2009

# Bioplastics

## A sustainable solution?

Bachelor thesis

Industrial Design

University of Twente


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# Content

# Introduction

The Dutch ministry of agriculture, nature and food quality is financial supporting a big project based on the development and improvement of bioplastics. This is just one project that has recently started but the interest in bioplastics is increasing all over the world. The attention of the upcoming plastics calls responses from the public; the consumer and costumers. People start to have an opinion about the topic without really knowing if it contributes to a better world or not. In America, Wall Mart is asking their suppliers to measure and report their packaging's contribution to the climate change on so called 'scorecards' . It is not that this card has been implemented in The Netherlands but there is a change that companies like Albert Heijn will follow this initiative. A company does not want to show that they produce environmental unfriendly packaging.  Therefore is would be better to take precautions and reduce a packaging's impact on climate change before Dutch companies start to implement these scorecard or other comparable indicators.

Next to the impact of plastics on climate change there is also the impact on the depletion of fossil resources. Fossil resources are depleting and a solution has to be brought up before it is not possible to extract them anymore. Oil prices will increase as a result of the shortcomings and it would not be possible to produce fossil resource based plastics in a large scale. There are multiple ways to reduce the environmental impact of a packaging. One of these ways could be by substituting synthetic plastics by bioplastics.  Bioplastics are based on renewable resources such as corn and/ or are able to degrade by biological means.

Leaf BV is an international confectionary company with a lot of plastic packaging. For them it could be very useful to take a closer look at bioplastics and their possible benefits. The word bioplastic is a combination of the word 'bio' and 'plastic' what insinuates that the plastic has an environmental friendly character. But is this bioplastic really better for the environment than conventional plastics? and is it even possible for Leaf BV to use bioplastics instead of their current plastics?

# Initiator

The initiator, Leaf Holland BV, is a confectionary company located in The Netherlands. They own a lot of national and international brands like Red band, Venco, Sportlife, Läckerol, etc. The mission of Leaf is to create value for its shareholders through its brands and customers. Their vision is to become the most admired company within the European confectionary industry; admired by consumers, costumers, competitors and employees.

Leaf develops confectionary to impress their costumers, costumers, competitors and employees. To stay admired and to impress the people around them it is important for Leaf to stay ahead of the market. A big upcoming trend is sustainability. Leaf is taking a closer look at this trend and how they can contribute to it. Sustainability is very broad and deals with a lot of different aspects on the environmental, social and economic field. One of the aspects that also have to do with sustainability is packaging. Leaf is interested in the new upcoming material built up out of biopolymers. They would like to know if bioplastics are more environmental friendly than their current packaging material and if it is possible for them to replace their existing packaging material by this material.

# Objective and project scope

The objective of this report is to show if a packaging made of bioplastics is better for the environment than the current packaging material without influencing the shelf life, look & feel, process ability and costs of a packaging in a negative way; focussing on filmflexibles and rigids.

Sustainability is a very broad and diverse subject.  A relatively small part of that subject is related to bioplastics. Bioplastics are plastics that could be suitable as a replacement of current plastics and this report will focus only on these plastics. The bioplastics in this report will be judged and compared on environmental impact, shelf life (of the product), look & feel, process ability and costs.

The report will firstly focus on bioplastics itself; information, markets and benefits of the material. Later it will elaborate on the bioplastics and if they could be suitable as a replacement of Leaf's packaging material. The report consists of six chapters. The first chapter will focus on the bioplastics in general, the second on the type of bioplastics and their strengths and weaknesses. The third chapter gives an overview of Leaf's packaging and the materials that they mainly use and the fourth chapter will give an overview of bioplastic suppliers and where they are located. The first four chapters illustrate the information found about bioplastics and chapter five will elaborate on that information with test. This chapter contain the tests that have been executed to determine the environmental impact, shelf life, look & feel, process ability and costs of the bioplastics. The last chapter, chapter 6 is a continuation of the previous chapter. It shows in what way bioplastic could be interesting for Leaf BV and for what products they could use them as a replacement of their current packaging material. Appendix A contains the project plan with the steps that have been followed in this report. The steps consist of a main question and sub questions.

# Summary

Sustainability is a broad topic with the focus on three pillars: economics, social and environmental. A packaging is just a small part of sustainability but this does not mean that it cannot contribute to sustainability.

A packaging can contribute to sustainability by working on the three packaging R's; by reducing, reusing or recycling the materials needed for a packaging. An addition to those three 'R's' could be replacing, the replacement of current materials by a more sustainable material. Bioplastics could be used as a substitute for the current packaging materials

Bioplastics are a relatively new and upcoming market. The potentials are high and there are already some packaging on the market that are made of these plastics. Bioplastics are plastic that are made from renewable resources (biobased) such as corn or plastics that are biodegradable. They could also be both of them, biobased and biodegradable.

There are four different type of bioplastics on the market:

- Polymers directly extracted from biomass
- Polymers produced by biological derived monomers
- Polymers produced by microorganism
- Plastics produced by classical synthesis from synthetic monomers

These types have their own properties and therefore also their own strengths and weakness. Most of the bioplastics have poor moisture barrier properties while the oxygen barrier is relatively high.

Leaf BV is a confectionary company interested in bioplastic. Their packaging mostly consists of filmflexibles and rigids. Several bioplastics have been tested on environmental impact, shelf life, look & feel, process ability and costs and the results have been compared to their conventional materials.

Bioplastics have less impact on climate change and fossil resources while they have more impact others such as eutrophication, ozone layer depletion and land use. The total impact (weighed with the eco indicator 9 weighing set) of bioplastics is higher than the total impact of conventional plastics. Most of the bioplastics are not able to maintain the shelf life of the products as good as their conventional plastics because of the low moisture barrier properties. The look & feel of the bioplastics are different from the conventional plastics but it cannot be said that this will have a negative effect. The process ability of bioplastics is difficult. The costs of conventional plastics also seem to be higher that the costs of conventional plastics but there are biodegradable plastics on the market that costs around the same as conventional plastics. These biodegradable plastics have been 'made' biodegradable through the addition of a particular additive.

Bioplastic do not seem to be suitable as replacemet of their current transwrap material but there are other options where bioplastics could be suitable. The market potentials are high and the change that big companies will start to push suppliers to pack environmental friendly will make these options attractive. The options are plastics that are biobased and biodegradable, biobased and biodegradable (secondary packaging and components), partly biobased; not biodegradable, biodegradable; not biobased, and biodegradable and partly biobased.

# Chapter 1: Introduction of bioplastics

## 1.1 Sustainability

### 1.1.1. What is sustainability?

The definition 'sustainable development' has been founded by the Brundtland Commission in 1987. The definition states: 'Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This involves addressing economic, social and environmental factors and their interdependence in an organization's decision-making and activities.'

