and finally 285 ktonnes per year (Nova, 2013).

No reliable data are available on the environmental impact of PHA production, mainly because PHAs are not yet produced on a large commercial scale.

3.4.2.3 Starch and starch blends

Starch-based materials are complex blends of starch with e.g. compostable polyesters such as PLA, Ecoflex, PBS and PHAs. Starch blends are widely used in ‘loose fill’ materials (foams), films, and (foam) trays. One well-known everyday application is compostable bin liners. Not all starch blends can be used for food contact applications. Starch plastics are usually blends and often contain additives such as compatibilisers and plasticisers. These components can migrate out of the starch blend, which is only permitted to a very limited extent in food contact applications. Producers of starch blends include Novamont (Mater-bi®), Plantic, Biotec (Bioplast) and Rodenburg (Solanyl®). In a review article, Dr Martin Patel has indicated that in general 25% to 75% less energy is required for the production of starch plastic granules than for PE and that the greenhouse gas emissions are 20% to 80% lower (Patel, 2002).

3.4.2.4 Starch derivatives

The Plantic company has chosen an alternative approach for making starch plastics. They modify starch with a high amylose content (from corn) via their own patented process. This modified (hydroxypropyl) starch plastic can be processed into containers, dishes and trays via standard thermoform processes.

Gaïalene® of the Roquette company is one example of a starch hybrid. This material is based on starch and PE that are bonded via a chemical reaction. Accordingly, Gaïalene is not compostable. The biobased content (via the starch) of Gaïalene is about 50%. Gaïalene is suitable for injection moulding products (pots, lids and caps) and for films (plastic bags, refuse sacks). According to Roquette, Gaïalene has a 65% lower carbon footprint than the least environmentally harmful petrochemical plastics.

### *3.4.3 Other examples of biobased plastics*

This category includes cellulose (in the form of cellophane). Cellulose has long been used as a packaging material, but has recently attracted renewed attention because of its biobased character. In addition, the ongoing development of biobased building blocks is giving rise to a steadily widening range of wholly or partly biobased plastics. Examples are PBS (e.g. Mitsubishi) and PEF (e.g. Avantium).


*Figure 17. Cellophane is widely used as a transparent packaging film.*

### 3.4.3.1 Cellulose

Besides being a chief component of paper, cellulose is also used to make products such as cellophane (film), viscose (fibres) and cellulose derivatives such as cellulose acetate. Cellophane is widely used as a packaging material for e.g. confectionery and floral bouquets. Cellophane is transparent and, unlike many other films, has a 'dead fold'. This means that once folded, it does not fold back. Cellophane can not be processed thermoplastically (i.e. via melting) and a separate sealing layer is required to make the material sealable. Cellophane offers extremely good biodegradability in diverse environments. Thanks to a wide selection of additional sealing and barrier layers, many different types of cellulose-based films are available on the market for a broad spectrum of applications. Cellophane is frequently combined with starch-based sealing layers (such as Mater-bi®), but also with a sealing layer of amorphous PLA in order to manufacture extremely transparent sealable films. This type of film remains highly compostable when a thin layer of aluminium oxide is used as a barrier material. Cellophane is produced by Innovia.

Another cellulose-based material is cellulose acetate. Because of the excellent properties at high temperatures, cellulose acetate is extremely suitable for disposables such as cups for hot drinks and cutlery. Cellulose acetate (Biograde®) for disposables is supplied by various manufacturers, such as FKuR.

No public LCA data are available for cellophane and cellulose acetate. Producers (Innovia) indicate that the production of cellophane has become much less environmentally harmful in the past years, but LCA experts (e.g. Dr Martin Patel) expect the environmental impact of these materials to remain higher than that of many conventional plastics.

### 3.4.3.2 PBS(A)

PolyButylene Succinate (PBS) is a polyester of petrochemical origin. Since the development of biobased succinic acid, PBS is now also available as a 50% biobased material. When biobased 1,4-butanediol (1,4 BDO) is also used, PBS can even be made 100% biobased. PBS(A) is applied in carrier bags in combination with other biopolymers such as starch blends. PBS can be used to improve the heat resistance of PLA. Another interesting feature of PBS is its strong similarity to PP in terms of processing and properties. The most important producers of PBS are Mitsubishi Chemicals (GSPla®) and Showa Denko (Bionolle™). The former manufacturer markets PBS based on biobased succinic acid. Many initiatives are also being taken to advance the production of biobased succinic acid, also in Europe (DSM, Reverdia, Corbion, BASF). No public LCA data are available for biobased PBS(A).

3.4.3.3 PEF

One interesting alternative for 100% bio-PET (based on bio terephthalic acid) is PEF based on 2,5-furandicarboxylic acid (FDCA). FDCA can be produced from sugars via routes that are currently cheaper than the production of bio-terephthalic acid. As FDCA has a different molecular structure from terephthalic acid, PEF has different properties from PET. For instance, PEF has better barrier properties (for $CO_2$, water and oxygen) than PET. This is interesting for applications in bottles. PEF is not yet commercially produced.

3.4.3.4 Arnitel Eco

Arnitel® Eco is a high-grade copolyester based on rape seed oil that is marketed by DSM. Arnitel is applied in various sectors. One new development is Arnitel-eco with a biobased content of 50%. This product is also suitable for packaging applications such as the ‘freezer-to-oven bag’ (see section 5.4).

3.4.3.5 PA

Polyamides, or nylons, are applied in packaging as a barrier material. Specific types of nylon are used for the production of barrier bottles. Various producers have meanwhile brought (partially) biobased nylons onto the market, often on the basis of castor oil, and with a varying biobased content. They are primarily looking to the automotive industry for commercial success. Examples are PA-4,10 and PA-6,10, as well as PA-11 which is completely biobased. PA-4,10 (EcoPaXX®) of DSM is applied as a barrier film.

### *3.4.4 Foam products*

3.4.4.1 Starch/cellulose fibre blend (Paperfoam)

Paperfoam is foam packaging material based on starch and natural fibres (Paperfoam, 2014a). Paperfoam packaging is used for such diverse products as electronics and eggs. Weighing about 180 g per litre, Paperfoam is much lighter than board or plastic. The main component is starch (about 70%), which is supplemented with about 15% natural fibres and a premix amng others for the foaming process and to give the material the required properties. The material is Vinçotte-certified as biobased (4 stars). One exceptional characteristic is its suitability for recycling both with paper and with organic residues (Vinçotte-certified as compostable). According to the producer, it is one of the least environmentally harmful packaging materials. Research of the

Copernicus Institute shows that the $CO_2$ emissions from Paperfoam are 85% lower than of comparable plastic packaging (Paperfoam, 2014b).

3.4.4.2 Foamed PLA (Biofoam)

Biofoam® is ‘styrofoam’ based on PLA instead of PS (Biofoam, 2014). Biofoam® is suitable for the same applications as EPS and is both biobased and compostable (due to the use of PLA). Its carbon footprint is 60% to 70% lower on average than that of conventional plastic foams.

Besides Biofoam, there are also foamed PLA trays on the market. These are made using a different technology (extrusion foaming) and are available in the Netherlands via Depron. Another major European player in the foam PLA market is Coopbox (Italy).

*Figure 18. Biofoam® looks like traditional ‘styrofoam’, but is made of PLA.*

3.4.4.3 Starch foams

Starch foams are among the first commercial starch-based packaging applications. Starch foams easily with the aid of water. The material’s main disadvantage is its water sensitivity. Foamed starch is used as loose fill during transportation to protect products against falls and other impacts.

Biobased plastics are discussed in more detail in two other publications in the ‘Groene Grondstoffen’ series: the ‘Bioplastics 2012’ booklet contains information on the material properties of biobased plastics (Bolck et al., 2011), while the ‘Groene bouwstenen voor biobased plastics’ booklet focuses on the manufacture of everyday plastics from biomass (Harmsen and Hackmann, 2012).

### 3.5 Composite materials

Many packaging products (both biobased and petrochemical) contain composites, such as film laminates and coated board. Composites are applied when a mono-material lacks certain vital properties for an application, such as barrier properties (for e.g. oxygen, water or carbon dioxide), heat resistance or sealability (important for closing a packaging). Examples of partially or wholly biobased composites are:

- Tetrapaks: board coated with PE to make the material waterproof and aluminium for improved barrier properties
- Cardboard drinking cups with a PE or PLA coating to waterproof the cups
- Barrier bottles (e.g. for tomato ketchup): Multi-layer bottles made of PET with an intermediate nylon and/or PET layer with oxygen scavengers (additives that absorb oxygen)
- Film laminates: Various cellophane materials provided with sealing layers (such as Mater-bi or amorphous PLA) and barrier layers such as aluminium oxide or PVdC.

The use of different materials for closures and the addition of labels or windows is another reason why many packaging products are made up of diverse materials. Composite materials are difficult to recycle but can be composted – but only if all packaging components are carefully selected to ensure that the entire packaging complies with the EN13432 standard for compostable packaging. The rule is that all components representing more than 1% of the total product mass must be biodegradable. This can have implications for the use of inks and glues.

### 3.6 Inks and glues

Many inks are applied in order to add information and advertising on packaging. Glues are particularly important for closing packaging. Biobased materials often consist of polyesters, which are generally suitable for printing and gluing. Inks rarely contain biobased components, but there is a range of biobased glues. Starch and proteins are very suitable for use in glues. Examples are labelling glues and various hotmelts. As noted in the section on composite materials, the correct choice of glues and inks is particularly important when the EN13432 standard for compostable packaging must be complied with. When inks and glues constitute less than 1% of the total product weight, they need not be tested for biodegradability. However, inks often contain heavy metals and the EN standard specifies a clear limit for the percentage of heavy metals that a compostable packaging may contain. Various manufacturers can supply EN13432-compliant inks and glues. Where glues are used in film laminates, the 1% limit is often exceeded. Meanwhile, there are several manufacturers offering glues that

are suitable for application in EN13432-compliant laminates (Epotal of BASF, BioTAK of SAP, Adhesive S9500 of Avery Denison, ST6093G of Sci-Tech).
Regarding biobased glues, Yparex (Enschede) offers an extrudable adhesive agent for multi-layer films based on PE with 95% biobased content (Yparex, 2012). This adhesive agent can be used for film blowing and film casting of PE-based multi-layered systems containing PA or EVOH.

# 4 Key properties of (biobased) packaging

## 4.1 Food contact

Food packaging is an important application of biobased plastics. Various biobased materials such as PLA, bio-PE, cellophane and some PHAs have been approved for food packaging. Meeting the migration requirements is more difficult for starch blends as these often contain plasticisers such as glycerol and sorbitol. Nevertheless, some starch-based materials such as various Mater-bi® grades (Novamont) and Bioplast grades (Biotec) meet the requirements for food contact applications.
PLA is a much-used component in blends. Ecovio® is a blend of PLA with Ecoflex®, which is an example of a material that is suitable for food packaging. However, various alternative materials for blends such as PBS have not been approved for food contact applications.

## 4.2 Barrier properties

PE and PP are the most commonly used plastic packaging materials. One important characteristic of these plastics is their excellent water vapour barrier, meaning that PE or PP packaging can prevent products going dry or stale. Except for bio-PE, biobased plastics do not have a good water vapour barrier and when PE or PP is replaced with PLA, for instance, it is important to check whether the PLA's water vapour barrier is sufficient. PLA is applied on a small scale in water bottles (mainly the small sizes). As water slowly escapes through PLA, the volume of water in the bottles diminishes gradually during storage. This can be a problem, particularly for products with a long shelf life and a long time gap between production and sale.

*Figure 19. Barrier properties are crucial for many food packages.*

One interesting new material with good barrier properties is PolyEthyleneFuranoate (PEF). PEF is seen as a 100% biobased alternative for PET and has better barrier properties than PET for water, oxygen and $CO_2$ (see also sections 3.4.3.3 and 10.2).

As well as a water vapour barrier, some packaging also requires a good gas barrier (oxygen and/or $CO_2$). Alongside glass and aluminium, only a few plastics have a good gas barrier. Examples are EVOH, PVdC, PGA (polyglycolic acid) and MXD6 (nylon). Multilayer structures (laminates) are used to make barrier films or bottles. The gas barrier of EVOH is only good if used in combination with a material that has a good water vapour barrier such as PE. When the moisture content of EVOH becomes too high, the material's oxygen barrier deteriorates enormously. As a result, EVOH cannot be used in combination with most biobased plastics. MXD6, too, is only known from use in combination with traditional plastics, partly because of the high temperature at which MXD6 needs to be processed.
PVdC is used to improve the barrier properties of cellophane. When applied in an extremely thin coating, PVdC still meets the EN13432 standard (less than 1% non-degradable components).
PGA was tested in combination with PLA (barrier bottles) but is too expensive to permit widespread commercial availability. The advantage of using PGA as a barrier material is that it can be easily broken down (hydrolysed) prior to recycling, thus allowing the PLA bottle to be recycled as a mono-material. No commercial products containing PGA as a barrier material are currently available on the market.
Starch has a poor water vapour barrier but its oxygen barrier is good in principle. As starch is applied in blends, the morphology (structure) of the blend is important in determining the achieved gas barrier. Various gas barrier materials based on starch/PE are described in the patent literature. These materials are regarded as a partially biobased alternative for EVOH.

One alternative method for improving the barrier properties of plastics is to apply a thin layer of $SiO_x$ (glass) or $Al_2O_3$ (aluminium oxide). Various manufacturers market barrier films made of PLA/$SiO_x$, including Amcor (formerly Alcan) and Extendo. Barrier bottles based on this system are technically feasible but not commercially available. Innovia frequently uses $Al_2O_3$ as a barrier layer for cellophane.
$Al_2O_3$ and $SiO_x$ coatings are suitable for compostable packaging. As the materials are applied in an extremely thin layer, the 1% limit is not exceeded. In addition, composters regard aluminium as a trace element that makes a positive contribution to the compost's quality.

## 4.3 Recycling

It is not the actual nature of the material (biobased or petrochemical) but the purity of the recyclate streams that is important to enable recycling. This is demonstrated by Coca-Cola with the PlantBottle$^{TM}$ based on bio-PET and in combination with PET recyclates. Unfortunately, the volume of new biobased materials is often too small to make separate collection and recycling economically viable. One exception concerns the collection of PLA cups at festivals. Apart from being compostable, these cups can also be chemically recycled using e.g. the Loopla process (Loopla, 2014). PLA is already industrially recycled, notably at the manufacturing facilities of Huhtamaki and Desch, while PLA recyclate is also marketed to a limited extent for the production of PLA flower pots.

# 5 Fresh food

## 5.1 Introduction

Fresh food refers to pure and mostly unprocessed products with a limited shelf life such as fruit and vegetables, dairy produce, eggs and meat. The correct packaging is crucial for many types of fresh food. Packaging can extend the shelf life of fresh food and slow spoilage (Thoden van Velzen, 2008).

Australian researchers of RMIT University (Melbourne) have demonstrated that packaging helps to reduce fresh food waste, which is a vital priority in the Netherlands and Europe (AFN, 2013). A further consideration is that packaging helps to guarantee food safety.

Biobased materials are widely used in fresh food packaging. Both the natural look and feel of some biobased materials such as paper and moulded board and the technical properties of various biobased plastics (such as breathability and permeability) make them eminently suitable for these applications.