Individuals value their own life and the life of their descendant. They do not always share the same opinion about what is good or bad with each other. This results a great variety of interpretations of the definition sustainability. It is also the fact that the world is changing, more knowledge about important topics is gained which influence the focus on sustainability. As stated in the definition of sustainable development the three pillars of sustainability are economic, social and environmental. These three pillars are linked to each other and cannot be developed in isolation. The Renewed Sustainable Development Strategy as adopted by the European Council on 15/16 June 2006 offers an explanation of the pillars:

*- Environmental protection - planet*

Safeguard the earth's capacity to support life in all its diversity, respect the limits of the planet's natural resources and ensure a high level of protection and improvement of the quality of the environment. Prevent and reduce environmental pollution and promote sustainable consumption and production to break the link between economic growth and environmental degradation.

*- Social equity cohesion - people*

Promote a democratic, socially inclusive, cohesive, healthy, safe and just society with respect for fundamental rights and cultural diversity that creates equal opportunities and combats discrimination in all its forms.

*- Economy prospective- profit*

Promote a prosperous, innovative, knowledge-rich, competitive and eco-efficient economy which provides high living standards and full and high-quality employment throughout the European Union.

### *1.1.2 Life cycle analysis*

A life cycle analysis can be used to criticize products and services on their environmental impact. The life cycle analysis gives a systematic and objective overview of all the processes that appear during the life of a product or service and their impact. In ISO 14040 a life cycle is defined as "consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resource to final disposal" and a life cycle analysis is defined as "compilation and evaluation of the inputs, outputs and the potential environmental impact of a product system throughout its life cycle". A life cycle analysis is also known as a 'cradle to grave' analysis because is covers the entire lifetime from extraction to disposal.

Besides criticizing a product on their environmental impact it is also possible to compare products or services with each other on behalf of their impacts. This can be done by creating a life cycle analysis for one product and compare it with the life cycle analysis of another product. In this way a life cycle analysis can be used as a tool to show that the environmental impact is lower or higher than another or previous product.

### *1.1.3 Carbon footprint*

The effect of climate change is of high concern for our society, because of the high impact on our world nowadays and probably even more in the future. Man-made influences are considered as the main reason for the climate change. Burning fossil resources increase the share of $CO_2$ in the atmosphere, which causes an increase of the average temperature, also known as the greenhouse effect (European bioplastics, 2009). The climate change is causing an increase of thunderstorms, floods and water shortcomings. Because of the enormous negative consequence that climate change brings along it is becoming one of the most important environmental issues where we have to deal with.

A way to indicate the impact of a product and/or material on climate change is by a so called 'carbon footprint'. In relation to a product, a carbon footprint is defined in the PAS 2050 standard as "the overall amount of carbon dioxide ($CO_2$) and other greenhouse gas (GHG) emissions (e.g. methane, laughing gas, etc.) associated with a product".

A carbon footprint is a way to indicate the impact on climate change because it compares products to each other on behalf of $CO_2$ and other greenhouse emissions during its lifetime.

A marginal comment to the carbon footprint is that it only focuses on greenhouse emissions and not on other emissions which occur during the lifetime of a product. The other emissions which are not stated in the carbon footprint could also have a negative influence on the environment but are not of the highest concern nowadays. It can be also be said that a carbon footprint is a life cycle assessment with the analysis limited to emissions that have an effect on climate change (European commission, 2007).

### *1.1.4 Packaging's role in sustainability*

Packaging makes a valuable contribution to economic, environmental and social sustainability through protecting products, preventing waste, enabling efficient business conduct, and by providing (ECR Europe/EUROPEN, 2009). This can be illustrated by the lack of packaging or inadequate packaging in the developing countries. The lack of packaging or inadequate packaging in distribution results in thirty to fifty per cent to decay before it reaches the consumer (Madi L.F., 1984) in comparison to two to three per cent in Western Europe where the food is efficiently packed (Pro Europe, 2004).

Products itself represents more resources than the packaging that is wrapped around them (Kooijman, J.M., 1994). A lot of environmental savings can be made by not underestimating the function and the sustainability of packaging itself.

As stated above packaging contributes to sustainability itself. This is already a positive aspect but it is still possible to decrease their environmental impact and to make them even more environmental friendly. Packaging is an important sustainable aspect because it is the waste where a consumer has to deal with and what they have to dispose by themselves. Figure 1 shows an overview of the stages of a packaging's life where it is possible to work on sustainability and which aspects of these stages can be improved.

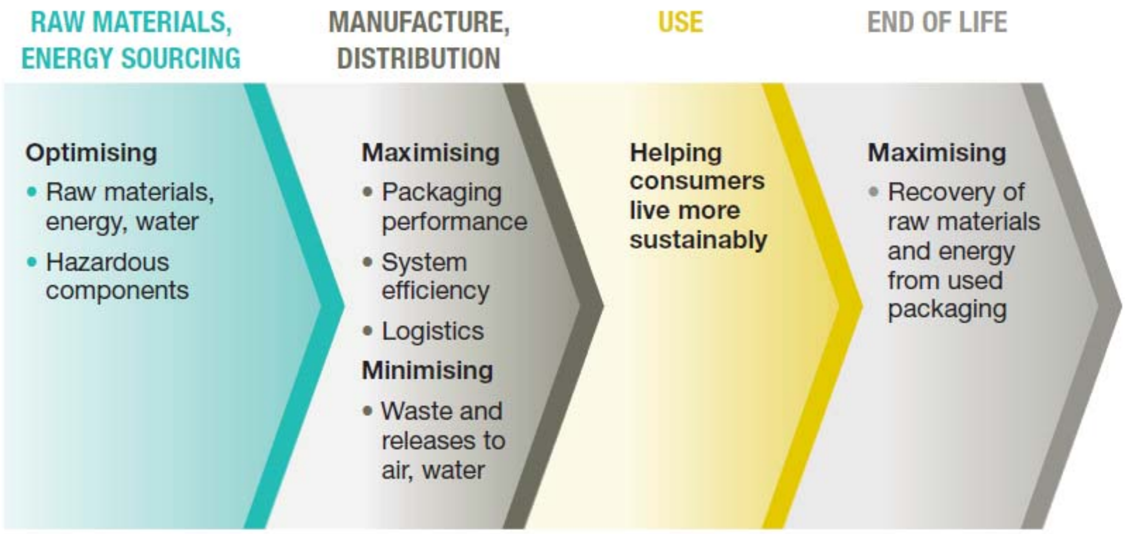



**Figure 1:** concept for sustainability for packaging and product systems (source: incpen, 2008)

The first step in the manufacturing of packaging materials is the extraction of raw materials. Raw materials can contribute to climate change because big amounts of carbon dioxide emissions will be released during the burning of fossil fuels. Synthetic polymers are derived from oil and are the main component in most of today's plastics. The negative effect of oil is that they contribute to the climate change due to the carbon dioxide emissions that will be released.

A way to make a plastic less dependent of oil and to reduce the impact on climate change is by replacing its raw material by another material that contributes less to the climate change than oil. A relatively new and upcoming type of raw material is the naturally based one. These raw materials are also known as biopolymers and the plastics that will be produced of these materials are known as bioplastics. This report will only focus on bioplastics and will leave the other sustainable solutions aside.

## 1.2. Bioplastics

A bioplastic is a biobased and/or biodegradable plastic. This means that the plastic is derived from the nature (biopolymers) and/or is able to go back (biodegrade) in the nature.

According to the association European bioplastics and other associations which also use the same twofold description, a bioplastic is a:

- biobased plastics produced on the basis of renewable resources
- biodegradable polymers which meet all criteria of scientifically recognised norms for biodegradability and compostable of plastics and plastic products. In Europe this is the EN13432.

Figure 2 shows the life cycle of a bioplastic when it meets both of the descriptions. It starts with the agricultural feedstock and also ends after the 'product/user phase' and 'composting' eventually into agricultural feedstock again. This life cycle is a 'cradle to cradle' life cycle because it starts at the origin and also ends at the origin.

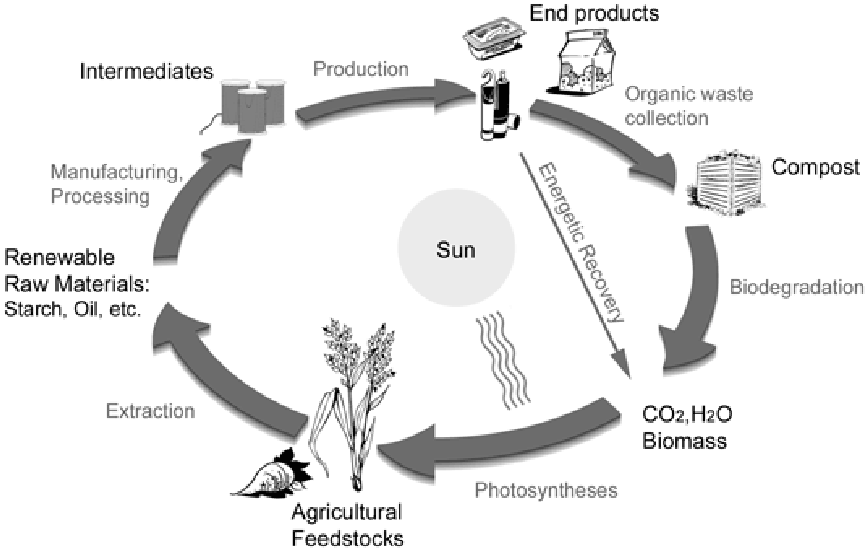



**Figure 2: ideal closed loop life cycle of an ideal bioplastic**

Different biological term can be used to indicate that a plastic is ´biological´, but not all of these terms mean that a plastic is a bioplastic. Some terms refer to the origin of the material while others refer to the end of its life. These biological terms give the consumer the feeling that a product is natural and therefore good for the environment, but there are a lot of misinterpretations about these terms. A research performed by WRAP (2007) about ´consumers attitude to biopolymers´ shows that most of the consumers do not really know what the difference between the terms, degradable, biodegradable and compostable is. They associate them with the term 'bio' and therefore as ´good´. It is still important to make a distinction between the terms 'biobased' , 'degradable', 'biodegradable' and 'compostable' because they are often (incorrectly) used and it is easy to mix them up because some terms overlap other terms. For example, a compostable product is also biodegradable while a biodegradable product does not need to be compostable.

### *1.2.1 Biobased*

A biobased product is as the name summons biologically based. This means that it made of natural polymers which are derived from renewable resources. A renewable resource is a natural resource that replenishes itself in the short term. For example, trees can be harvested and new trees can grow back in the same place. The opposite is a non renewable resource such as copper or oil. Once it is pulled out of the ground it isn't going to come back, at least not in this geological age.

### *1.2.2 Degradable, biodegradable and compostable*

The terms degradable, biodegradable and compostable say something about the way that the product will break down. Despites that they all say something about the way it will break down it is important to make a distinction between them, because there all mean something quite different.

It can take different length of times for a bioplastic to completely break down depending on the type of material, the thickness and the environmental conditions where it will break down in. A commercial composting facility with higher temperature can accelerate the degradation process whereas in an environment without any artificial facilities it can take more time to complete the degradation process. Depending on the amount of time it takes for a product to degrade, the components where a product will degrade in and other criteria it can be determined if a product is degradable, biodegradable and/or compostable.

**Compostable Plastics** are plastics which are "capable of undergoing biological decomposition in a compost site as part of an available program, such that the plastic is not visually distinguishable and breaks down to carbon dioxide, water, inorganic compounds, and biomass, at a rate consistent with known compostable materials (e.g. cellulose). and leaves no toxic residue." (American Society for Testing& Materials (ASTM)). In order for a plastic to be called compostable by the European standard and others, four key criteria have to be met:

- Chemical composition — There are limits for volatile water, heavy metals (Cu, Zn, Ni, Cs, Pb, Hg, Cr, Mo, Se, As) and fluorine.
- Biodegradation — Chemical breakdown of the materials into $CO_2$, water and minerals. At least 90% of the material have to be broken down by biological action within 6 months.
- Disintegrate — The physical decomposition of a product into tiny pieces. After twelve weeks at least 90% of the product should be able to pass through a 2 x 2 mm mesh.
- Eco toxicity — The quality of the compost should not declined as a result of the added material. The standard specifies checking this via eco toxicity tests: this involves making an examination to see if the germination and biomass production of plants are not adversely affected by the influence of the composted material.

**Biodegradable Plastics** are plastics which will degrade from the action of naturally occurring microorganism, such as bacteria, fungi etc. over a period of time. There is no requirement for leaving "*no toxic residue*", and as well as no requirement for the time it needs to biodegrade.

**Degradable Plastic**s are plastics which will undergo a significant change in their chemical structure under specific environmental conditions resulting in a loss of some properties. There is no requirement that the plastic has to degrade from the action of "naturally occurring microorganism" or any of the other criteria required for compostable plastics.

### *1.2.3 Biobased and/or biodegradable*

The term 'bio' initiates that a material is biological, which results in a positive consumer attitude towards bioplastics. As stated before there are biobased and biodegradable materials and there are materials that are both biobased and biodegradable and all go along with a 'bio' term. The different 'bio' terms lead to misunderstandings and mix-ups of the real meaning of the words. However, it is important to distinguish the difference between biobased and biodegradable because it does not necessarily have anything to do with one another (WRAP,2007). The term 'Biobased' indicates that the origin of the material is based on 'bio' material which refers to renewable recourses. In contrast to 'biobased', 'biodegradable' refers to the destination of the product, so how it will break down at the end of its lifetime. See figure 3 for an illustration of biobased and/or biodegradable plastics. The figure shows that bioplastics can be biobased or biodegradable or both of them.

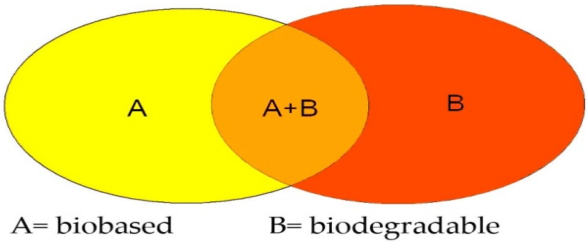



**Figure 3: biobased and/or biodegradable**

Plastics based on biopolymers or monomers can lose their biodegradability through chemical modification and polymerization. In other words, biodegradability is linked to the chemical structure of the plastic rather than the origin. See paragraph 2.1.4 for more information about plastics that are only biodegradable and not biobased.