*Figure 20. The positive image of biobased packaging is important.*

The compostability of various biobased materials can offer advantages in the end-of-life phase (e.g. for retailers) as fresh products that are past their sell-by date can be discarded together with the packaging in the green waste container. This saves waste removal and labour costs as the packaging does not need to be separated from the product. In recent years, biobased plastics have also become more competitive in the wake of negative reports about the migration of possibly harmful substances from plastics such as PC and PS. Thanks to improved technical properties and savings on waste removal costs, biobased materials are now able to compete with petrochemical materials in these applications.

The various biobased packaging options are discussed per product category in this chapter. Each section follows the same pattern, answering the following questions:

- What materials and types of packaging are traditionally used?
- What requirements must be met?
- What biobased examples are known?
- What are the advantages/disadvantages of the biobased packaging?
- What are the additional applications of biobased packaging?
- What are the current developments?

For each packaging category, several key properties are summarised with the aid of pictograms for easy reference. A brief explanation of the pictograms is given in the 'Pictograms' appendix.

## 5.2 Fluids

Fresh fluids notably consist of fruit juices, milk and dairy produce such as yoghurt, yoghurt drinks, quark and custard. Common packaging types for fluid foods are beverage cartons, bottles, pouches and cups. 'Bag-in-a-box' packaging is frequently used in catering.

- Beverage cartons are usually made of a combination of board coated with PE, sometimes also including PE closures (e.g. caps). For cost reasons, these beverage cartons are the most widely used packaging for this type of product.
- Bottles are mainly made of PE (e.g. 1.5 litre milk bottles), glass (fruit juices) and a small amount of PET (transparent plastic bottles for juice).
- Pouches are mainly made of film laminates based on PE and PET, sometimes provided with an aluminium barrier layer.
- Non-transparent cups for e.g. quark, yoghurt and cream are traditionally made of PS.
- Bag-in-a-box packaging are cardboard boxes containing a plastic bag with a tap. The plastic bag is made of a barrier film laminate based on PE with an EVOH barrier material and comes with a PE tap.

Fresh fluids only keep for a few days and must be kept refrigerated. For this reason, it is often not necessary to use packaging with good barrier properties. As a result, the threshold for applying new biobased materials is relatively low provided these are allowed to be used in contact with food.

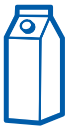
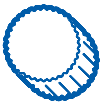
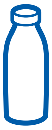
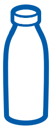
### *5.2.1 Milk and other dairy produce*

Most dairy produce are packaged in beverage cartons. The biobased content of these beverage cartons is already about 75% due to the use of board. In addition, PE is used to coat the board (for waterproofing purposes) and often also for closures and caps. Replacement of PE caps with bio-PE caps increases the biobased content by an extra 4%. Bio-PE caps are already applied by Tetrapak (Tetrapak, 2013). The biobased percentage can be raised even further by also producing a bio-PE coating. Tetrapaks with a bio-PE coating will be available on the market from 2015.

HDPE milk and dairy bottles are mainly used for large (>1 litre) and small packaging. These can be replaced with bio-PE bottles. One example is the small bio-PE Actimel bottles of Danone. Crucially, this bio-PE can be recycled in the petrochemical PE stream (Danone, 2014).
PLA is also suitable for dairy packaging. PLA milk bottles first appeared on the US market in 2007 (NatureWorks, 2007) and are suitable for recycling as well as composting.


*Figure 21. Activia packaging made of PLA.*

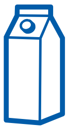
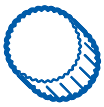
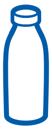
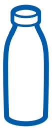
PLA is also very suitable for replacing PS cups. Together with PLA manufacturer NatureWorks and the World Wide Fund for Nature, Danone has developed a thermoformed PLA cup for Activia yoghurt (NatureWorks, 2011). Thanks to the reduced wall thickness of the packaging, less material is used. With this packaging, Danone also entered into commitments regarding recycling, sustainable resource harvesting and the non-use of genetically modified crops. Though PLA is compostable, Danone initially chose to emphasise the use of biobased resources, the reduction of the environmental footprint and also the recycling aspect to highlight its green credentials. In the meantime, however, due to negative publicity arising from court action taken by a German environmental organisation over vague sustainability claims, Danone now still markets its yoghurt in PLA packaging but no longer communicates this to the consumer.

| Packaging | | Material | Properties | Recycling |
|---|---|---|---|---|
| Beverage carton |  | Board |  |  |
| Caps |  | Bio-PE |  |  |
| Bottles |  | PLA |  |  |
| Bottles |  | Bio-PE |  |  |
| Cups |  | PLA |  |  |

Apart from board, no other biobased materials are used in bag-in-a-box packaging. The transition to biobased materials for pouches is more difficult in view of the strict requirements regarding barrier properties and strength (including sealing strength).

### *5.2.2 Fruit juices*

Fresh fruit juice (unpasteurised) only keeps for a few days (three to four at most) in the fridge. Glass bottles are mainly used for this purpose. Many fruit juices are processed to extend their shelf life, while approximating the quality of fresh juices. This type of juice must be kept chilled. As with milk and other dairy produce, beverage cartons can be used for this purpose, either with or without a bio-PE cap. The US company Odwalla has replaced HDPE bottles with bio-HDPE bottles for fruit juices. Transparent PET bottles can be replaced with PLA bottles. The US company Noble has demonstrated this with its transparent PLA bottles with PLA-based labels. The entire packaging is thus almost 100% biobased. In Europe the Italian company Polenghi packages its organic lemon juice in PLA squeeze bottles.

| **Packaging** | **Material** | **Properties** | **Recycling** |
|---|---|---|---|
| Beverage carton  | Board |  |   |
| Caps  | Bio-PE |  |  |
| Bottles  | PLA |  |  |
| Bottles  | Bio-PE |  |  |

Longer-life fruit juices that do not require refrigeration are predominantly packaged in Tetrapaks or metal cans. This packaging must have excellent oxygen transmission properties. Apart from Tetrapaks, no biobased alternatives are available for this application. Bottles based on bio-PET coated with $SiO_x$ or even PLA coated with $SiO_x$ do meet the oxygen transmission requirements. However, $SiO_x$ is still only used on a limited scale because of the high costs of investment in $SiO_x$ technology.

## 5.3 Solids

Fresh solids comprise a very broad category of fruit and vegetables, animal products such as cheese, eggs and meat, and processed grain and vegetable products such as bread. These products must be consumed within a few days to several weeks after purchase. Though fresh solid foods such as fruit and vegetables can also be sold unpacked, packaging still often has a vital role to play here in slowing spoilage and reducing waste. The requirements that packaging must meet vary widely, depending on the product being packaged.

### *5.3.1 Fruit and vegetables*

Though consumers are not keen on fruit and vegetable packaging, it can provide protection against damage and spoilage. Another advantage is that packaging makes it possible to offer smaller portions, which is one strategy for preventing food waste. Many fruit & vegetable packaging consists of collection and display packaging, which does not need to meet high requirements. The most common types of packaging used in this segment are flexible films, trays and dishes. The materials vary from PE (films), PS and PET (trays and dishes) to paper and board (trays). The natural image and transparency of the materials offer added value.

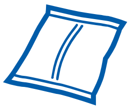
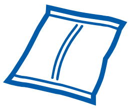
| **Packaging** | **Material** | **Properties** | **Recycling** |
|---|---|---|---|
| Transparent film  | PLA<br>Cellophane |  |  |
| Translucent film  | Starch blends<br>Ecovio |  |  |
| Transparent covering film  | PLA |  |  |
| Trays/dishes  | PLA<br>Pulp (board)<br>Paperfoam |  |  |
| Containers  | PLA<br>Board |  |  |


*Figure 22. Garden cress in cardboard box.*

Fruit and vegetables are often packaged in biobased materials; particularly organic fruit and vegetables tend to be sold in biopackaging in supermarkets. Most often compostable materials are used, which offer advantages in the end-of-life phase. The compostable packaging can be placed in the green waste container together with the green waste residues. The Greenery, which already started using compostable packaging back in 2005, is one of the leaders in this sector. Today, the Greenery is focusing more on the renewability of the packaging. Commonly applied biobased packaging includes:

- Transparent films for packaging e.g. tomatoes and bell peppers (often PLA, sometimes cellophane).
- Translucent films made of e.g. starch blends (e.g. Mater-bi) for packaging potatoes and winter carrots.
- Foamed PLA trays with a PLA top film or flowpack.
- Pulp trays with a PLA top film or flowpack. Based on e.g. sugarcane (Moonen) and tomato stalks (developed by Wageningen UR).
- Transparent PLA bags for pre-chopped lettuce and salads.
- Plastic trays and containers based on PLA (transparent or coloured) for cut fruit, salad, strawberries and mushrooms.
- Fruit nets based on Bioflex (FKuR).

The additional advantages of alternative biobased packaging are also worth mentioning. For instance, chopped lettuce and salads packaged in PLA film keep


*Figure 23. Potatoes in translucent compostable bags.*

several days longer and there is also a packaging that significantly extends the shelf life of potatoes (Tukker Tuffels, 2011).

Moreover, PE can be replaced with bio-PE. Unfortunately, bio-PE offers no advantages in the end-of-life phase as it cannot be composted with vegetable residues, but bio-PE film can be recycled via Plastic Heroes.

### *5.3.2 Meat and cold cuts*

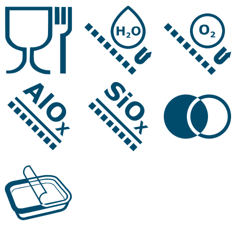
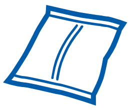
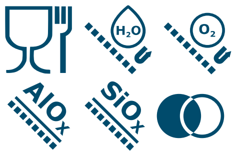
The sale of pre-packed meat and cold cuts is increasing, particularly in supermarkets. The current packaging consists of foam or hard plastic trays (PS or PET) covered with a top film (film laminate). Meat packaging must meet high specifications, particularly in terms of gas barriers. As $CO_2$ causes meat to go brown, meat is often packed in MAP (modified atmosphere packaging) where specific gas concentrations keep the meat fresh longer and prevent discolouration. The packaging must be well sealed and the top film must also have good barrier properties.

Meat and cold cuts are not yet frequently packed in bioplastics, but various options are already available. Hard plastic trays (PS or PET) can be made from PLA and foam trays (PS) can also be replaced by foam PLA.

The number of commercially available top films that have a good oxygen barrier and are therefore suitable for meat packaging is even greater. Examples are:

- PLA-based films with an $SiO_x$ barrier layer (Amcor, Extendo)
- PLA/cellophane films (Bio4Pack)
- Cellophane barrier film Natureflex N913 (Innovia)
- High amylose starch (Plantic)

One example of a meat packaging that has been on the market since 2005 is the NaturalBox of Coopbox. This NaturalBox consists of a foam PLA tray that can have a stretch film or a PLA-based film (for a 100% biobased solution). Besides being biobased, this packaging is compostable and suitable for MAP packaging of fresh food with a shelf life up to 15 days.
The meat packaging can be provided with a compostable absorbent pad, for instance of Elliot Absorbent Products (Elliot, 2014).

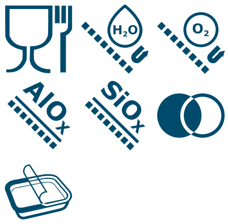
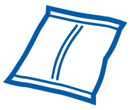
| **Packaging** | **Material** | **Properties** | **Recycling** |
|---|---|---|---|
| Trays  | PLA<br>Pulp (board) |  |  |
| Covering films with barrier function  | PLA<br>Cellophane<br>Starch (Plantic) |  |  |
| Packaging film  | PLA<br>Cellophane |  |  |

Ter Beke uses meat packaging that is more than 80% biobased and has been certified by Vinçotte (4 stars). This company also has EN13432-compliant compostable packaging. Ter Beke's packaging is made of a combination of coated paper and film, which gives them a natural look and feel (Ter Beke, 2014).

### *5.3.3 Fish*

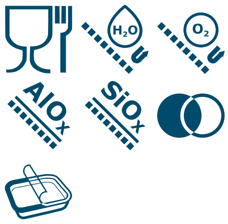
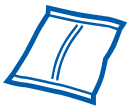
Fish has similar packaging requirements to meat, but is packaged under different conditions (MAP gas concentrations). Fatty fish requires low- or zero-oxygen packaging. Fish packaging can be made of the same biobased materials as meat packaging. In this market too, there are examples of companies that use biobased packaging for their products. In 2013 Profish from Twello introduced a packaging based on Plantic eco Plastic™ which is 60% to 80% biobased (Vinçotte three-star

quality mark) and fully compostable (Profish, 2013). The NaturalBox of Coopbox is also suitable for fish packaging (Naturalbox, 2014).
Fish is transported in ice in styrofoam boxes. Synbra's PLA-based Biofoam™ can be used for this purpose.

| Packaging | Material | Properties | Recycling |
|---|---|---|---|
| Trays  | PLA<br>Pulp (board) |  |  |
| Top films with barrier function  | PLA<br>Cellophane<br>Starch (Plantic) |  |  |
| Barrier films  | PLA<br>Cellophane |  |  |

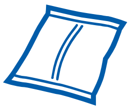
### *5.3.4 Cheese*

Cheese is packaged in many diverse ways. Examples are hard and flexible trays, sometimes with a top film, and vacuum packaging in flexible film. Cheese must be kept in refrigerated and oxygen-free conditions to extend its shelf life. Cheese packaging must therefore meet specific oxygen barrier requirements. Cheese is also increasingly being packaged using MAP. Clear Lam supplies cheese packaging made of a film laminate based on PLA and petrochemical plastic. This film is 50% biobased (Clear Lam, 2012). The Dutch company Bio4Pack offers biobased cheese packaging.
Meat and fish packaging is also suitable for cheese, provided these have a good oxygen barrier. Examples are the use of Plantic materials and Mater-bi (both starch-based), Innovia materials (cellulose-based) and the Naturalbox of Coopbox. In addition, soft cheese can be packaged in PLA/paper combinations and cellophane-based films. The Innovia website contains information on the various options for cellulose-based films for packaging hard cheese (Innovia Kaas, 2014).

| Packaging | Material | Properties | Recycling |
|---|---|---|---|
| Trays  | PLA<br>Pulp (board)<br>Mater-bi |  |  |
| Top film with barrier function  | PLA<br>Cellophane<br>Starch (Plantic) |  |  |
| Barrier film  | PLA<br>Cellophane |  |  |

### 5.3.5 *Butter*

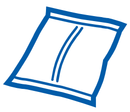
Butter is packaged in barrier paper (often a combination of paper and aluminium), PE bottles (liquid butter) or tubs (PP, polypropylene) which often come with an aluminium covering film. Butter packaging is hard to recycle because it is smeared with fat (OIVO, 2008). Oxygen strongly affects the quality of butter and, once opened, butter can only be kept in the fridge for a limited period of time.

| Packaging | Material | Properties | Recycling |
|---|---|---|---|
| Bottles  | Bio-PE |  |  |
| Packaging films  | Cellulose/paper<br>PLA/paper |  |  |

Possible applications of biobased materials consist of the replacement of the current PE bottles by bio-PE bottles. In addition, Innovia manufactures paper/cellophane-based films that are suitable for packaging butter. Bio-PP is not yet commercially available in the market, but can be used in the future to replace PP.

### *5.3.6 Bread*

Bread is traditionally packaged in thin PE film to prevent it going dry or stale. Plastic with a good water barrier is important, particularly for bread that is to be kept in the freezer. In addition, paper bags (often with a window) are used for luxury bread and oven-fresh bread (that still needs to breathe). Micro-perforated films are often used for oven-fresh rolls.

| **Packaging** | **Material** | **Properties** | **Recycling** |
|---|---|---|---|
| Packaging films  | Paper<br>Bio-PE<br>Paper/PLA<br>Paper/cellophane | |  |

PE film can be easily replaced with bio-PE (I'm green™) film. This film is produced by various companies (e.g. Oerlemans).
One very suitable alternative for paper bags with a window consists of paper/PLA combinations or paper/cellophane. These types of materials are produced by Sidaplax and Innovia.

### *5.3.7 Eggs*

Eggs are traditionally packaged in paper pulp trays, whose principal function is to prevent breakage. Various alternative biobased materials are available on the market, including thermoformed PLA trays, trays based on Paperfoam and pulp trays based on grass.

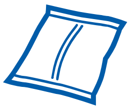
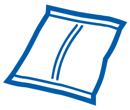
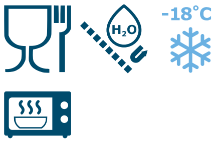
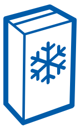
| **Packaging** | **Material** | **Properties** | **Recycling** |
|---|---|---|---|
| Trays  | Pulp<br>PLA<br>Paperfoam | |  |

*Figure 24. Paperfoam egg tray.*

## 5.4 Freezer

In the freezer section of supermarkets, most products (vegetables, meat, fish and ready-made meals) are packaged in cardboard boxes (sometimes with an inner bag) and in bags. Ice cream is frequently packaged in thermoformed plastic packaging. Freezer boxes, which are used for the packaging of individual product items, are made of moisture-resistant and usually fat-resistant folding cardboard. Folding cardboard is biobased, recyclable (waste paper), biodegradable and compostable (PRN, 2014). Folding cardboard is often given a thin PE coating for sufficient moisture resistance and fat resistance. The Netherlands Paper Recycling Foundation (PRN) advises against discarding coated cardboard freezer packaging as waste paper. As an alternative, BASF has developed Ecovio® PS, a biodegradable extrusion coating with more than 50% biobased content which adheres well to paper and cardboard and is suitable for freezer boxes (BASF, 2014). The material has been cleared for food contact, gives a good barrier against fluids, fat and smells, and offers temperature stability up to 100°C. After use, the material can be composted, but BASF claims that paper recycling also remains possible.

Various deep-frozen products can dehydrate (lose water) when frozen. With conventional packaging solutions, PE packaging is sufficient to prevent dehydration. Biobased PE can be used to replace traditional PE. A PLA-based packaging (BioFlex®) that is suitable for freezer applications has also been on the market for some time (FKuR, 2014). This packaging, which is applied by such manufacturers as McCain, has a high biobased content and is also compostable.

| Packaging | Material | Properties | Recycling |
|---|---|---|---|
| Packaging film  | Bioflex |   |  |
| Barrier film  | Arnitel Eco |   | |
| Trays  | PLA (Biofoam)<br>PHA |   |  |
| Freezer boxes  | Coated cardboard |   |  |

New developments are:

- Ice cream packaging based on Biofoam (PLA) launched by Sandro Zandonela (Sandros Bio, 2014).
- A cardboard packaging for frozen fruit from Coop. A biodegradable coating makes the packaging compostable (Invercote Bio). Thanks to the use of cardboard, the packaging is largely biobased (Invercote Bio, 2014).
- The 'freezer-to-oven' bag of DSM based on Arnitel® Eco, a 50% biobased thermoplastic copolyester based on rape seed oil that is resistant to both low and high temperatures. The packaged deep-frozen food product can be placed directly from the freezer in the oven without 'repackaging' (DSM, 2014).
- A PHA grade of Metabolix (Mirel™ F1006) with high toughness, has been approved for food packaging and is suitable for the freezer, microwave and boiling water (Metabolix, 2014).

# 6 Non-perishable foods

## 6.1 Introduction

As packaging of non-perishable foods must protect these products for an extended period of time, good barrier properties are often essential. Examples are protection against oxygen (wine, beer), staling (biscuits) and (UV) light. A broad range of biobased packaging is available to comply with the diverse needs of different products.

## 6.2 Fluids

The most important categories of non-perishable fluids are soft drinks and water, beer and wines, sauces and soups. These products are packaged in bottles, pouches, glass pots and cans.

### *6.2.1 Soft drinks (carbonated)*

Soft drinks are traditionally packaged in PET bottles (large volumes) as well as in glass and metal cans. A sufficient barrier for $CO_2$ is crucial for these products. Well known is the PlantBottle that Coca-Cola recently launched, which is made of bio-PET (30% biobased at maximum) and contains recycled PET. Bio-PET is chemically identical to traditional PET and therefore offers the great advantage of being entirely compatible with the existing PET recycling systems. The recycling industry strongly resists the use of alternative materials (such as PLA) in replacement of traditional PET. As the current PET bottles constitute a mono-material stream, these alternatives are perceived to be a threat to the existing recycling system. With the introduction of new materials recycling will become more complex and labour-intensive. Looking to the future, PEF (polyethylene furanoate) bottles can provide a 100% biobased alternative for PET. However, this material is not yet commercially produced. Another technological alternative is a $SiO_x$ coated PLA bottle, but this solution is relatively expensive.

| **Packaging** | **Material** | **Properties** | **Recycling** |
|---|---|---|---|
| Bottles  | Bio-PET |  |  |

### *6.2.2 Water*

Non-carbonated water requires less specific to barrier properties and can be packaged in PLA Bottles. However, due to its inferior water barrier compared to PET, PLA is only suitable as an alternative for short shelf-life packaging (shorter than one year;

otherwise water will evaporate, leaving the bottles short-measured). Sant'Anna is one company that has been packaging its water in PLA bottles for years (Sant'Anna, 2014).

| **Packaging** | **Material** | **Properties** | **Recycling** |
|---|---|---|---|
| Bottles | Bio-PET | | |
| Bottles | PLA | | |

### *6.2.3 Beer and wine*

Beer and wine are traditionally packaged in glass, which satisfies all barrier requirements. Beer and wine both need protection against oxygen. Moreover, beer must be protected against UV light and it is important to ensure the $CO_2$ remains in the beer. Plastic bottles are applied on a small scale, their main advantages being that

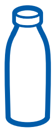
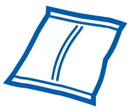
| **Packaging** | **Material** | **Properties** | **Recycling** |
|---|---|---|---|
| | Bio-PET | | |
| | PLA | | |

they are lighter and less sensitive to breakage. $SiO_x$-coated PET meets the strict barrier requirements. Some Belgian beer brewers have $SiO_x$ production lines, but the technology is expensive and no bio-PET beer bottles are made yet, though it is technically possible. Another biobased solution is a multi-layer bottle based on PLA with a central layer consisting of PGA (polyglycolic acid). This, too, is a costly option that has not yet been commercialised. PEF is another option for the future. However, despite having better barrier properties than PET, PEF still does not meet the requirements for beer and requires a barrier coating (such as $SiO_x$).

### *6.2.4 Sauces*

A very diverse range of packaging is used for sauces, varying from HDPE and PET squeeze bottles, to glass bottles and pots, metal cans and plastic pouches (made of film laminates). Sauces in unopened packaging usually have a shelf life of at least 12 months, which makes good barrier properties essential (for oxygen and also water). As the barrier properties of PET are not adequate, a multi-layer bottle incorporating a barrier material is used. One well-known biobased sauce packaging is Heinz's bio-PET ketchup bottle. In addition, biobased (and compostable) pouches are available on the market (e.g. Ampac), while bio-PE is also processed in some pouches such as in CheerNext of Gualapack.

Future biobased alternatives are PEF-based barrier bottles or, for instance, PLA/$SiO_x$ barrier bottles.

| Packaging | Material | Properties | Recycling |
|---|---|---|---|
| Bottles  | Bio-PET |  |  |
| Barrier films  | Bio-PE laminate |  |  |

### *6.2.5 Soups*

Soup was traditionally packaged in metal cans, but is now increasingly being packaged in pouches. The packaging has the same characteristics as sauce packaging, but they are usually larger. The same pouches as described for sauces could in principle be used for soups, but there are no commercial examples of this. Innovia is working together with Corbion on a new heat-stable film laminate based on cellophane and heat stable PLA. This laminate would be ideal for soup pouches.

## 6.3 Solid foods

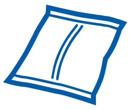
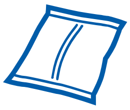
Differences between packaging for solid and fluid non-perishable foods are:

- the types of packaging that are traditionally used
- the closure of packaging (need not always be waterproof)
- the water barrier is less important

In addition, there are, of course, product-specific properties. Coffee, for instance, is sensitive to oxygen and biscuits can go stale. This chapter is subdivided by product type, with specific product requirements being mentioned in each section.

### *6.3.1 Biscuits and bakery products*

Biscuits and other bakery products are packaged in cardboard (boxes), paper (rolls) or plastic trays with a film wrap. Depending on the type of biscuit or bakery product,

| Packaging | Material | Properties | Recycling |
|---|---|---|---|
| Films  | PLA |  |  |
| Barrier films  | Cellulose |  |  |
| Boxes  | PLA |  |  |

it is important to prevent staling or softening. A good water barrier can prevent these problems. The simplest example of such a material is PE film, so the obvious next step would seem to be bio-PE. However, many biobased materials such as cellophane and PLA have a poor water barrier and are therefore not immediately suitable for packaging biscuits. Innovia offers various cellophane-based barrier films that can be used for packaging biscuits. Plastic trays can be made of PLA, and combinations of Innovia film with PLA trays make the biscuit packaging entirely compostable. The company Le Clerc uses bioplastics commercially in its packaging of Vital Oats and dark chocolate cookies. Combinations of cardboard and bioplastic give the packaging a natural look and feel.

### 6.3.2 Crisps

Crisps are packaged in metallised PP film, which is PP film with a thin vaporised layer of aluminium oxide. This film is used to meet the specific requirements for crisps, which must be packaged in oxygen- and moisture-free bags to prevent the fat going rancid and the crisps becoming soft due to moisture (the salt in crisps attracts moisture). Metallised biopackaging is also suitable for crisps. One example is the compostable crisp packaging of SunChips. This packaging is 90% biobased (use of PLA) and compostable (thin $AlO_x$ layers are EN13432-compliant). One alternative is a metallised cellulose film of Innovia as used by e.g. Boulder Canyon Natural foods.

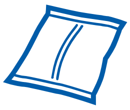
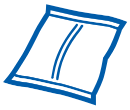
| Packaging | Material | Properties | Recycling |
|---|---|---|---|
| Barrier films | PLA | | |
| Barrier films | Cellulose | | |

### 6.3.3 Confectionery and chocolate

Confectionery and confectionery packaging come in all shapes and sizes. The requirements for packaging depend on the type of confectionery, but a barrier against moisture (to prevent stickiness) and preservation of aroma is often important. Films

*Figure 25. Cellophane films for confectionery and chocolate (Innovia).*

and PET/PE-laminate pouches are common, while boxes (board and paper) and trays are used for luxury confectionery. Cellophane (cellulose film) is traditionally used for the twist wraps of individual chocolates and sweets – not just because it is biobased, but above all because of its 'dead fold' (cellophane does not fold back when folded or twisted around the product). Innovia offers various types of cellophane films for packaging confectionery, both twist wraps and films that are wrapped around boxes. Metallised cellophane can be used to package chocolate (Alce Nero, fair trade chocolate). These films are biobased and also compostable. Water-soluble trays made of e.g. Plantic are also being actively promoted for confectionery packaging (e.g. for Swiss chocolate). The Plantic material is based on modified starch.

| **Packaging** | **Material** | **Properties** | **Recycling** |
|---|---|---|---|
| Transparent film  | Cellulose<br>PLA |  |  |
| Barrier films  | Cellulose |  |  |
| Containers (transparent)  | PLA |  |  |
| Containers  | Modified starch |  |  |

### *6.3.4 Coffee*

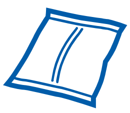
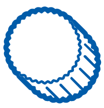
Coffee packaging must meet strict oxygen and light (UV) transmission requirements. Coffee is typically packaged in pouches based on PET/PE barrier laminate (beans and ground coffee) and in vacuum packaging made of plastic/aluminium and paper. One striking feature of pouches for ground coffee is the valve used to let the gases (e.g.

$CO_2$) from ground coffee escape from the packaging. Coffee pouches are traditionally made of film laminates with aluminium barrier layers.

The coffee industry is taking a keen interest in sustainable packaging. Newer laminates without aluminium are seen as a more sustainable alternative. Options for both compostable and biobased packaging are being explored. As the laminates used in the

*Figure 26. Coffee packaging based on Innovia material.*

packaging are difficult to recycle, compostable packaging offers an advantage. Innovia markets biobased film laminates that are suitable for packaging coffee. These laminates consist of cellophane, a cellophane barrier layer coated with $AlO_x$ and a biopolymer seal layer. Innovia's coffee laminate is mainly used in the US and Australia/New Zealand.

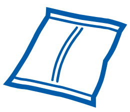
| **Packaging** | **Material** | **Properties** | **Recycling** |
|---|---|---|---|
| Barrier films  | Cellulose<br>Paper<br>PLA |  |  |
| Cup  | PLA blend<br>Heat-stable PLA |  |  |

Paper-laminate biobased alternatives are produced by e.g. Amcor. The paper is laminated with traditional petrochemical materials (PE).

In addition to whole bean and ground coffee, more and more coffee is sold in the form of pads (Senseo) and cups (Nespresso). After use, compostable coffee pads and cups can be placed complete with coffee residues in the green waste container.
Swiss Coffee Company AG has teamed up with BASF to develop a cup for their FairTrade coffee based on Ecovio, a blend of PLA and fossil oil-based Ecoflex, which is 100% compostable. The cups are packaged in a three-layer compostable laminate with an outer layer made of paper, a compostable barrier film and an Ecovio seal layer. The adhesive material (used between the three layers) is Epotal glue (compostable BASF glue). Previously, the Ethical Coffee Company already brought compostable (EN13432-compliant) coffee capsules onto the market. The website claims that the capsules are made of plant fibres and starches, but the material is more likely to consist of PLA. A more recent development concerns capsules based on heat-stable PLA. Demo capsules were demonstrated by Corbion at the Interpack trade fair in 2014.

### *6.3.5 Tea*

Tea likes dry, air-tight and dark conditions. Tea is sold as loose leaf or in teabags, with the latter accounting for the bulk of tea sales. Teabags are packaged in film-wrapped cardboard boxes. One cup teabags are wrapped separately in paper and then packed in a box. Though tea packaging already have a fairly high biobased content (due to the

| **Packaging** | **Material** | **Properties** | **Recycling** |
|---|---|---|---|
| Films  | Cellulose<br>PLA fibres for teabags |  |  |
| Boxes  | Cardboard | |  |

use of filter paper for the teabag (abaca fibres) and paper and cardboard for the bags and boxes), various new advances in the field of biomaterials are under way. Sealable teabags traditionally contain PP fibres (20-30%) to permit sealing. Ahlstrohm produces sealable teabags based on 100% PLA fibres which are marketed under the name

Bioweb™. Innovia offers a series of films for packaging tea and teabags including films that can be wrapped around boxes and metallised films that are suitable for packaging loose leaf tea.