### *1.2.4 Standards*

A standard contains a method to measure and/or evaluate something. It is not mandatory to use a particular standard to prove that your product is, in this case, compostable.

Despites that a standard is not obliged by law, companies are relying on it. They know that these standards proof that a product is compostable and that multiple test have been performed to proof so.

Dutch composting firms only accept certified packaging by the European standard EN13432 and Belgium is the first European country to draw an official link between the standard EN 13432 and a national legislation about claims (Belgisch staatsblad, 2008). If you want to claim that a product is compostable in Belgium, the law clearly defines that the product has to fulfil the requirements of the standard EN 13432 (for industrial compostability). Belgium is the first country to adopt this standard into a law but it expected that other countries will follow them (Vincotte, 2009).

Different international organizations created standards and testing methods for compostability:

| **Organization** | **Standard** |
|---|---|
| European Standardization Committee (CEN) | EN13432 |
| American Society for Testing and Materials | ASTM-6400 |
| International Standards Organization (ISO) | ISO14855 (only for biodegradation) |
| German Institute for Standardization (DIN) | DIN V49000 |

The EN13432 is the European standard and therefore also the leading standard in The Netherlands. The key component of this standard is the need to recover packaging waste on the basis of industrial composting. The standard defines both the test program and the assessment criteria compostable packaging has to meet. The main assessment criteria are described under the topic 'compostable plastics' in paragraph 1.2.2..

### *1.2.5 logos*

Dutch waste management operators do not accept bioplastics in their compost facilities unless the plastics are tested and approved according to the EN13432 standard. Independent third party certifiers perform these tests and provide compostable logos if the plastic meets the EN13432 criteria.

A frequently occurring and accepted logo is the 'seedling' logo, see figure 4. This logo is developed by European bioplastics and DIN CERTCO.

Figure 4: Seedling label

A Belgium company named AIB Vinçotte also develops logos and performs tests to determine the degree of compostability, biodegradability and the degree of biobased raw material of a product. All the testing criteria are based on the EN13432 standard. See table 1 below for Vinçotte logos and their meaning.

| | | |
|---|---|---|
| OK biobased | | This logo indicates the percentage of raw materials in the product. 1 star stands for 20 to 40% biobased, 2 stars for 40 to 60% biobased, 3 stars for 60 to 80% biobased and 4 stars for 80 and more % biobased. |
| OK compost | | Packaging or products featuring the OK compost logo are guaranteed as biodegradable in an industrial composting plant. This applies to all components, inks and additives. The sole reference point for the certification program is the harmonised EN 13432. |
| OK compost home | | Packaging or products featuring the OK compost HOME logo guarantee complete biodegradability in the light of specific requirements, even in your garden compost heap. |
| OK biodegradable soil | | The OK biodegradable SOIL logo guarantees that a product completely biodegrades in the soil without adversely affecting the environment. |
| OK biodegradable water | | Products certified for OK Biodegradable WATER guarantee biodegradation in a natural fresh water environment, and thus substantially contribute to the reduction of waste in rivers, lakes or any natural fresh water. Note that this not automatically guarantees biodegradation in marine waters. |

Table 1: AIB Vinçotte logos

The logos mentioned above are the most common logos for bio packaging in The Netherlands. There are more logos available worldwide. Some of these logos are also based on the European standard but there are also American logos that are based on the American standard ASTM 6100. See appendix B for an overview of the other logos.

Advantages of logos are firstly that waste operators can recognise bioplastic products and secondary that consumers can also recognise the packaging on being compostable. Another advantage is that they show that a plastic is tested by independent third party certifiers.

A disadvantage of logos is that products need to be tested before they obtain their logo. These tests take time and have a price. The time that it takes to obtain a certificate varies between zero and twelve months depending on the type of certificate. The costs also vary a lot depending on the type of certificate. See appendix C for a 'Schedule of fees for the certification of products made of compostable materials' (DIN CERTCO, 2009).

## 1.3 Components and constituents

The EN13432 standard specifies that packaging may be regarded as compostable if all of its constituents may be considered as such but it is acknowledge that some components may not be compostable.

The difference between a constituent and a component is that a component is an element that may be easily separated from the rest of the packaging and a constituent not. Components and/or constituents that may influence the compostability of a packaging are: film seals, colouring, inks, labels and the combination of certified materials. All constituents and components should be registered to be suitable for biological waste processing or certified by the EN13432 standard for compostability. Each registered product should not exceed a percentage of one per cent in mass of the total weight, with a maximum of five per cent for all registered constituents and components. The components inks and label are described below and the other components mostly influence the compostability of a packaging with their thickness or toxic materials that they maintain.

### 1.3.1. Inks

Inks may contain heavy metals whose upper levels are specified by the EN13432 standard. Biodegradable inks and other inks that are certified according to the European standard can be used in compostable packaging. The certified inks are tested on heavy metals and eco toxicity but are not biodegradable itself. The total concentration of these inks must be limited to one per cent of the products weight per ink and five per cent of the product's weight in total. The disadvantages of bio inks are that the performance is lower and the costs are higher.

### 1.3.2. Labels

The thickness of a label in combination with the thickness of a film may disrupt the biodegradation process of the film. An option to solve this problem is by using smaller labels that affect the biodegradation process less.

See chapter four for information about component and constituents suppliers.

## 1.4 Application area

Bioplastics are covering a relatively small part of the plastic market. It is expected this will change a lot in upcoming years.  More and more research is put into this market what results in improved technical properties and innovations that will open new application areas and application areas with higher profit potentials.

Today's main applications areas are packaging, medicines, agriculture and horticulture. There are more areas of applications but they are relatively small.

### 1.4.1 Packaging

Bioplastics are mainly employed as packaging in the form of films and foams. They can be used as a primary, secondary or tertiary packaging. This means that they can be used as a packaging in direct contact with the product, second from direct contact or third from direct contact with the product. Films are mostly used as primary packaging of fresh food like fruits and vegetables and foams are commonly used for transport packaging. Next to the films and foams there are also others forms such as bottles and thermoformed packs.

Three bioplastic bottles are displayed in Figure 5 below. The first bottle is Belu's compostable bottle made from Polylactic acid (PLA). PLA is made of corn. The second bottle is Aquamantra's biodegradable and recyclable PET bottle and the third bottle is Coca Cola's 'PlantBottle'. This bottle is made for thirty per cent of plant based materials and is fully recyclable.


Figure 5: bioplastic bottles and the SunChips bag

Another application is FritoLay's SunChips bag. This is a bag made for thirty three per cent of plant based materials. They plan to introduce a fully compostable chips bag in 2010. The chips bag is illustrated in figure 5 on the right side.

Companies such as Nestlé, L'oreal, Schneider Electronics and PSA Peugeot Citroen are investing in bioplastic research. It is expected that they are investing in research because they are interested in bioplastic applications (engineeringNet, 2009).