*Figure 27. Tea packagings with Innovia films.*

### *6.3.6 Various dry products*

Other dry foods that are packaged in 'new' biobased packaging concepts include breakfast cereals, nuts, herbs, pasta and rice. One of the oldest examples is Jordans' breakfast cereal packaging, which uses a barrier film consisting of biobased films from Innovia (cellophane) and Novamont (Mater-bi, starch blend). More recent developments are packaging films for nuts from Bio4Pack. This film is based on cellophane (Innovia) and PLA (Taghleef). Innovia boasts a strikingly large share in various segments, partly thanks to its very broad range of barrier films.

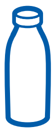
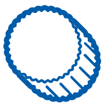
# 7 Non-food

## 7.1 Fluids

Examples of fluid non-food products are detergents and soaps, personal care products such as shampoo and toothpaste, and cosmetics. Some of these products have a limited shelf life and are sensitive to e.g. oxygen (cosmetics). In general, however, shelf life is much less important for non-food than for food packaging. Closures and caps are important for dispenser functions and child safety (detergent closures). Biodegradability of packaging is usually not an issue, but recycling is important. Some of the fluid non-food products contain components that could affect plastic packaging such as fats and oils in personal care products and acid and alkaline components in detergents. Not all plastics are suitable for packaging these products. Common packaging types are bottles, tubes and pots.

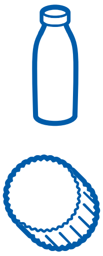
## 7.2 Detergents

The vast majority of detergents (e.g. all purpose and toilet detergents) and soap are packaged in HDPE bottles, because HDPE is insensitive to the ingredients used in detergents. HDPE bottles can be replaced one on one by bio-PE. The Belgian company Ecover, manufacturer of ecological detergents, was the launching customer for bio-PE in Europe and has packaged its products in bio-PE since 2011. Dishwasher and laundry detergents (liquitabs or pods) are wrapped in water-soluble PVA films. Though not biobased, PVA is slowly biodegradable in the presence of certain microorganisms.

| **Packaging** | **Material** | **Properties** | **Recycling** |
|---|---|---|---|
| Bottles  | Bio-PE | |  |
| Caps  | Bio-PE | |  |

## 7.3 Personal care products

HDPE is also frequently used for the packaging of personal care products, for instance in bottles and tubes. In addition, products such as gel and some luxury products are

| Packaging | Material | Properties | Recycling |
|---|---|---|---|
| Bottles and caps  | Bio-PE | |  |
| | PHA | |  |

sold in pots made of PP. A sustainable image is more important in the personal care industry than for detergent manufacturers.

Back in the 1980s and 90s shampoo in Japan was already packaged in PHA, a biodegradable and 100% biobased plastic. This was one of the first commercial applications of PHA. Today, PHA is no longer applied in this type of packaging, mainly due to the high cost. Procter & Gamble currently uses bio-PE bottles for some of its shampoos and conditioners (Pantène). Alongside bottles, it is also possible to make tubes and dispensers (e.g. for soap) from bio-PE. The German company FKuR is a distributor of bio-PE (and bio-PE compounds brand-named Terralene$^{TM}$) in Europe and advertises various examples of its packaging on its website. Several years ago biodegradable tubes (Tectubes) for toothpaste were brought onto the Swedish market based on materials of FKuR (PLA blends). This shows that biobased packaging for personal care products definitely have potential.

*Figure 28. Various cosmetics packagings of FKuR.*

## 7.4 Cosmetics

Image and the look and feel of the product are even more important for cosmetics than for personal care products. This is clearly visible in the more luxurious and heavier packaging (higher materials consumption), while glass is also regularly used alongside plastic.

| Packaging | Material | Properties | Recycling |
|---|---|---|---|
| Bottles and caps | Bio-PE | | |
| Transparent bottles and caps | PLA<br>Cellulose acetate | | |

Biopolymers such as PLA and cellulose acetate are ideal for cosmetics packaging due to their attractive gloss and pleasant feel to the touch. Moreover, these materials are

*Figure 29. Cosmetics packagings based on Ingeo™ PLA (NatureWorks).*

transparent, rigid and suitable for injection moulding (e.g. pots, lids or lipstick casings). Examples can be seen on the websites of FKuR (Biograde®) and NatureWorks (Ingeo™).

### 7.5 Electronics and electrical appliances

Electronics and electrical appliances must be packed dry and protected against impact damage. Common types of packaging are styrofoam (EPS), thermoformed trays and moulded fibre trays (board). In addition, boxes (board) and flexible films are also used to provide protection against moisture as well as to demonstrate that the packaging has not been opened. The protective characteristics of the packaging are vital as product losses in this sector are costly. Alongside the already widely-used board, various forms of biobased packaging are available. Paperfoam® is an alternative for moulded fibre or thermoformed products. It shows that biobased materials can meet the stringent specifications for electronics packaging. Paperfoam is applied by such manufacturers as Philips for packaging electric shavers. Other examples are boxes for hearing aids, toothbrushes and computer hard-disks. EPS foam can be replaced with EPLA foam that is marketed by Synbra Technology under the name Biofoam™. Thermoformed trays (PS or PET) can be replaced by PLA trays and a range of flexible films is also available, varying from bio-PE to Ecovio®.

*Figure 30. Shaver in a Paperfoam packaging.*

| Packaging | Material | Properties | Recycling |
|---|---|---|---|
| Foam | EPLA | | |
| Trays | Moulded fibre<br>Paperfoam | | |
| Trays | PLA | | |
| Packaging film | Bio-PE | | |
| Packaging film | Ecovio | | |
| Boxes | Board | | |

## 7.6 Ornamental flowers, plants and trees

The horticulture sector is a driving force behind the development of biodegradable materials and products. Compostability is a highly appreciated property in this sector, but soil biodegradability is often the main objective. As with traditional packaging materials, many horticulture articles are only intended for temporary use and compostable materials offer advantages in the end-of-life phase. Plant pots are one example of a packaging that is currently receiving a lot of attention.

*Figure 31. D-grade flower pots of Desch Plantpack.*

One successful product line consists of the D-grade plant pots of Desch Plantpack which are used for packaging organic herbs that are available in many Dutch supermarkets. These pots are made of partially recycled PLA and are compostable (EN13432 certified). Soil degradable pots have been less successful thus far because most soil degradable biopolymers break down so fast that they impair plant growth. Metabolix supplies PHA types that are suitable for e.g. flower pots and degrade in the soil. Only one type of pot in the market has an OK Soil certificate for soil degradability (NaturePots of Biofibre). Whether this material meets all of the growers' specifications is unknown. Smaller pots and trays are used for plant propagation. Biobased alternatives are Biofoam™ (EPLA foam) and Jiffy (fibre material).

Also widely used in the horticulture sector is flexible film for covering and packaging products. A range of biobased materials are used in this sector. Examples are compostable packaging for flower bulbs from Hapece – 95% biobased laminate film consisting of NatureFlex™ (cellophane), paper and PLA – and a flower bulb packaging made of PHA. PLA-based films are on the market for packaging cut flowers.

Alongside pots and films, advances are also being made in the field of nets and twine. These are traditionally made of recycled PP. Alternatives for making nets (for plants with root ball) and twine (for tying up products) include natural fibres such as jute and hemp as well as PLA (on its own or in a blend). One example is Bio Twine® of Lankhorst.

# 8 Packaging of packaging

## 8.1 Shrink film

Shrink films are used to keep products (e.g. drinks bottles, boxes and pallets) together as well as to protect products (e.g. cucumbers). The most widely used materials for conventional shrink films are PE and PP. The shrink properties are achieved through the 'relaxation' of tensions that have been 'frozen into' the film during the production process.

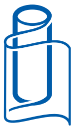
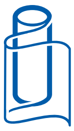
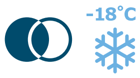
| Packaging | Material | Properties | Recycling |
|---|---|---|---|
| Shrink film | Ecovio | -18°C | |
| Shrink film (labels) | PLA | | |
| Shrink film | Bio-PE | -18°C | |

A number of partially biobased shrink films have appeared on the market. BASF has developed a compostable shrink film based on Ecovio® FS, a 66% biobased blend of PLA and Ecoflex (BASF, 2009; BASF Ecovio, 2013). As well as having a high biobased content, BASF claims that the shrink film required for a six-pack of 0.5 l drinks bottles can be 50% thinner and, moreover, that the shrink process can take place at a temperature that is 30°C lower than for conventional PE shrink film (BASF Ecovio Shrink film, 2013).

PLA is also very suitable for making shrink films and is mainly applied for shrink labels. In Europe these are produced by e.g. Clondalkin and Penn Packaging.
Alongside these compostable shrink films, it is also possible to make shrink film from bio-PE. The distributor of (Wenterra®) biobased shrink films in the Netherlands is Van der Windt Packaging.

## 8.2 Stretch film

While shrink films are made of LDPE and heat is applied to ensure the films cling tightly around a pallet or product, stretch films are made of LLDPE (which makes them more flexible) and pulled tight by mechanical or manual means. Stretch films are widely used in industry because they are cheaper than shrink films. Biobased stretch films can be made from bio-PE.

| Packaging | Material | Properties | Recycling |
|---|---|---|---|
| Stretch film  | Bio-PE |   |  |
| Shrink film  | Biopolyester |   |  |

EcoLake (UK) sells biodegradable and compostable stretch films of Cortec (EcoCortec, Croatia), but it is not clear whether these are also biobased. Due to the need for extreme flexibility, PLA (a very rigid material) is less suitable for stretch films. Ecoflex is a likelier option, but this material, though compostable, is not yet biobased.

## 8.3 Boxes

Boxes used to pack one or more already packaged items are usually made of corrugated board. Corrugated board is biobased, recyclable (waste paper), biodegradable and compostable.

Boxes with a transparent PLA window are available for display purposes.

For cardboard that needs to be coated, BASF has developed Ecovio® PS, a biodegradable extrusion coating with more than 50% biobased content. This coating adheres well to paper and board. The material is suitable for food contact, provides a good barrier against fluids, fats and smells, and has a temperature stability up to 100°C. The material is particularly recommended for paper- and board-based (food) packaging, including for frozen products. The material can be composted after use, but BASF claims that paper recycling also remains possible.


*Figure 32. Smart biobased packaging systems.*

## 8.4 Crates

Conventional crates for drinks bottles are made of HDPE. These must be sufficiently strong and have good shape retention properties to permit stable stacking under considerable weights. They must also have sufficient impact strength to prevent cracking or breakage when crates are moved or stacked. The company Schoeller Allibert uses biobased Terralene® (bio-PE) of FKuR for the production of its drinks crates.

*Figure 33. Beer crate of Schoeller Allibert based on Terralene® from FKuR. © FKuR Kunststoff GmbH.*

## 8.5 Pallets

Pallets must be sufficiently strong and have good shape retention properties to permit stable stacking under considerable weights. They must also be fireproof and easy to clean. Pallets are mainly made of wood. Wooden pallets are suitable for reuse and can be repaired. Plastic pallets are manufactured through injection moulding using recycled plastics such as PE (recycled HDPE) and PO (recycled PE/PP mix). It is difficult for biobased plastics to compete with cheap recycled plastics.

Axios (Ontario, Canada) manufactures biobased pallets. The material is claimed to be inherently fire-retardant, so that no chemical fire retardants need to be added. Axios pallets are FDA approved and therefore suitable for the pharmaceutical, food and drinks industries. In the end-of-life phase the material can be regranulated, allowing up to 15% to be reused in new pallets. It is unclear which biobased materials Axios uses for these pallets.

Yellow Pallet from Haarlem develops pallets based on banana plants (Yellow Pallet, 2012). In Australia, CSIRO has developed pallets based on compostable starch-bound cellulose fibre composite (Biofiba®) (CSIRO, 2014). CSIRO claims that these Biopallets® are sterile without requiring heat treatment. Inka Pallets (UK) manufactures pallets from pressed wood (Presswood®), so that no heat treatment is necessary. Inka also makes wood fibre composite pallet blocks.

# 9 Disposables

## 9.1 Carrier bags and refuse sacks

Conventional carrier bags and refuse sacks are usually made of recycled PE. The most important requirement for a carrier bag is that it must be strong enough to carry products with the least possible thickness. Refuse sacks must ensure that the waste container remains clean until emptied. Compostable refuse sacks are very suitable for the collection of green waste. Many of these compostable refuse sacks are partly biobased and consist of Ecovio (PLA/Ecoflex) and starch blends. Metabolix has developed an alternative based on PHA/Ecoflex. Compostable carrier bags are often made of the same types of film, but are usually thicker to give the bag sufficient strength. Carrier bag manufacturers advise reusing the compostable carrier bag as a bin liner. Examples of materials and products are:

- Ecovio (PLA/Ecoflex blend);
- Mater-bi (starch/polyester blend);
- Bunzl carrier bags and refuse sacks;
- Moonen carrier bags, fruit & vegetable bags, refuse sacks;
- Van der Windt carrier bags.

*Figure 34. Compostable refuse sacks for organic waste and carrier bags.*

A 100% biobased alternative is available in the form of paper carrier bags. Various retail chains now use carrier bags based on bio-PE (Kruidvat, Jumbo). These bags are recyclable (Plastic Heroes), but not biodegradable or compostable. All bio-PE bags on the European market are manufactured by the German company Papier-Mettler.

Reusable carrier bags are often based on natural fibres such as jute, cotton or banana fibres.

## 9.2 Catering

Conventional disposable catering items are typically made of PS. The main requirements for catering disposables are: approved for food contact, sufficient strength and rigidity for safe eating, sufficient temperature stability for hot foods and drinks, and the least possible thickness to minimise materials consumption. Biobased catering packaging products are now available from various suppliers (Chapter 12). One important sales argument is the biodegradability or compostability of these products.

*Figure 35. Coffee cup based on heat-stable PLA.*

### *9.2.1 Cups for hot drinks*

| Packaging | Material | Properties | Recycling |
|---|---|---|---|
| Coated board | Board based on wood or side streams. PLA or Ecovio coating | | |
| Heat-stable PLA | PLA | | |

Cups for hot drinks must be able to withstand temperatures higher than 90°C. The currently available paper cups typically feature a PE, Ecovio (Ecovio® PS), starch-based (BiomeEasyFlow) or PLA inner coating for the moisture barrier. PLA-coated products are in principle 100% biobased and fully biodegradable and compostable. Such PLA-coated paper cups are used by e.g. KLM (KLM, 2009). Ecovio-coated cups have a high biobased content and are also compostable. Sugarcane board can replace traditional board (Moonen Natural). In May 2014 Huhtamaki and Corbion presented coffee cups based on heat-stable PLA at the Interpack trade fair in Düsseldorf.

#### *9.2.2 Cup lids*

Cup lids keep drinks hot for longer and prevent spillage on the move. As the lid only has contact with evaporating water, the thermal requirements are less stringent than for hot drink cups. Compostable lids for hot and cold drink cups are often made of PLA.

#### *9.2.3 Cups for cold drinks*

| **Packaging** | **Material** | **Properties** | **Recycling** |
|---|---|---|---|
| Coated board  | Board based on wood or side streams. PLA or Ecovio coating |  |  |
| PLA  | PLA |  |  |

Cold drinks cups do not need to be stable at high temperatures and are therefore made of pure PLA. These products are in principle 100% biobased and compostable. The Colombian airline Avianca is one well-known user of PLA cups for serving cold drinks (Avianca, 2010). In the Netherlands this type of cup is frequently used at festivals such as Lowlands. After use, the cups are collected and composted or recycled into PLA in Belgium (Loopla, 2014). Coca-Cola, in conjunction with International Paper (Tennessee, US) and NatureWorks, has developed a compostable PLA-coated paper Ecotainer$^{®}$ cup for soft drinks (NatureWorks, 2009).

#### *9.2.4 Cutlery*

Disposable cutlery requires the right balance between rigidity (the knife and fork must not bend too much during use) and strength (the cutlery must not break easily during use). Biobased cutlery is made from coated wood (Aspenware, Bioware) or on the basis of injection mould grade biodegradable polyester (Ecovio$^{®}$ IS, BioFlex$^{®}$), cellulose acetate (Biograde®), PHA grade (Mirel™) or PLA (Ingeo™, Synterra®). These products are all compostable. Starch PP-based cutlery is also available, which has a lower carbon footprint but is not compostable.

*9.2.5 Plates and dishes*

Plates must, first and foremost, be sturdy. Board is extremely suitable for making disposable plates and dishes but it is important to prevent the plates and dishes from softening due to moisture or fat. A broad range of biobased and compostable products based on paper fibre, palm leaves or sugarcane fibre are available. Products based on sugarcane fibre are claimed to be suitable for use as soup bowls and have a broad temperature stability: resistant to oil up to 150°C, to water up to 100°C, to oven temperatures up to 220°C and to freezer temperatures down to -20°C. They are also microwave resistant (Moonen Roots, 2014). Palm leaf dishes are manufactured by hot-pressing without using glue and are suitable for use in the microwave and freezer (SD Trading, 2013).

*Figure 36. Disposables with a natural look and feel consisting of various biobased materials.*

Alongside board-type products, a range of biobased and compostable plastic plates and dishes is available on the market. Frequently used raw materials are PLA, PLA blends (Ecovio®, BioFlex®) and starch blends (Mater-bi®). Extensive information on this type of products is available in product catalogues of such companies as Huhtamaki (BioWare), Moonen (e.g. Roots), Bunzl and Van der Windt.

## 9.3 Medical / lab

PET and PETG are frequently used materials for medical packaging (Asit Ray, 2013). Important requirements for the packaging are to preserve the sterility of the packaged products, preserve the quality of the packaged medicines and enable optimal usage of the medicines or medical products. For some products, identification of a product or material during the producer-to-end user cycle may be necessary.

Several companies offer materials that are suitable for medical packaging.
Metabolix has a PHA grade (Mirel™ F1006) that has received FDA approval for medical packaging. The material can be processed through injection moulding and is suitable for freezer storage as well as heating in a microwave or boiling water.
Biome Bioplastics has developed a cellulose-based compostable material (BiomeHT90) with a biobased carbon content above 50%. The material can be processed through injection moulding, sheet extrusion and thermoforming, and is suitable for medical instruments that require sterilisation.
Arkema (France) offers Rilsan® Clear G830 Rnew, a transparent polyamide (PA) with 54% biobased content. This material is used by e.g. TricorBraun for the production of medical bottles with low permeability and high tear resistance (Omnexus, 2009). A micro tracer can also be added for identification of the product during the producer-to-end user cycle.
Cereplast (Italy), part of Trellis Earth (US) since July 2014, offers biobased plastic compounds for medical packaging. The materials are based on PLA, PHA, PBS, PBAT, PP and/or thermoplastic elastomer (TPE) and are suitable for injection moulding, extrusion blow moulding, sheet extrusion and thermoforming. These materials can be up to more than 95% biobased (Sustainable Plastics, 2014).

Clear Lam (Illinois, US) supplies a film for medical packaging based on Ingeo PLA with at least 40% biobased content. The film is suitable for high seal speeds.

## 9.4 Other

Various biobased materials are available on the market that are used in combination with other biobased materials. Examples are labels and loose fill materials. Biobased and compostable labels (based on PLA, NatureFlex, paper and bagasse) that are food contact approved and resistant to oil fat, alcohol and water, have (amongst others) been developed by the companies Berkshire Labels and SAP. The labels are based on BioTAK® adhesives and are supllied by Bio4Life. Additionally companies like Moonen Natural and Bunzl offer compostable labels.

Loose fill materials based on starch have already been on the market for a very long time and are supplied by e.g. Moonen and Bunzl. In addition, bubble film and air cushion film can be manufactured on the basis of PLA blends such as BioFlex®.

# 10 Developments

The list below, though not exhaustive, indicates certain important and/or noteworthy developments.

## 10.1 Bio-PET

The currently available bio-PET bottle (PlantBottle™) is based on biobased ethylene glycol. The terephthalic acid component is still fossil-sourced, so that the material is 30% biobased. Several companies are developing biobased paraxylene as a building block for terephthalic acid (Packaging Gateway, 2013). This material is not expected to become commercially available before 2020.

## 10.2 PEF

One alternative for bio-PET is PEF. In this case terephthalic acid is replaced with furandicarboxylic acid, which can be produced more simply and efficiently from biomass (Harmsen, 2012). The most active player in the development of PEF is Avantium. Avantium is working together with such companies as Coca-Cola and Danone on e.g. PEF bottles and other types of packaging.

## 10.3 Transport protection materials

The EU ReBioFoam Project, a consortium including Recticel and Novamont, has developed starch-based 3D foam for transport protection applications (ReBioFoam, 2013).

In the United States, Ecovative Design LLC has developed a material under the brand name EcoCradle™ that can serve as protective packaging during the transportation of products such as domestic appliances and office furniture (Ecovative, 2014). The material consists primarily of agricultural side streams such as straw and seed husks that are bound together by letting mycelium grow on them (Mushroom materials, 2014). Mycelium is the vegetative part of fungi that creates a mass of branching threads. The growth of the fungi is inhibited to prevent the occurrence of traces. The material is reportedly compostable in 30-45 days. Steelcase Inc., a worldwide player in office furniture, was the first to use this material (Steelcase, 2014). In the Netherlands, EcoConsult (Tiel) has carried out research into similar materials (EcoConsult, 2013).

Ingenia, GKID and Wolters Europe have developed a 100% biobased packaging material, Haynest®, consisting of natural fibres and binders (Rijksoverheid, 2013). As

a packaging material, it is suitable for the protection of domestic appliances, furniture and food products. Haynest is compostable in conformity with EN13432.
Fibres are the main components of Haynest and can consist of e.g. grass, straw, linseed and cane (Ingenia, 2014). The binding agents are made from sugar-, starch- or cellulose-based side-products from e.g. the food-processing industry. Haynest claims that the quantity of $CO_2$ released during the production and use of Haynest is four to five times lower than with comparable products made of EPS and pulp paper (Rijksoverheid, 2013).

## 10.4 Edible packaging

The Brazilian fast food chain Bob’s has launched an edible packaging based on rice paper (Packonline, 2013). This packaging can be eaten with the hamburgers, so that customers can sink their teeth straight into the burger without unwrapping it. Bob’s sees this concept as a solution for the litter problem that has dogged the fast-food sector for years; if so, it may prove to be a breakthrough solution for the waste problem.

## 10.5 Alternative biobased materials

Wageningen UR Food & Biobased Research, Biobase Westland and the Plant Ingredients and the Paper and Board Knowledge Centres have developed a method for making good paper pulp from tomato plant leaves and stalks. This pulp can be used to manufacture moulded fibre trays for packing e.g. tomatoes. The manufactured prototype trays emanate a fresh tomato aroma and are green thanks to the processed leaves, but can also be given a different colour and print. Grass is now also being used in paper pulp trays.

# 11 Glossary

| | |
|---|---|
| $AlO_x$ | Aluminium oxide (film coating to protect against light and oxygen) |
| $Al_2O_3$ | Aluminium oxide (film coating to improve barrier properties) |
| ASTM | American Standard for Testing and Materials |
| BDO | 1,4-butanediol |
| Bio-PE | Polyethylene containing biobased materials |
| Bio-PET | Polyethylene terephthalate containing biobased materials |
| $CaCO_3$ | Calcium carbonate (chalk or limestone) |
| $CH_4$ | Methane |
| $CO_2$ | Carbon dioxide |
| EN | European standard |
| EPS | Expanded polystyrene (styrofoam) |
| EVOH | Ethylene vinyl alcohol |
| FDA | Food and Drug Administration |
| HDPE | High-density polyethylene |
| ISO | International Organization for Standardization |
| LDPE | Low-density polyethylene |
| LLDPE | Linear low-density polyethylene |
| NEN | Dutch Standard |
| PA | Polyamide |
| PBAT | Poly(butylene adipate-co-terephthalate) |
| PBS | Polybutylene succinate |
| PE | Polyethylene |
| PEF | Polyethylene furanoate |
| PET | Polyethylene terephthalate |
| PETG | Polyethylene terephthalate glycol-modified |
| PGA | Polyglycolic acid |
| PHA | Polyhydroxyalkanoate |
| PHB | Polyhydroxybutyrate |
| PHBV | Poly(hydroxybutyrate-co-valerate) |
| PLA | Polylactic acid |
| PP | Polypropylene |
| PS | Polystyrene |
| PVA | Polyvinyl acetate |
| PVC | Polyvinyl chloride |
| PVdC | Polyvinylidene chloride |
| $SiO_x$ | Silicon oxide (coating on film to improve barrier properties) |

# 12 Adopters and possible suppliers

| Supplier | Product | URL |
|---|---|---|
| Biobased materials | | |
| BASF (GER) | PLA/Ecoflex blend (Ecovio®), Ecoflex® | www.basf.com/group/corporate/en_GB/brand/ECOVIO |
| Biomer (GER) | PHB (Biomer®) | www.biomer.de |
| Biotec (GER) | Starch blends (BIOPLAST) | www.biotec.de/bioplast |
| Braskem (Brazil) | Bio-PE (I'm green™) | www.braskem.com.br/site.aspx/Im-greenTM-Polyethylene |
| Corbion (Gorinchem, NL) | Heat-stable PLA | www.purac.com/EN/Bioplastics/PLA-applications.aspx |
| DSM (Geleen, NL) | Polyamide-4.10 (EcoPaXX®), Copolyester (Arnitel® Eco) | www.dsm.com/products/ecopaxx/en_US/home.html ; www.dsm.com/products/arnitel/en_US/home.html |
| Ecomann (China) | PHA (Ecomann®) | www.ecomann.com |
| FKuR (Willich, GER) | PLA blends (BioFlex®), Cellulose acetate (Biograde®), Bio-PE (Terralene® = I'm green of Braskem), Fibre-filled PLA materials (Fibrolon®) | www.fkur.com |
| Innovia (UK) | Cellophane films | www.innoviafilms.com/NatureFlex.aspx |
| Metabolix, (Cologne, GER) | PHA (Mirel™) | www.metabolix.com/products/biopolymers |
| Mitsubishi Chemical Europe (GER) | Biobased PBS (GS Pla®) | www.mitsubishi-chemical.de/no_cache/products/bio-polymers/index.html |
| NatureWorks (Naarden, NL) | PLA (Ingeo™) | www.natureworksllc.com |
| Novamont (Italy) | Starch blends (Mater-bi®) | www.novamont.com ; www.novamont.com/default.asp?id=2503 |

| | | |
|---|---|---|
| Plantic (Jena, GER) | Hydroxypropyl starch (Plantic eco Plastic™) | www.plantic.com.au |
| Rodenburg (Oosterhout, NL) | Starch blends (Solanyl®) | www.biopolymers.nl |
| TGBM (China) | PHA (Sogreen™) | www.tjgreenbio.com/en |
| Tianan (China) | PHBV (ENMAT™) | www.tianan-enmat.com |
| Milk and dairy produce | | |
| Nestlé in Brazil | Uses bio-PE (I'm green™) cap on milk carton | www.nestle.com |
| Danone in Germany | Uses PLA (Ingeo™) cup for Activia yoghurt | www.danone.com ; www.greenerpackage.com/bioplastics/danone_first_switch_pla_yogurt_cup_germany |
| Danone in UK | Uses bio-HDPE (I'm green) bottle for Actimel yoghurt drink | www.danone.com ; www.foodmanufacture.co.uk/Manufacturing/Actimel-boost-for-UK-green-plastics |
| NatureWorks in US | Supplies PLA-based (Ingeo™) milk bottle to cooperative in Iowa (US) | www.natureworksllc.com/Ingeo-Earth-Month/Earth-Month-2007/Participating-Partners/EM-Partners-NA/Naturally-Iowa-LLC |
| Tetra Pak (Switzerland) | Manufactures beverage carton cap based on bio-HDPE | www.tetrapak.com/about-tetra-pak/press-room/news/first-bio-based-cap-for-gable-top-carton-packages |
| Fruit juice | | |
| Noble Juice in US | Uses PLA (Ingeo™) bottles for fruit juices | www.natureworksllc.com/News-and-Events/Press-Releases/2006/9-18-06-Noble-Juice-Goes-Natural |
| Odwalla in US | Uses bio-HDPE bottles (PlantBottle™) | www.odwalla.ca/help/PlantBottle.jsp |
| Polenghi (Italy) | Uses PLA (Ingeo™) bottle for lemon juice | www.polenghigroup.it/en/sostenibilita/ |

| Fruit and vegetables | | |
|---|---|---|
| Albert Heijn (Zaandam, NL) | Uses PLA film for organic fruit and vegetables<br>Uses starch-based (Mater-Bi®) film for organic potatoes and vegetables | Cannot be found on AH website. Kesko (Finland) does provide info: www.kesko.fi/en/Responsibility/Topical/Innovation-biodegradable-packaging-material |
| Bio4Pack (Haaksbergen, NL) | Manufactures PLA-based films and starch-based net packaging | www.bio4pack.com |
| Biofutura (Rotterdam, NL) | Supplies containers for Deli based on PLA | www.biofutura.nl |
| FKuR (Willich, GER) | Manufactures PLA-based (BioFlex® A4100 CL / F2201 CL / A4100 CL) raw material for multi-layer film,<br>Makes PLA-based (BioFlex® F1130 / F2110) raw material for fruit nets | www.fkur.com/produkte.html |
| Huhtamaki (Franeker, NL) | Manufactures PLA trays and containers | www2.huhtamaki.com/documents/10502/6e784cdd-0bac-42dc-83f8-9d0f1934cef4; www2.huhtamaki.com/web/foodservice_de/products/product_sector/root/?nodeId=161&rootId=133 |
| Nedupack (Duiven, NL) | Manufactures PLA trays and containers | www.nedupack.com/category/17-PLA-packaging.html |
| Innovia (Merelbeke, B) | Manufactures laminated cellulose-based (NatureFlex™) film for fruit and vegetables | www.innoviafilms.com/NatureFlex/Applications/Fresh-Produce.aspx |
| Novamont (Italy) | Manufactures starch blends (Mater-bi®) for translucent films | www.novamont.com |
| Toyota Tsusho Europe (Düsseldorf, GER) | Manufactures 30% biobased bio-PET (GLOBIO) trays | www.globio.jp |

| | | |
|---|---|---|
| VDH Concept (Schoten, B) | Supplies up to 85% biobased and compostable bags (JBreeze®) for potatoes, onions and carrots<br>Supplies paper pulp trays (EcoBox) with transparent PLA lids and PLA (NatureFlex) flowpack film | www.vdhconcept.com |
| Willem Dijk A.G.F. (Enschede, NL) | Sells potatoes in compostable starch-based bag | www.willemdijk.nl ; www.agf.nl/artikel/69026/Nieuwe-verpakking-Tukker-Tuffels |
| Meat | | |
| Amcor (Culemborg, NL)<br>Taghleef (Koblenz, GER) | Manufactures PLA films with $SiO_x$ coating (Ceramis®-PLA, Extendo™) | www.amcor.com/products_services/Ceramis_Biodegradable_Films.html ; www.ti-films.com/global/en/press-releases/nativia-and-extendo-films-best-protection-against-migration-of-mineral-oils-9024 |
| MS Folien (Kempten, GER) | Manufactures film based on polyamide-4.10 (EcoPaXX®) with 70% biobased content and high oxygen barrier for food packaging | www.dsm.com/campaigns/k2013/en_us/news/2013-04-02-mf-filmn-introduces-first-film-made-from-dsms-ecopaxx.html |
| Bio4Pack (Haaksbergen, NL) | Manufactures PLA/cellophane film | www.bio4pack.com |
| Depron (Weert, NL) | Manufactures trays based on PLA | www.depron.nl/materialen/pla |
| Elliot (UK) | Manufactures absorbent pads (Dry-Line®) suitable for meat | www.elliottabsorbents.co.uk/en/dryline.html |
| Innovia (Merelbeke, B) | Manufactures laminated cellulose-based (NatureFlex™) film | www.innoviafilms.com/NatureFlex/News/Media-Centre.aspx?id=8 ; www.innoviafilms.com/NatureFlex/Applications/Meat.aspx |