### *1.4.2 Medical application*

Bioplastics are widely used for medical applications such as in medical devices, gloves and blood containers. They are also used for implants because of their biodegradability. The plastic will 'vanish' by itself and does not need to be removed afterwards. Other applications include cardiovascular, burn and wound dressings, drug delivery systems and dental implants.

### *1.4.3 Agriculture and horticulture*

The agriculture and horticulture is a common field for bioplastics. It is handy for the consumer to put flowers or plants in a biodegradable pot because they do not have to throw it away. They can plant it together with the flower itself and will biodegrade eventually. Other applications in this area are mulching film, flower bulb packaging, fastening technology, fertilizer rods and pheromone traps. See figure 6 for agriculture and horticulture applications.

**Figure 6: agriculture and horticulture applications**

### *1.4.4 Others*

Other areas of application are the automobile industry such as the car tires of Goodyear. Bioplastics are also gaining more popularity in consumer electronics and there are also toys and disposal applications such as cutlery and plates made from bioplastics. Figure 7 illustrates applications of bioplastics in the electronic and car industry.


**Figure 7: bioplastics phones and the Toyota 1X hybrid concept car**

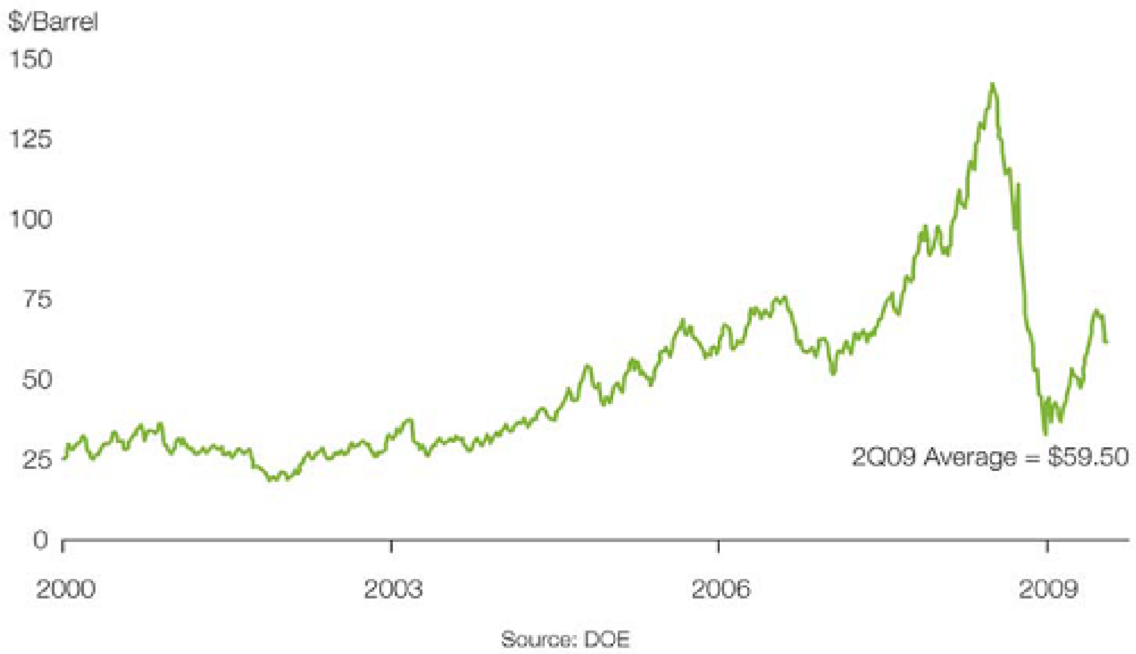
Bioplastics are also used as fibres which are mostly used for apparel, carpets furnishing, nonwovens and industrial applications.

## *1.5 Ad- and disadvantages of bioplastics*

Advantages are that they give a better image to plastics, independence of petroleum, solutions for waste problems, contribution to environmental protection and a new source of income for the agriculture (Ceresana Research, 2009).

Life cycle analysis show that bioplastics based on renewable resources result in savings in energy consumption and a reduction in carbon dioxide emissions in comparison to the production of conventional plastics (bioplastics, 2006). On the other hand, they score lower on other environmental impacts such as ozone layer depletion and eutrophication. (Patel, Bastioli, Marini Geookol, Wurdinger, 2003)

Bioplastics based on renewable resources have the advantage of being independent of the oil industry. Fossil fuels, which are used for synthetic polymers, are non renewable and therefore exhaustibly. It is not known when the fossil resources will exhaust but it is already getting harder to extract the oil what results in higher oil prices.




**Graph 1: West Texas Intermediate Crude Oil Price**

Graph 1 shows the oil prices of west Texas intermediate over the last ten years. It shows that the crude oil price has been increasing over the last ten years with an exception at the end of 2008. In the past few months, the crude oil prices are climbing up again what probably results in a price growth of the conventional plastics in comparison to the prices of bioplastics which are independent of the oil industry.

At the moment, it still not possible for bioplastics to compete with the standard plastics because of the high research and development costs and the high production costs caused by small scale production.

Nowadays, waste systems are not able to process biodegradable bioplastics. A benefit of biodegradable plastics is that they can be composted and end up in the nature afterwards. Just like the closed loop in figure 2. This benefit cannot be accomplished without a good waste system that separates compostable plastics from conventional plastics. Bioplastics can even influence the recycling process of conventional plastics in a negative way. Conventional plastics and bioplastics will get mixed up and will influence the recycled plastic s negatively.

The bioplastics market is growing and so is the competitiveness. It is expected that the market will increase in the future through more effective processes, increasing competition of new market players and higher scale productions.

As said before bioplastics are still in the 'research and development' stage which besides high costs also brings performance limitations; both mechanical and processing. The shelf life, moisture and oxygen barrier and seal strength are characteristics that are not yet as good as the conventional plastic´s characteristic. Researchers are working on those problems and are trying to make bioplastics as suitable for every type of packaging just as the conventional plastics.

Another advantage of bioplastics is that they are unique. At the moment they are trying to replace the conventional plastics but they could eventually also open a new market because of their properties. New plastics come with new properties which could be very useful for particular markets segments. Properties that could make them suitable for other application areas are their barrier properties and surface textures.

In short:

Advantages:

- Independent of oil
- Less carbon dioxide emissions
- Give a better image to plastics
- Unique properties
- Could solve the waste problems
- Income for the agriculture

Disadvantages:

- High cost
- Waste systems are not able to separate bioplastics from conventional plastics
- Poor recycled material if conventional plastics and bioplastics will be mixed
- Performance limitations
- Higher impact on ozone layer depletion and eutrophication

### *1.6 Consumer's attitudes to biopolymer*

A research executed with six hundred participants in 2002, named 'The Kassel Model Project' took place to get more depth into the consumer's opinion about bioplastics (D. Bidlingmaier, A. Jakobi, H  Kaeb, M. Klauss, M. Lichtl, 2003). The results were very positive and show that eighty nine per cent of the participants thought that it is a good thing to replace conventional plastics by compostable plastics. Eighty percent of Kassel's population which had bought the new products thought the quality was "high" or "very high" and eighty seven per cent would purchase the products again. Both the arguments 'because it is made from renewable raw material' and 'because of its compostability' will be convincing for a packaging to be environmental-friendly.  Seventy five per cent of the consumers would consider paying more for a packaging made from compostable bioplastics of whom forty one percent would be prepared to pay more in every case.