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| Coopbox (Italy) | Manufactures (foamed) PLA (Ingeo™) trays | www.coopbox.it/Naturalbox |
| Plantic (Jena, GER) | Manufactures high amylose starch-based material (Plantic eco Plastic™) for production of barrier film and containers | www.plantic.com.au/technologies/120227%20Extended%20Shelf%20Life%20Case%20Study%20new%20pic%202.pdf ; www.plantic.com.au/technologies/120227%20Outback%20Spirit%20Trays%20Case%20Study.pdf |
| Ter Beke (B) | Uses coated paper | www.terbeke.com |
| Fish | | |
| Coopbox (Italy) | Manufactures (foamed) PLA (Ingeo™) trays | www.coopbox.it/Naturalbox |
| Profish (Twello, NL) | Uses starch-based (Plantic eco Plastic™) containers with 60-80% biobased content | www.profish.nl ; www.profish.nl/nieuws/profish-introduceert-nieuwe-verpakking |
| Synbra (Etten-Leur, NL) | Manufactures PLA (BioFoam®) foam boxes, suitable for transportation of fish | www.biofoam.nl ; www.synprodo.nl/en/2/236/what_is_biofoam.aspx |
| Cheese | | |
| Bio4Pack (Haaksbergen, NL) | Manufactures PLA-based film | www.bio4pack.com |
| Clear Lam in US | Uses PLA-based (50%) film | www.clearlam.com/news/article.aspx?articleId=23 ; www.foodproductiondaily.com/Packaging/Bio-based-food-packaging-rolled-out-for-cheese-producer |
| Coopbox (Italy) | Manufactures (foamed) PLA (Ingeo™) trays | www.coopbox.it/Naturalbox |
| Innovia, (Merelbeke, B) | Manufactures laminated cellulose-based (NatureFlex™) film | www.innoviafilms.com/NatureFlex/Applications/Dairy.aspx ; www.innoviafilms.com/NatureFlex/Case-Study.aspx?id=5 |

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| Butter | | |
| Innovia, (Merelbeke, B) | Manufactures laminated cellulose-based (NatureFlex™) film | www.innoviafilms.com/NatureFlex/Applications/Dairy.aspx |
| Bread | | |
| Amcor Flexibles | Manufactures bio-PE bread bag for Hovis | www.bioplasticsmagazine.com/en/news/meldungen/Amcor-supports-greening-of-bread-packaging-in-UK.php |
| Biofutura (Rotterdam, NL) | Supplies paper bread bag and sandwich containers with PLA window<br>Supplies starch-based sandwich bags (Mater-bi®) | www.biofutura.nl |
| Hovis (UK) | Uses bio-PE bread bags for highest segment | www.bioplasticsmagazine.com/en/news/meldungen/Amcor-supports-greening-of-bread-packaging-in-UK.php |
| Oerlemans (Genderen, NL) | Manufactures bio-PE (I'm green™) bags | www.oerlemansplastics.nl/nl/Nieuws/Bioplastics- |
| Innovia, (Merelbeke, B) | Manufactures laminated cellulose-based (NatureFlex™) film | www.innoviafilms.com/NatureFlex/Applications/Biscuit-and-Bakery.aspx |
| Sidaplax (B) | Manufactures PLA (Ingeo™) films | www.earthfirstpla.com |
| Eggs | | |
| Biopla (China) | Manufactures PLA egg boxes | www.2wplastic.com/PLA-Cold-Tray.htm |
| Huhtamaki (Franeker, NL) | Manufactures paper pulp-based egg boxes | www.huhtamaki.com/web/molded-fiber/products-solutions/egg-packaging |
| ISAP (Italy) | Manufactures PLA egg boxes | www.innovations.eu.com/FishWrap/Oct-2003/28.htm |
| Kwetters (Veen, NL) | Packs organic eggs in grass pulp trays | www.kwetters.com/nl/producten/assortiment.aspx |
| Paperfoam (Barneveld, NL) | Manufactures starch cellulose fibre-based (Paperfoam®) egg boxes | www.paperfoam.nl |

| Freezer | | |
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| BASF (GER) | Extrusion coating (Ecovio® PS 1606) for paper/board with claim that paper recycling remains possible | www.plasticsportal.net/wa/plasticsEU~en_GB/portal/show/content/products/biodegradable_plastics/ecovio_applications_paper_coating ; www.plasticsportal.net/wa/plasticsEU~de_DE/function/conversions:/publish/common/upload/biodegradable_plastics/ecovio_PS_1606.pdf |
| Biofutura (Rotterdam, NL) | Supplies paper ice cream cups with PLA coating | www.biofutura.nl |
| Coop in Sweden | Uses compostable coating (Mater-bi®) on cardboard frozen fruit packaging | www.bio-based.eu/news/environmental-choice-material-coop-updated-packaging ; www.iggesund.com/en/Invercote/Invercote/Bio-coatings |
| DSM (Geleen, NL) | Manufactures 50% biobased copolyester (Arnitel® Eco) based on rape seed oil for 'freezer-to-oven' films | www.dsm.com/products/arnitel/en_US/markets/packaging.html |
| FKuR (Willich, GER) | Manufactures PLA-based (BioFlex® F2110 / A4100 CL) material for bags | www.fkur.com/produkte.html |
| Metabolix, (Cologne, GER) | Manufactures PHA-based (Mirel™ F1006) material suitable for freezer, microwave and boiling water | www.metabolix.com/Products/Biopolymers/Functional-Biodegradation/P1004-F1006 |
| Sandros (GER) | Ice cream packaged in PLA-foam (BioFoam®) thermobox | www.sandros-bio.de |

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| Soft drinks | | |
| Coca-Cola | Manufactures and uses bio-PET (PlantBottle™) with 22.5% biobased content for bottles | www.coca-colanederland.nl/Recycling.aspx?gclid=CL7o1eKpqLsCFY_MtAod7H8A1Q ; www.coca-colacompany.com/our-company/introducing-plantbottle |
| Toyota Tsusho Europe (Düsseldorf, GER) | Manufactures bio-PET with 30% biobased content for bottles | www.globio.jp |
| Water | | |
| Dasani in US | Uses bio-PET with 22.5% biobased PlantBottle™ | www.dasani.com |
| Cool Change in Australia | Uses PLA (Ingeo™) bottle for mineral water | greend.com.au/content/green-news-and-events/health-and-lifestyle/bottled-water-leading-sustainable-packaging-revolution |
| Sant'Anna in Italy | Uses PLA (Ingeo™) bottle for mineral water | www.santanna.it/en/acqua_en/bio_bottle_en.html |
| Toyota Tsusho Europe (Düsseldorf, GER) | Manufactures bio-PET with 30% biobased content for bottles | www.globio.jp |
| Sauces | | |
| Ampac (GER) | Manufactures biobased and compostable pouches | www.ampaconline.com/innovations/biopouch |
| Gualapack (Italy) | Manufactures bio-PE (CheerNEXT) pouches based on LamiNEXT film of Safta | www.gualapack.com/en/news/newsinten/num/7/cheernext-bio-based-premade-stand-up-spouted-pouch ; www.safta.eu/en/sustainable-packaging-biodegradable-packaging |

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| Heinz | Uses bio-PET (PlantBottle$^{TM}$) with up to 30% biobased content for tomato ketchup bottles | www.european-bioplastics.org/wp-content/uploads/2011/04/fs/Packaging_eng.pdf |
| Toyota Tsusho Europe (Düsseldorf, GER) | Manufactures bio-PET with 30% biobased content for bottles | www.globio.jp |
| Biscuits and bakery products | | |
| Innovia, (Merelbeke, B) | Manufactures laminated cellulose-based (NatureFlex$^{TM}$) film for biscuits | www.innoviafilms.com/NatureFlex/Applications/Biscuit-and-Bakery.aspx |
| Leclerc (Rotterdam, NL) | Uses bioplastic packaging for biscuits | www.european-bioplastics.org/press/press-pictures/food-packaging |
| Crisps | | |
| Genpak (Canada) | Manufactures compostable cellulose-based (NatureFlex$^{TM}$) film with 90% biobased content for Boulder Canyon crisps | www.innoviafilms.com/News---Events/Media-Centre/Boulder-Canyon-adopts-Metallised-NatureFlex-Film.aspx ; www.genpakca.com ; www.bouldercanyonfoods.com |
| Innovia, (Merelbeke, B) | Manufactures laminated cellulose-based (NatureFlex$^{TM}$) film | www.innoviafilms.com/NatureFlex/Applications/Crisps-Chips.aspx |
| SunChips in US | Uses 90% biobased (partially PLA) compostable bag | www.greenbiz.com/news/2010/03/10/sunchips-stacks-first-compostable-bags-canadian-shelves |
| Confectionery and chocolate | | |
| Alce Nero in Italy | Uses cellulose-based (NatureFlex$^{TM}$) film for chocolate | www.innoviafilms.com/News---Events/Media-Centre/Chocolate-Wrapped-in-Compostable-Packaging-Film.aspx |
| Cadbury in Australia | Uses starch-based (Plantic® R1) biodegradable tray for Cadbury® Eden chocolates | www.plantic.com.au/Case%20Studies/Plantic_Cadbury_CS.pdf |

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| Innovia, (Merelbeke, B) | Manufactures laminated cellulose-based (NatureFlex™) film for confectionery and chocolate | www.innoviafilms.com/NatureFlex/Applications/Confectionery-Candy.aspx |
| Marks and Spencer in UK | Uses starch-based (Plantic®) biodegradable tray for Swiss chocolate | www.plantic.com.au/Case%20Studies/Plantic_MS_CS.pdf |
| Van der Windt (Honselersdijk, NL) | Supplies biobased (Wenterra®) film for confectionery | www.vanderwindt.com/site/nl/product/770-natureflexfilm |
| Coffee | | |
| Amcor (Zutphen, NL and Ghent, B) | Manufactures partially biobased coffee packaging that is also compostable | www.amcor.com/about_us/media_centre/news/131878608.html www.benecafe.eu/en/bio-based-packaging |
| BASF (GER) | Manufactures PLA-based (Ecovio® IS1335) compostable plastic for coffee packaging | www.basf.com/group/pressrelease/P-13-302 |
| Beanarella (Switzerland) | Packages coffee in compostable PLA-based cups (Ecovio®) | www.beanarella.ch ; www.bioplastics.basf.com/ecovio.html |
| Beyers Koffie (Breendonk, B) | Sells coffee in a 58% biobased packaging, via e.g. Makro and Sligro | www.beyers.eu ; www.benecafe.eu |
| Caffe Prima (New Zealand) | Sells coffee in compostable packaging | www.caffeprima.co.nz/bury-me |
| Corbion (Gorinchem, NL) | Showed demo of heat-stable PLA coffee capsules | www.foodbev.com/news/franois-de-bie-from-corbion-and-the-adva |
| Ethical Coffee Company (in various European countries) | Uses capsules which are claimed to be based on biofibre and starch | www.ethicalcoffeecompany.com/en/capsule-biodegradable-biodegradabilite |
| Innovia, (Merelbeke, B) | Manufactures laminated cellulose-based (NatureFlex™) film | www.innoviafilms.com/NatureFlex/Applications/Coffee.aspx |

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| Swiss Coffee Company (Switzerland) | Packages Beanarella coffee in cups of injection mouldable PLA-based Ecovio® IS1335 and an outer wrapper made of paper Ecovio®-compostable barrier film | www.beanarella.ch ; www.basf.com/group/pressrelease/P-13-302 ; www.bioplastics.basf.com/ecovio.html |
| Tea | | |
| Ahlstrom (Finland) | Manufactures pyramid teabags (BioWeb®) based on PLA (Ingeo™) | www.ahlstrom.com/en/Products/Food-and-Beverage/Tea-bags/BioWeb-Ultrasonic--heatsealable-teabags |
| Innovia, (Merelbeke, B) | Manufactures laminated cellulose-based (NatureFlex™) film | www.innoviafilms.com/NatureFlex/Applications/Tea.aspx |
| Twinings (UK) | Uses compostable cellulose-based (NatureFlex™) film to wrap around the teabag | www.sustainableisgood.com/blog/2009/02/twiningstea.html ; www.innoviafilms.com/News---Events/Media-Centre/Twinings-teabags-wrapped-in-compostable-NatureFlex.aspx |
| Dry food (grains, pasta, rice, nuts) | | |
| Amcor (Zutphen, NL) | Manufactures compostable film laminate based on cellulose (NatureFlex™) and starch (Mater-Bi®) for Jordans cereal products in the UK | www.amcor.com ; www.innoviafilms.com/News---Events/Media-Centre/Jordans-Muesli-Bag-Uses-NatureFlex%E2%84%A2-Film.aspx |
| Bio4Pack (Haaksbergen, NL) | Manufactures PLA-based film for nuts and rice | www.bio4pack.com |
| Hain Celestial, (Aalter, B) | Uses compostable cellulose-based (NatureFlex™) film with 95% biobased content for rice | www.innoviafilms.com/News---Events/Media-Centre/Organic-Rice-In-Compostable-Packaging-Film.aspx ; www.hain-celestial.eu |
| Innovia, (Merelbeke, B) | Manufactures laminated cellulose-based (NatureFlex™) film | www.innoviafilms.com/NatureFlex/Applications/Dried-Foods.aspx |

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| Nedupack (Duiven, NL) | Manufactures PLA trays and containers | www.nedupack.com/category/17-PLA-packaging.html |
| Detergents | | |
| Ecover (B) | Uses bio-PE Bottles (Plant-astic) for ecological detergents | uk.ecover.com/en/why-ecover/faqs/#Green_PE_Packaging-243 |
| Plantic (Jena, D) | Manufactures starch-based (Plantic®) material for biodegradable packaging for insecticide against dengue mosquitoes | www.plantic.com.au/Case%20Studies/Plantic_BLO_CaseStudy.pdf |
| Personal care products | | |
| FKuR (Willich, GER) | Manufactures bio-PE (Terralene®) material for bottles | www.fkur.com/produkte.html |
| Innovia (Merelbeke, B) | Manufactures laminated cellulose-based (NatureFlex™) film for personal care products | www.innoviafilms.com/NatureFlex/Applications/Home-and-Personal-Care.aspx |
| Novamont (Italy) | Manufactures starch blends (Mater-bi®) for personal care products | www.novamont.com/default.asp?id=504 |
| Toyota Tsusho Europe (Düsseldorf, GER) | Manufactures bio-PET with 30% biobased content for bottles | www.globio.jp |
| Cosmetics | | |
| FKuR (Willich, GER) | Manufactures PLA-based materials: BioFlex® S5640 for pots/lids, BioFlex® F6510 for bottles | www.fkur.com/produkte.html ; www.fkur.com/anwendungen/kosmetikartikel.html |
| Innovia (Merelbeke, B) | Manufactures laminated cellulose-based (NatureFlex™) film | www.innoviafilms.com/NatureFlex/Applications/Home-and-Personal-Care.aspx |
| NatureWorks (Naarden, NL) | Manufactures PLA (Ingeo™ 3100HP) for cosmetics | www.natureworksllc.com/Ingeo-Earth-Month/Earth-Month-2007/Participating-Partners/EM-Partners-NA/Cargo |

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| Electronics | | |
| FKuR (Willich, GER) | Manufactures PLA-based materials: BioFlex® S5630 for inlays, Biograde® C7500 for pens and keyboards | www.fkur.com/produkte.html |
| Paperfoam (Barneveld, NL) | Manufactures starch cellulose fibre-based (Paperfoam®) packaging for diverse electronics products | www.paperfoam.nl/portfolio.html |
| Synbra (Etten-Leur, NL) | Manufactures expanded PLA (BioFoam®) foam, similar to EPS | www.biofoam.nl/index.php?page=physical-and-thermal-properties |
| Office | | |
| FKuR (Willich, GER) | Manufactures PLA-based materials: BioFlex® F6510 for pens, Biograde® C7500 for pens and keyboards | www.fkur.com/produkte.html |
| Henkel (GER) | Manufactures Pritt correction pen roller with 89% PLA content (Ingeo™) | www.natureworksllc.com/News-and-Events/Press-Releases/2010/09-08-10-Henkel-Launch |
| Kaneka (Geel, B) | Manufactures PHA (Aonilex™) material for e.g. document sleeves | www.kaneka.be/new-business/kaneka-biopolymer-aonilex |
| Paper Mate (Australia) | Manufactures PHA (Mirel™) pens | www.papermategreen.net/au/products.html |
| Rodenburg (Oosterhout, NL) | Manufactures starch-based (Solanyl®, FlourPlast®) material for a variety of products | www.biopolymers.nl |
| Horticulture | | |
| Biofibre (GER) | Manufactures plant pots (NaturePots) with 70% biofibre that is biodegradable in the soil | www.biofibre.de/index.php/naturepot/articles/biofibre-naturepot-125.html |
| Desch Plantpak (Waalwijk, NL) | Manufactures PHA (D-Grade®) flower pots and trays | www.desch-plantpak.com/en/D-grade.aspx |
| FKuR (Willich, GER) | Manufactures PLA-based materials: BioFlex® F1130 and F2110 for nets | www.fkur.com/produkte.html |

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| Hapece (Assen, NL) | Manufactures laminate consisting of cellulose-based NatureFlex™ NVS, paper and PLA for flower bulbs | www.innoviafilms.com/News---Events/Media-Centre/NATUREFLEX%E2%84%A2-FILM-BLOSSOMS-INTO-FLOWER-BULB-PACKAGI.aspx |
| Jiffy Products (Moerdijk, NL) | Supplies biofibre flower pots (Jiffypots®) and plant propagation trays (Jiffystrips®) | www.jiffypot.com |
| Lankhorst (Sneek, NL) | Manufactures binding twine based on PLA (Bio Twine®), viscose-jute (Vertomil®), viscose-cotton (Ecolin®) and jute (Prima® and Vertoma®) | www.elite-horti.com/bio-twine.php |
| Metabolix (Cologne, GER) | Manufactures PHA (Mirel™ P4001) for flower pots, clips and cut flower film | www.metabolix.com/Products/Biopolymers/Functional-Biodegradation ; www.metabolix.com/sites/default/files/MirelP4001Datasheet.pdf |
| Novamont (Italy) | Manufactures starch blends (Mater-bi®) for horticulture | www.novamont.com/default.asp?id=504 |
| Plantic (Jena, GER) | Manufactures starch-based (Plantic eco Plastic™) material for biodegradable flower pots | www.plantic.com.au/Case%20Studies/PLANTIC_PLANTPOTS_CS.pdf |
| Synbra (Etten-Leur, NL) | Makes expanded PLA (BioFoam®) foam for e.g. plant propagation trays | www.biofoam.nl/index.php?page=physical-and-thermal-properties |
| Van der Windt (Honselersdijk, NL) | Manufactures PLA films for cut flowers | www.vanderwindt.nl/site/en/mainmenu/news/news/tulipsleevemadefromrenewablerawmaterial |
| Suppliers of biofibre twine and burlap cloths | Hemp<br>Jute<br>Cotton<br>Manila hemp | www.elite-horti.com/bio-degradable.php<br>www.jutewereld.nl<br>www.npibv.com<br>www.touwenwinkel.nl<br>www.vannifterik.com<br>www.wildeboer-groep.nl/tuinbouw-producten |

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| Shrink film | | |
| BASF (GER) | Manufactures PLA- partially biobased polyester (Ecovio® FS) shrink film | www.plasticsportal.net/wa/plasticsEU~en_GB/portal/show/content/products/biodegradable_plastics/ecovio_applications_shrink_film |
| Chlondalkin (Wieringerwerf, NL) | Manufactures PLA shrink sleeves | www.clondalkingroup.com/globalhome-ge/flexible-packaging/europe/creative-solutions/shrink-sleeves |
| Penn Packaging (UK) | Manufactures PLA shrink sleeves | www.penn-packaging.co.uk/sleeving |
| Van der Windt (Honselersdijk, NL) | Supplies biobased (Wenterra®) shrink film | www.vanderwindt.com/site/en/product/996-wenterra-krimpfilm ; www.wentus.de/index.php?id=97 |
| Stretch film | | |
| EcoCortec (Croatia) | Manufactures compostable polyester stretch film (EcoWrap™), it is unclear whether this is biobased | www.ecocortec.hr/en/docs/PDS/Eco_Wrap.pdf |
| EcoLake (UK) | Supplies compostable polyester stretch film (EcoWrap™), it is unclear whether this is biobased | www.ecolake.co.uk/biodegrading_and_composting_plastic_films.html |
| FKuR (Willich, GER) | Manufactures raw material for stretch film based on bio-PE (I'm green™ SLH118) | www.fkur-biobased.com/fileadmin/user_upload/01-fkur-biobased/Produkte/Filmnextrusion/SLH118/LLDPE_SLH118.pdf |
| Polythene (UK) | Manufactures bio-PE (Polyair™) stretch film | www.polytheneuk.co.uk/products/polyair |
| Boxes | | |
| BASF (GER) | Manufactures raw material (Ecovio® PS) for coating on paper and board | www.plasticsportal.net/wa/plasticsEU~en_GB/portal/show/content/products/biodegradable_plastics/ecovio_applications_paper_coating |

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| Bunzl (Almere, NL) | Supplies boxes with PLA window | foodservice.bunzl.nl/sites/bunzlalmere/files/Bewust%20Bunzl%20catalogus_0.pdf |
| Moonen Natural (Weert, NL) | Supplies boxes with PLA window | www.moonennatural.com/disposables-in-een-retailverpakking.html |
| Crates | | |
| FKuR (Willich, GER) | Manufactures bio-PE-based (Terralene®) raw material for crates | www.fkur.com/produkte.html |
| Schoeller Allibert (GER) | Manufactures beer crates based on bio-PE (Terralene®) | www.schoellerallibert.com |
| Pallets | | |
| Axios (Canada) | Manufactures pallets based on ‘bio resin’, recyclable | www.axiosma.com/environment/index.html |
| CSIRO (Australia) | Develops pallets (Biopallets®) based on cellulose fibres, starch and binders | www.csiro.au/~/media/CSIROau/Flagships/Future%20Manufacturing/BioFiba%20Fact%20Sheet.pdf |
| Inka Pallet (UK) | Manufactures presswood pallets and wood fibre composite pallet blocks | www.inkapallets.co.uk |
| Yellow Pallet (Haarlem, NL) | Develops pallets based on banana plants | www.yellow-pallet.com |
| Carrier bags / refuse sacks | | |
| BASF (GER) | Manufactures PLA/Ecoflex (Ecovio®) raw material for carrier bags and sacks | www.plasticsportal.net/wa/plasticsEU/portal/show/content/products/biodegradable_plastics/ecovio |
| Biofutura (Rotterdam, NL) | Supplies biobased and compostable vest type carrier bag | www.biofutura.nl |
| Bunzl (Almere, NL) | Supplies biobased (starch, jute, paper) carrier bags | foodservice.bunzl.nl/sites/bunzlalmere/files/Bewust%20Bunzl%20catalogus_0.pdf |

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| FKuR (Willich, GER) | Manufactures PLA-based (BioFlex® F1130 / F2110) raw material for carrier bags and refuse sacks | www.fkur.com/produkte.html |
| Jumbo | Uses bio-PE (I'm green™) bags for fruit | |
| Kruidvat | Uses bio-PE (I'm green™) carrier bags | |
| Moonen Natural (Weert, NL) | Supplies starch-based carrier bags, fruit & vegetable bags, refuse sacks and jute shoppers | www.moonennatural.com/carrier bags.html ; www.moonennatural.com/compostable-groente-en-fruit-zakken-refuse sacks.html |
| Novamont (Italy) | Manufactures starch-polyester (Mater-bi®) raw material for carrier bags and sacks | www.novamont.com/default.asp?id=1100 |
| Oerlemans (Genderen, NL) | Manufactures starch- and PLA-based film and carrier bags | www.oerlemansplastics.nl/producten/view_article/109/1770 |
| Papier-Mettler (GER) | Manufactures bio-PE (I'm green™) carrier bags | www.papier-mettler.com/Ueber-uns_Umwelt-Nachhaltigkeit_Materialien_Im-green.htm |
| Van der Windt (Honselersdijk, NL) | Supplies biobased and compostable carrier bags and refuse sacks | www.vanderwindt.com/site/en/product/1004-hemdcarrier bags ; www.vanderwindt.com/site/en/product/901-bio-based-afvalzakken |
| Catering (broad package) | | |
| Biofutura (Rotterdam, NL) | Supplies cups for hot and cold drinks, cup lids, wine glasses, cutlery, plates, dishes, containers, bread bags, sandwich containers, sandwich bags | www.biofutura.nl |
| BioHart (Uden, NL) | Manufactures biobased and compostable plates, containers, cutlery and film | www.biohart.nl/html/biobased-plastic.html |

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| Biopak (Australia, New Zealand) | Manufactures cups for hot drinks based on PLA-coated paper (BioCup), PLA lids and cutlery based on PLA and a starch/PP blend | www.biopak.com.au/products.php?id=23 |
| Bunzl (Almere, NL) | Supplies cups for hot and cold drinks, cup lids, straws, cutlery, plates, dishes and containers | foodservice.bunzl.nl/assortiment/duurzame-disposables ; foodservice.bunzl.nl/sites/bunzlalmere/files/Bewust%20Bunzl%20catalogus_1.pdf |
| Moonen Natural (Weert, NL) | Supplies cups for hot and cold drinks, cup lids, cutlery, plates and dishes | www.moonennatural.com/volledig-assortiment-van-compostable-packaging-en-compostable-disposables-van-hernieuwbare-materialen.html |
| Huhtamaki (Franeker, NL) | Manufactures cups for hot and cold drinks, cup lids and cutlery (Bioware®) | www2.huhtamaki.com/web/foodservice_de/bioware ; www.pfmonline.com/manufacturers/huhtamaki/documents/huhtamaki_sustainability.pdf |
| StalkMarket (UK) | Manufactures cups for cold drinks, cutlery and containers (Jaya) based on PLA (Ingeo™), and plates and dishes (StalkMarket) based on sugarcane fibre | www.stalkmarketproducts.com/products/category/jaya ; www.stalkmarketproducts.com/products/category/stalkmarket |
| Van der Windt (Honselersdijk, NL) | Supplies cups for hot and cold drinks, plates and dishes | www.vanderwindt.com |
| Cups for hot drinks (compostable) | | |
| BASF (GER) | Manufactures PLA-Ecoflex (Ecovio® PS) raw material suitable for extrusion coating on paper and board, >50% biobased | www.plasticsportal.net/wa/plasticsEU~en_GB/portal/show/content/products/biodegradable_plastics/ecovio_applications_paper_coating |

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| Biofutura (Rotterdam, NL) | Supplies paper cups with PLA coating<br>Supplies reusable washable microwave-safe cups based on rice hulls and lignin | www.biofutura.nl |
| BioLogical Solutions (Rotterdam, NL) | Supplies coffee cups (NatureCup) based on paper with PLA inner coating | http://biologicalsolutions.nl/nieuwe-producten |
| Biome Bioplastics (UK) | Supplies cellulose-based compostable material (BiomeHT90) for injection moulding, sheet extrusion and thermoforming, biobased carbon content >50% | www.biomebioplastics.com/product-ranges/high-temperature |
| Biome Bioplastics (UK) | Supplies starch-based coating for paper (BiomeEasyFlow), GMO free, no plasticisers, good fat barrier | www.biomebioplastics.com/product-ranges/coating |
| Bunzl (Almere, NL) | Supplies paper-based coffee cups with biodegradable polyester (Ecoflex®) inner coating | foodservice.bunzl.nl/sites/bunzlalmere/files/Bewust%20Bunzl%20catalogus_1.pdf |
| Corbion (Gorinchem, NL) | Heat-stable PLA for coffee cups | www.purac.com/EN/Bioplastics/PLA-applications/High-heat-packaging.aspx |
| Huhtamaki (Franeker, NL) | Manufactures coffee cups based on paper with PLA inner coating (Bioware®) and based on heat-stable PLA | www2.huhtamaki.com/web/foodservice_de/products/product_sector/root/category ; www.purac.com/_sana_/handlers/getfile.ashx/14d85c7d-3ec5-48b3-a428-e04458a984cb/Corbion+Purac+at+K+2013+14102013.pdf |
| International Paper (US) | Manufactures paper-based coffee cups with PLA inner coating (Ecotainer®) | www.internationalpaper.com/US/EN/Products/ecotainer/Aboutecotainer.html |