In a research executed five years later by Waste & Resources Action Programm (WRAP, 2007) about the consumer's attitude to biopolymers resulted in quite different answers than the first research. In the first place it seems that consumers do not really look for advice on how to dispose a packaging, fifty per cent claims they never do. 'The implications for anyone bringing new forms of packaging onto the market that require different approaches to disposal, may be very great indeed- consumers are unlikely to seek advice on this independently it seems.' (WRAP, 2007).

The respondents also indicated that they do not really bother if a packaging is recyclable or compostable. Consumers simply want their packaging to be as 'good' for the environment as possible. Since they see composting as 'good' and recycling as 'good', they want both.

If even became apparent that they do not really understand the meaning of the terms degradable, biodegradable and compostable and that there is a significant confusion between them. These results are in contradiction with the results from the first research because participants cannot answer in a good way when they do not know what the terms mean.

The research also shows the consumers opinion about composting, biodegradation, degradation and recycling. This resulted in a positive feeling about composting and a mixed feel about biodegradation and degradation. The answers on biodegradation and degradation were also rated lower than on recycling.

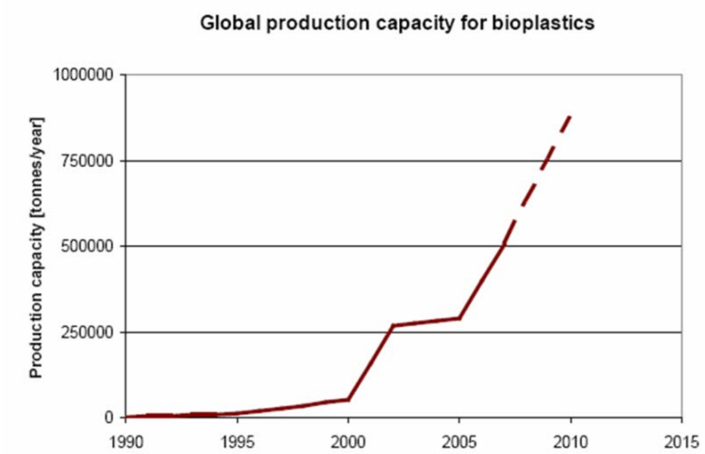
So it seems that consumers do not know much about biopolymers and that only half of the respondents had not even heard of biodegradable plastics and only fifteen per cent had heard of compostable plastics.  On the question on how consumers will behave as they are exposed to greater quantities of biopolymers, the research resulted in three different answers. First of all, consumers are not generally aware that they may already be buying biodegradable and compostable plastics. Secondly, consumers do not, in general, look for information on how to dispose a packaging on the packaging itself. And lastly, even when told that they are using biodegradable or compostable plastic, most consumers will dispose it as they would dispose a similar product made from conventional plastic.

### 1.7 Bioplastic market: today and in the future

The report 'bioplastics market worldwide 2007-2025' written by the Helmut Kaiser consultancy (2008) illustrates today's bioplastic market and the expected market in the future.

Bioplastics cover approximately ten to fifteen per cent of the total plastic market. With an annual growth of eight to ten per year it is expected that the market share will increase to twenty five to thirty per cent by 2020. Over five hundred bioplastic companies are already available and there will be more than five thousand in 2020. Europe is being the most important market due the limited amount of crude oil reserves. In recent years bioplastics have been used in the food and packaging industry, medical, toys and textile industries but it is expected that with new innovations in the future, there would be more applications for bioplastics such as the automotive and electronics industry.

Another research performed by BCC research (2007) about biodegradable polymers states that it is expected that bioplastics will have a compound annual grow rate of seventeen per cent over the period from 2007 to 2012. COPA and COGEC (2001) also executed a study where they say that 'half of the six million tons of disposable plastic packaging in the European Union could be substituted by bioplastics' and that there is a 'Potential in the horticulture sector for 12.000-20.000 tons of degradable plant pots and 1.500 ton of mulching foils per year'. They also illustrated the expected global production capacity for bioplastic, see graph 2.




**Graph 2: Estimated global production capacity for bioplastics**

Studies about bioplastic market potentials are optimistic about the expected market and their developments. Big companies such as Wall Mart and McDonald's are already favouring biobased products in their purchasing policies. Wall Mart is even planning to oblige its suppliers to deliver their packaging with a carbon footprint so that consumer and Wall Mart itself can see how much impact the packaging has on climate change. If this continues suppliers do not have another choice than to step over to an environmental friendly way of producing and packing.

## *1.8. Summary*

Bioplastics are plastics produced on the basis of renewable resources and/or are plastics that are biodegradable. The EN13432 is the European standard which contains all criteria for biodegradability and compostability for Europe and therefore also for The Netherlands. There are different degrees in biobased and biodegradable plastics. For example, plastics based on fifty per cent of biobased materials and plastics based on more than eighty per cent of biobased materials. All these plastics need to be tested by independent third party certifiers to obtain a certified logo. These certified logos can be used as a communication tool to the consumer but also to the waste operators.

Bioplastics cover a relatively small part of the plastic market. Nowadays the main application areas are the packaging and medical industry, agriculture and horticulture and others like the toy and car industry. It is an upcoming and new market and offers advantages but also still some disadvantages in comparison to conventional plastics. The advantages are that they are independent of oil, produce less carbon dioxide, have their own unique properties, result in more income for the agriculture and that they could give a better image to plastics and could solve the waste problem. The disadvantages are high costs, performance limitations and a higher impact on ozone layer depletion and eutrophication. Another disadvantage is that the waste problem cannot be solved nowadays because separation systems that can separate bioplastics from conventional plastics have not been developed. Bioplastics and conventional plastics will be mixed up in the recycling process what results in poor recycled material.

The consumer's attitude to bioplastics is mixed. The Kassel model project (2002) show that consumers have a positive attitude when it comes to bioplastics but another research performed by the Waste & Resources Action Program (2007) shows that half of the consumers had not even heard of biodegradable plastics. On the question on how consumers will behave as they are exposed to greater quantities of biopolymers, the research resulted in three different answers. First of all, consumers are not generally aware that they may already be buying biodegradable and compostable plastics. Secondly, consumers do not, in general, look for information on how to dispose a packaging on the packaging itself. And lastly, even when told that they are using biodegradable or compostable plastic, most consumers will dispose it as they would dispose a similar product made from conventional plastic.

It is expected that the bioplastics market will grow. Studies about bioplastic market potentials are optimistic about the expected market and their developments. Big companies such as Wall Mart and McDonald's are already favouring biobased products in their purchasing policies

# Chapter 2: Type of bioplastics

Bioplastics can differ a lot from each other. Even when bioplastics have the same origin it is possible to produce different variations with different characteristics. The bioplastics will be divided into four different categories based on their origin to make a distinction between them. The four different origins of the bioplastics are:

- Polymers directly extracted from biomass
- Polymers produced by biological derived monomers
- Polymers produced by microorganism
- Plastics produced by classical synthesis from synthetic monomers

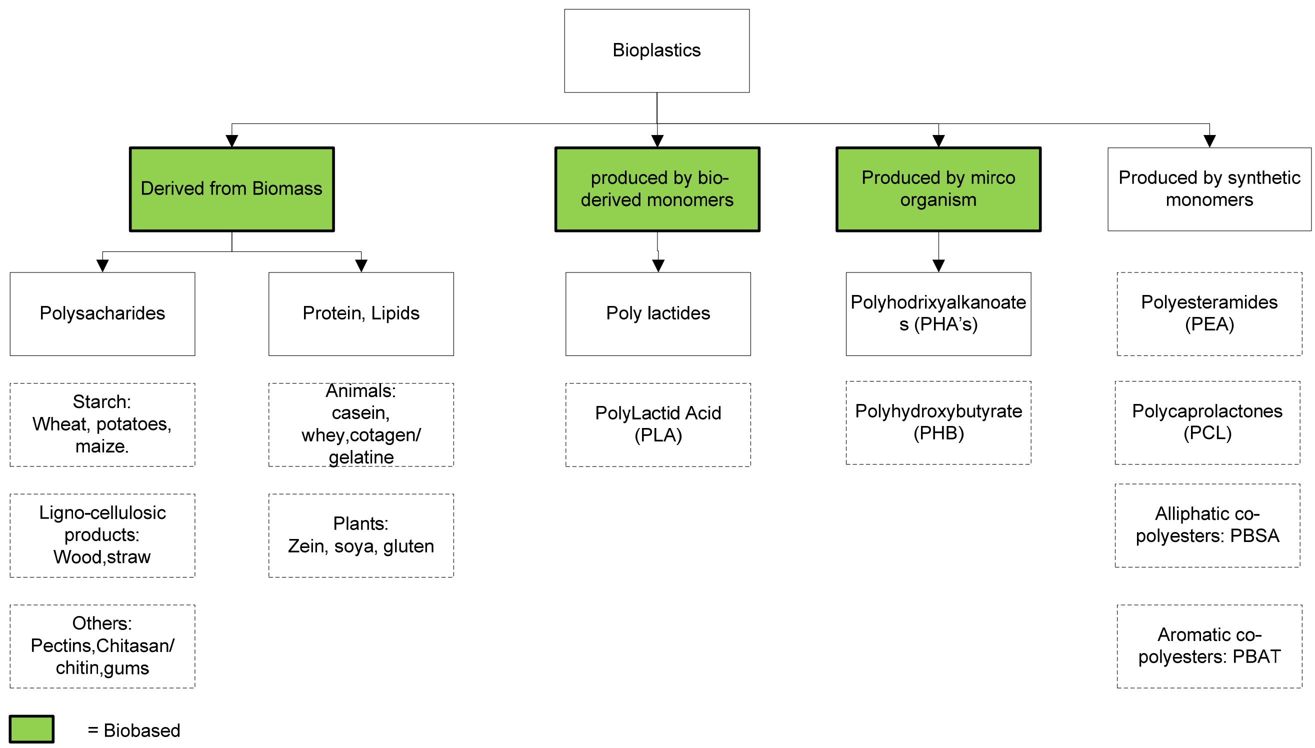



**Figure 8: classification of bioplastics (source: Averous. L, 2007)**

Figure 8 shows the four categories of bioplastics based on their origin. The raw materials that are required to make a bioplastics of a category are displayed in the closed blocks just below the categories. The blocks underneath the closed ones, display where this particularly material can be extracted from.

The first three categories are biobased and the last one is based on synthetic monomers. All the categories are in the first place biodegradable but it is possible that a biobased material becomes non biodegradable after modification. See paragraph 1.2.3 for more information about biobased and biodegradability plastics.

## 2.1. Polymers directly extracted from biomass

### 2.1.1.Thermoplastic Starch (TPS)

Starch is a polymer naturally occurring in crops such as wheat, potatoes and corn. The availability of starch is quite big, more than twenty five million ton per year what resulted in a low cost price (€ 0.40-0.50 per kilogram)

Thermoplastic starch can be obtained through the extrusion of starch. TPS can be used for further processing like injection moulding, blown film extrusion, extrusion or by pouring. It is possible to make the TPS more flexible and less water sensitive by adding plasticizer. This Plasticizer will be added to the starch during the extrusion process (Bioplastics, 2006).

Chemical starch modification can also improve the water sensitivity, but this strategy is strongly limited as far as toxicity and diversity of by-products, process costs (both modifications and purification stage) and mechanical properties of the product are concerned (Averous, 2007). Another way to improve the characteristics is by blending it with other biodegradable compounds. The only disadvantage is that TPS is normally blended with biodegradable polyesters which are rather expensive. So in order to keep the material cost low it, the starch portion should be kept as high as possible without loss of material performance. See table 2 for the strengths and weaknesses of TPS (CES EduPack; 2009; Bolck, C., 2006).

| Strengths | Weaknesses |
|---|---|
| o Purely or partially biobased<br>o Readily biodegradable in soil<br>o Compostable<br>o Relatively low costs<br>o Wide property range<br>o Good printability<br>o High $CO_2$, $O_2$ barrier | o Low maximum service temperature<br>o Moisture sensitive<br>o Not completely transparent<br>o poor water vapour barrier |

**Table 2 Strength and weaknesses of TPS**

### 2.1.2 Cellulose

Cellulose is just like thermoplastic starch derived from natural resources and is also known as the most important element of a plant's cell wall. The availability is high and it is mostly derived from trees where the percentage of cellulose is 50. It is also possible to derive cellulose from plants. Three type of biopolymers can be created of cellulose (Bolck, C., 2006):

- Natural cellulose fibres
  - Paper, cardboard and jute are made from natural cellulose fibres. For paper and cardboard the fibres will be separately placed together by a binder and for jute they will be woven. In most of the cases material based on natural cellulose fibres is known as compostable
- Regenerated cellulose (cellophane)
  - This type of cellulose is obtained by modifying the cellulose during the process. This complicated process, where a lot of organic solvents are involved is needed because it is not possible to process it thermoplastic and to dissolve it in conventional solvents.

- Modified cellulose
  - It is also possible to modify cellulose into a thermoplastic by a chemical way. These variants do not meet the criteria of compostability.

See table 3 for the strength and weaknesses of cellulose based plastics (CES EduPack; 2009; Bolck, C., 2006).

| Strengths | Weaknesses |
|---|---|
| o Cellulose is an biobased ingredient<br>o Mostly biodegradable<br>o Mostly compostable<br>o Relatively low costs<br>o Good Printability<br>o High $O_2$ barrier | o Limited heat resistance<br>o Weak seal strength<br>o High water vapour barrier<br>o Not completely transparent |

**Table 3: Strengths and weaknesses of cellulose based plastics**

## *2. 2 Polymers produced by biological derived monomers*

### *2.2.1 Polylactic Acid (PLA)*

PLA is as the name suggests a polymer derived from lactic acid. Lactid acid can be produced by fragmentation of sugars and starch. Nowadays sugar is still derived from corn but the prospective is that it will also be possible obtain it from whey, maize stalk waste and straw.