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| Moonen Natural (Weert, NL) | Supplies coffee cups based on sugarcane paper with PLA inner coating | www.moonennatural.com/compostable-koffiebeker.html ; www.moonenpackaging.com/en/node/470 |
| Van der Windt (Honselersdijk, NL) | Supplies paper cup with PLA coating | www.vanderwindt.com/site/en/product/798-drinkbeker-bio |
| Cup lids (compostable) | | |
| Biofutura (Rotterdam, NL) | Supplies transparent PLA lids | www.biofutura.nl |
| Bunzl (Almere, NL) | Supplies transparent PLA-based lids | foodservice.bunzl.nl/sites/bunzlalmere/files/Bewust%20Bunzl%20catalogus_1.pdf |
| Moonen Natural (Weert, NL) | Supplies transparent PLA lids | www.moonennatural.com/composstable-rietje-composteerbaar-deksel-composterbaar-roerstaafje.html |
| Huhtamaki (Franeker, NL) | Manufactures PLA lids (Bioware®) | www2.huhtamaki.com/web/foodservice_de/products/product_sector/root/category?categoryId=163&rootId=133&nodeId=161 |
| International Paper (US) | Manufactures PLA lids (Ecotainer®) | www.internationalpaper.com/documents/EN/Foodservice/ecotainer_Product_Br.pdf |
| Cups for cold drinks (compostable) | | |
| Biofutura (Rotterdam, NL) | Supplies PLA-based cups and wine glasses | www.biofutura.nl |
| Biome Bioplastics (UK) | Supplies cellulose-based compostable material (BiomeHT90), biobased carbon content >50% | www.biomebioplastics.com/product-ranges/high-temperature |
| Bunzl (Almere, NL) | Supplies transparent PLA-based cups | foodservice.bunzl.nl/sites/bunzlalmere/files/Bewust%20Bunzl%20catalogus_1.pdf |
| FKuR (Willich, GER) | Manufactures cellulose-based (Biograde® C6509 CL) raw material for cups | www.fkur.com/produkte.html |

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| Huhtamaki (Franeker, NL) | Manufactures transparent cups based on pure PLA (Bioware®) | www2.huhtamaki.com/web/foodservice_de/products/product_sector/root/category?categoryId=162&nodeId=161&rootId=133 |
| Moonen Natural (Weert, NL) | Supplies transparent cups based on pure PLA | www.moonennatural.com/compostable-disposables.html |
| NatureWorks (Naarden, NL) | Manufactures PLA (Ingeo™) for (transparent) cups | www.natureworksllc.com/News-and-Events/Press-Releases/2010/12-07-10-Cold-Cup-LCA |
| StalkMarket (UK) | Manufactures cups for cold drinks (Jaya) based on PLA (Ingeo™) | www.stalkmarketproducts.com/products/category/jaya |
| Van der Windt (Honselersdijk, NL) | Supplies paper cups with PLA coating | www.vanderwindt.com/site/en/product/798-drinkbeker-bio |
| Cutlery (compostable) | | |
| BASF (GER) | Manufactures biodegradable polyester-based (Ecovio® IS) raw material for injection moulding, >50% biobased content | www.plasticsportal.net/wa/plasticsEU~en_GB/portal/show/content/products/biodegradable_plastics/ecovio_applications_injection_molding |
| Biofutura (Rotterdam, NL) | Supplies cutlery based on PLA and wood | www.biofutura.nl |
| Biome Bioplastics (UK) | Supplies cellulose-based (BiomeHT90) raw material, biobased carbon content >50% | www.biomebioplastics.com/product-ranges/high-temperature |
| Bunzl (Almere, NL) | Supplies wooden cutlery and cutlery based on cellulose acetate filled with $CaCO_3$ | foodservice.bunzl.nl/sites/bunzlalmere/files/Bewust%20Bunzl%20catalogus_1.pdf |
| FKuR (Willich, GER) | Manufactures PLA-based (BioFlex® S9533) and cellulose-based (Biograde® C9550) raw material | www.fkur.com/produkte.html |
| Haval (Gemert, NL) | Manufactures heat-stable PLA (Synterra®) cutlery | www.biotulp.nl ; www.haval.nl/disposables/bio-disposables |

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| Huhtamaki (Franeker, NL) | Wooden cutlery and PLA cutlery (Bioware®) | www2.huhtamaki.com/web/foodservice_de/products/product_sector/root/category?categoryId=166&nodeId=161&rootId=133 ; www.pfmonline.com/manufacturers/huhtamaki/documents/huhtamaki_sustainability.pdf |
| SD Trading (Amsterdam, NL) | Supplies coated wooden cutlery | www.sdtrading.eu/aspenware#product |
| StalkMarket (UK) | Supplies cutlery (Jaya) based on PLA (Ingeo™) | www.stalkmarketproducts.com/products/category/jaya |
| Plates and dishes (compostable) | | |
| BASF (GER) | Manufactures biodegradable polyester material (Ecovio® IS), >50% biobased content | www.plasticsportal.net/wa/plasticsEU~en_GB/portal/show/content/products/biodegradable_plastics/ecovio_applications_injection_molding |
| Berry Plastics (US) | Manufactures plates (Abeo™) based on PLA | www.berryplastics.com/catalog/content/corporate/news/news%20articles/berry%20plastics%20announces%20abeo |
| Biofutura (Rotterdam, NL) | Supplies plates, dishes and bowls based on sugarcane fibre and palm leaves<br>Supplies PLA-based dishes and bowls<br>Supplies reusable, washable and microwave-safe dishes and bowls based on rice hulls and lignin | www.biofutura.nl |
| BioLogical Solutions (Rotterdam, NL) | Supplies plates and dishes based on palm leaves | http://biologicalsolutions.nl/nieuwe-producten |
| Biome Bioplastics (UK) | Supplies cellulose-based (BiomeHT90) raw material, biobased carbon content >50% | www.biomebioplastics.com/product-ranges/high-temperature |

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| Bunzl (Almere, NL) | Supplies plates, soup bowls and dishes based on sugarcane paper with PLA coating and based on palm leaves, and PLA-based containers | foodservice.bunzl.nl/sites/bunzlalmere/files/Bewust%20Bunzl%20catalogus_1.pdf |
| Depron (Weert, NL) | Manufactures PLA-based plates, dishes and containers | www.depron.nl/materialen/pla |
| FKuR (Willich, GER) | Manufactures cellulose-based (Biograde® C6509 CL) raw material | www.fkur.com/produkte.html |
| Moonen Natural (Weert, NL) | Supplies plates, soup bowls and dishes based on sugarcane fibre, recyclable as waste paper | www.moonennatural.com/suikerriet.html |
| Novamont (Italy) | Manufactures starch polyester (Mater-bi®) raw material | www.novamont.com/default.asp?id=521 |
| SD Trading (Amsterdam, NL) | Supplies dishes based on palm leaves (Hampi), sugarcane fibre (Sucadrops) or ordinary paper fibre (WASARA) | www.sdtrading.eu/hampi#product ; www.sdtrading.eu/sucadrops#about ; www.sdtrading.eu/wasara#about |
| StalkMarket (VK) | Manufactures plates and dishes (StalkMarket) based on sugarcane fibre | www.stalkmarketproducts.com/products/category/stalkmarket |
| Van der Windt (Honselersdijk, NL) | Supplies PLA plates and dishes | www.vanderwindt.com/site/en/product/910-pla-schalen |
| Drinking straws (compostable) | | |
| Bunzl (Almere, NL) | Supplies PLA drinking straws | foodservice.bunzl.nl/sites/bunzlalmere/files/Bewust%20Bunzl%20catalogus_1.pdf |
| FKuR (Willich, GER) | Manufactures PLA-based (BioFlex® F6510) raw material | www.fkur.com/produkte.html |
| Moonen Natural (Weert, NL) | Supplies drinking straws based on starch | www.moonennatural.com/compostable-rietje-composteerbaar-deksel-composterbaar-roerstaafje.html#composteerbaar%20transparant%20deksel |

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| Medical/lab | | |
| Arkema (France) | Manufactures PA (Rilsan® Clear G830) raw material, 54% biobased content | www.rilsanclear.com/en/rilsan-clear-product-line/rilsan-clear/index.html |
| Biome Bioplastics (UK) | Supplies cellulose-based (BiomeHT90) raw material, biobased carbon content >50% | www.biomebioplastics.com/product-ranges/high-temperature |
| Cereplast (Italy), now part of Trellis Earth (US) | Manufactures compounds for medical packaging based on PLA, PHA, PBS, PBAT | trellisbioplastic.com/wp-content/uploads/2014/08/Hybrid-Injection-Process-Guide.pdf ; www.sustainableplastics.org/companies/cereplast |
| Clear Lam (US) | Supplies PLA-based film | www.clearlam.com/flexiblefilms/products.aspx ; www.plasticstoday.com/articles/clear-lam-introduces-biobased-packaging-material-medical-kit-packaging |
| Metabolix, (Cologne, GER) | Manufactures PHA (Mirel™ F1006) for medical packaging | www.metabolix.com/Products/Biopolymers/Functional-Biodegradation/P1004-F1006 |
| TricorBraun (US) | Supplies sterilisable bottles based on PA (Rilsan® Clear G830) | www.omnexus.com/resources/editorials.aspx?id=23112 |
| Other | | |
| Berkshire Labels (UK) | Manufactures compostable labels based on paper, cellulose (NatureFlex™) and PLA | www.biotak.co.uk |
| Bio4Life B.v., Bleiswijk (NL) | Manufactures self-adhesive compostable (thermal) labels based on NatureFlex™, PLA, paper and agricultural waste | www.bio4life.nl |
| Bunzl (Almere, NL) | Supplies compostable PLA labels, food contact approved Supplies compostable starch-based (Flo-pak) loose fill | foodservice.bunzl.nl/sites/bunzlalmere/files/Bewust%20Bunzl%20catalogus_1.pdf |

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| FKuR (Willich, GER) | Manufactures PLA-based (BioFlex® F1130) raw material for air cushion film | www.fkur.com/anwendungen/luftpolster.html |
| Innovia, (Merelbeke, B) | Manufactures laminated cellulose-based (NatureFlex™) film for labels and lamination of board | www.innoviafilms.com/NatureFlex/Applications/Labels.aspx ; www.innoviafilms.com/NatureFlex/Applications/Board-Lamination.aspx |
| Moonen Natural (Weert, NL) | Supplies compostable PLA labels, food contact approved<br>Supplies compostable loose fill<br>Supplies PLA air cushion film | www.moonennatural.com/compostable-etiketten.html ; www.moonennatural.com/bio-opvulchips.html ; www.moonennatural.com/compostable-luchtkussenfilm.html |
| Recticel (Buren, NL) | Develops starch-based 3D foam | www.recticel.nl ; www.rebiofoam.eu |

# 13 Addresses

## 13.1 R&D and Knowledge Centres

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| DPI Value Centre | www.dpivaluecentre.nl |
| Sustainable Packaging Knowledge Institute (KIDV) | www.kidv.nl |
| Paper and Board Knowledge Centre (KCPK) | www.kcpk.nl |
| Wageningen UR - Food and Biobased Research (FBR) | www.wageningenur.nl/fbr |

## 13.2 Representative associations, platforms and network organisations

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| Afvalfonds Verpakkingen, Packaging Waste Fund | www.afvalfondsverpakkingen.nl |
| AfvalOnline, waste & recycling news website | www.afvalonline.nl |
| Belgian BioPackaging | www.belgianbiopackaging.be |
| Biobased Delta | www.biobaseddelta.nl |
| Dutch Waste Management Association (DWMA) | www.wastematters.eu |
| duurzaamgeproduceerd.nl, website for promoting sustainable industry | www.duurzaamgeproduceerd.nl |
| European Bioplastics | www.en.european-bioplastics.org |
| European umbrella organisation of beverage carton manufacturers (ACE) | www.beveragecarton.eu |
| Hergebruik Kartonnen Drankverpakkingen (HEDRA), initiative of beverage carton suppliers in the Netherlands to promote reuse | www.hedra.nl |
| Koninklijke vereniging voor afval- en reinigingsmanagement (NVRD), association of Dutch municipalities responsible for waste management and their waste removal companies | www.nvrd.nl |
| Meldpunt Verpakkingen, consumer information and participation initiative of KIDV and Milieu Centraal | www.meldpuntverpakkingen.nl |
| Nederlands Verpakkingscentrum (NVC), representative association of packaging companies throughout the supply chain of packaged products | www.nvc.nl |
| Nederlandse Vereniging van Frisdranken, Waters, Sappen (FWS), Netherlands Association of Soft Drinks, Waters & Juices Manufacturers | www.frisdrank.nl |

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| Nedvang, foundation that coordinates the collection and reuse of packaging on behalf of producers and importers in the Netherlands | www.nedvang.nl |
| Recycling Netwerk, recycling network | www.recyclingnetwerk.org |
| Stichting Retourverpakking Nederland, coordinates deposit bottle collection system | www.retourverpakking.nl |

### 13.3 Consumer information

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| Afvalscheidingswijzer, Waste Separation Guide | www.afvalscheidingswijzer.nl |
| Milieu Centraal, initiative to stimulate a sustainable society | www.milieucentraal.nl |
| Plastic Heroes, initiative of Nedvang | www.plasticheroes.nl |
| Stichting Nederland Schoon, dedicated to promoting a clean and litter-free Netherlands | www.nederlandschoon.nl |

### 13.4 Advice

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| Biobased Packaging Innovations, Amsterdam | www.biobasedpackaging.nl |
| Ingenia, Eindhoven | www.ingenia.nl |
| Milgro, Rotterdam | http://milgro.nl |

### 13.5 Other

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| Labelinfo.be | www.labelinfo.be |
| Vinçotte | www.okcompost.be |

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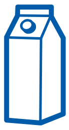
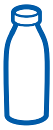
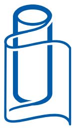
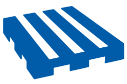
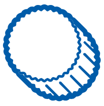
# 15 Pictograms

| Pictogram | Explanation | Pictogram | Explanation |
|---|---|---|---|
|  | Covering film.<br>Is sealed or glued onto a tray. |  | Carrier bag.<br>Bag for 'one-off' use. |
|  | Container.<br>For e.g. tomatoes or mushrooms. |  | Beverage carton.<br>Often used for dairy drinks and fruit juices. |
|  | Cup.<br>Used for cold and/or hot drinks. |  | Bottle.<br>Plastic or glass bottle for various drinks. |
|  | Protection.<br>Product to protect against impact damage. |  | Crate.<br>Grouped packaging for bottles. |
|  | Flower pot.<br>Indoor pot for plants. |  | Shrink film.<br>Used to keep products together. |
|  | Freezer container.<br>Container for packaging deep freeze products. |  | Pallet.<br>Used during transportation of products. |
|  | Box.<br>Used mainly for grouped and transport packaging. |  | Tray or dish.<br>Shallow packaging for e.g. fruit. |
|  | Cap.<br>Cap on bottle or beverage carton. |  | Packaging film.<br>Film (bag) used directly around a product. |

| Pictogram | Explanation | Pictogram | Explanation |
|---|---|---|---|
|   | Barrier for water. Very little water permeates the packaging. |   | Cold storage. Suitable for freezer applications. |
|   | Barrier for oxygen. Very little oxygen permeates the packaging. |  | Sealable. Can be provided with a top film via sealing. |
|  | Food contact. Approved for direct food contact. |   | Coatable with aluminium. Can be provided with an aluminium barrier layer. |
|  | Suitable for microwave. |   | Coatable with glass. Can be provided with a $SiO_x$ barrier layer. |
|  | Hot fill. Can be filled with hot product. |  | Transparent. |

| Pictogram | Explanation | Pictogram | Explanation |
|---|---|---|---|
|  | Composting. Compliant with EN13432 for compostable packaging. |  | Recycling. Can be recycled via e.g. Plastic Heroes. |
|  | Reuse. Suitable for reuse. |  | Incinerate. Not suitable for recycling other than incineration. |

# Publication details

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Karin Molenveld, Martien van den Oever and Harriëtte Bos

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Wageningen UR Food & Biobased Research
Bornse Weilanden 9
P.O. Box 17
6700 AA Wageningen
Internet: www.fbr.wur.nl
E-mail: info.fbr@wur.nl

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