There are two types of lactic acid monomers, the L and D mesoform. After the polymerization it is possible to end up with different kind of polymers, pure L or D polylactics or a combination between those two. The ecological disadvantage of poly-L-lactic is that it is not biodegradable; while poly-D-lactic will biodegrade in a few weeks.

To make PLA suitable as a material it first has to go through a couple of steps before it is 'ready'. The material itself is quite stiff and brittle and therefore modification using plasticizers is required. After the modification the material properties are better but it still has to be processed further because just the material itself is not useful. PLA can be blow moulded, thermoformed or injection moulded. PLA is often used for fresh food packaging. It can also be processed into fibres. See Table 4 for the strengths and weaknesses of PLA (CES EduPack; 2009; Bolck, C., 2006).

| Strengths | Weaknesses |
|---|---|
| o Purely biobased<br>o Compostable<br>o Relatively low costs<br>o Relatively broad available<br>o Good printability<br>o Transparent<br>o Relatively broad processing window<br>o Not sensitive for water | o Limited heat resistance<br>o Brittle<br>o Poor water vapour barrier<br>o Poor melt strength<br>o Slow crystallization |

**Table 4: Strengths and weaknesses of PLA**

## 2.3 Polymers produced by microorganism

### 2.3.1 Polyhydroxyalkanoates (PHA)

Polyhydrocyalkanoates are lineair polyester produced by bacterial fermentation of sugars or lipids derived from soybean oil, corn oil or palm oil. More than 100 different monomers can be combined within this family to create materials with a wide range of properties, from stiff and brittle thermoplastics to flexible elastomers. The most common type of PHA is PHB with properties similar to those of PP, although it is stiffer and more brittle. See Table 5 for the strengths and weaknesses of PHA (CES EduPack; 2009; Bolck, C., 2006).

| Strengths | Weaknesses |
|---|---|
| o Purely biobased<br>o Biodegradable in a range of environments<br>o Compostable<br>o Wide property range<br>o High maximum service temperature<br>o Transparent<br>o Good Barrier properties<br>o Good UV resistance<br>o Good mechanical properties | o High costs<br>o Not broadly available<br>o Narrow processing window<br>o Odour during processing |

**Table 5: Strengths and weaknesses of PHA**

## 2.4 Plastics produced by classical synthesis from synthetic monomers

Polyesteramides (PEA), polycaprolactones (PCL), alliphilatic copolyesters such as PBS and aromatic copolyesters such as PBAT are bioplastics made from synthetic monomers. The plastics are produced by classical synthesis from synthetic monomers and by processing these monomers in a specific way it is possible to make them biodegradable.

The costs of these biodegradable plastics are relatively high but the processing possibilities are comparable with conventional plastics. The biodegradability together with the good mechanical and barrier properties make them suitable as a replacement of conventional plastics. Despite the positive properties it would be wiser to mix them with other bioplastics to reduce the cost price. They can for example be mixed with starch to improve their moisture sensitivity. See Table 6 for the strengths and weaknesses of synthetic bioplastics (CES EduPack; 2009; C. Bolck, 2006).

| Strengths | Weaknesses |
|---|---|
| o Biodegradable<br>o Good mechanical properties<br>o Good properties (comparable with conventional plastics) | o High costs<br>o Synthetic raw material |

**Table 6: Strengths and weaknesses of synthetic bioplastics**

## 2.5 Strength and weaknesses overview

An overview of the strengths and weaknesses per type of bioplastic is shown in table 7. Leaf Holland BV considered the bold strengths and weaknesses the most important aspects for their packaging materials.

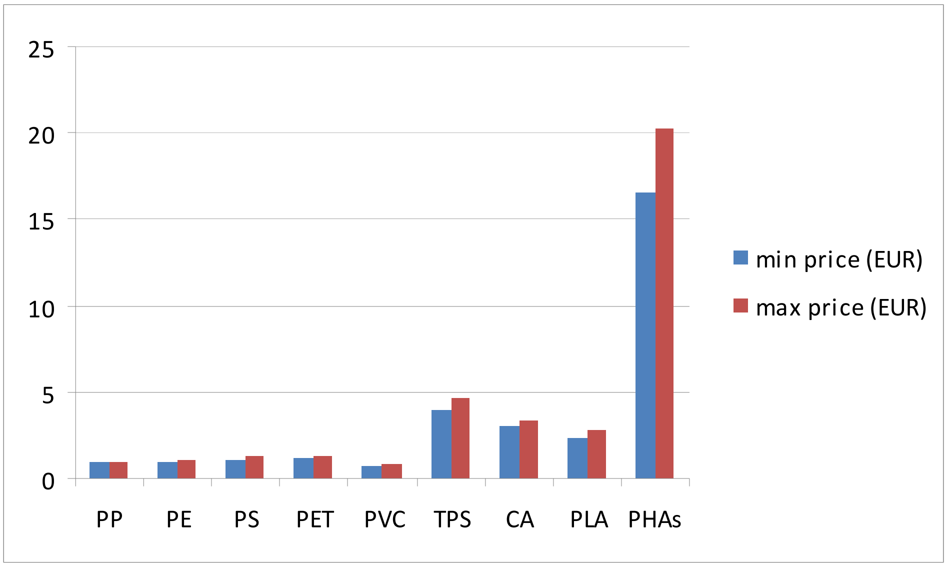
| | Strengths | Weaknesses |
|---|---|---|
| **TPS** | o Purely or partially biobased<br>o Readily biodegradable in soil<br>o Compostable<br>o **Relatively low costs**<br>o Wide property range<br>o Good printability<br>o **High $CO_2$, $O_2$ barrier** | o Low maximum service temperature<br>o **Moisture sensitive**<br>o Not completely transparent<br>o **Relatively poor water vapour barrier** |
| **Cellulose** | o Cellulose is an biobased ingredient<br>o Mostly biodegradable<br>o Mostly compostable<br>o **Relatively low costs**<br>o Good Printability<br>o **High $O_2$ barrier** | o Limited heat resistance<br>o **Weak seal strength**<br>o **Poor water vapour barrier**<br>o Not completely transparent |
| **PLA** | o Purely biobased<br>o Compostable<br>o **Relatively low costs**<br>o **Relatively broad available**<br>o Good printability<br>o **Transparent**<br>o Relatively broad processing window<br>o Not sensitive for water | o Limited heat resistance<br>o **Brittle**<br>o **Poor water vapour barrier**<br>o Poor melt strength<br>o Slow crystallization |
| **PHA** | o Purely biobased<br>o Biodegradable in a range of environments<br>o Compostable<br>o **Wide property range**<br>o High maximum service temperature<br>o Transparent<br>o **Good Barrier properties**<br>o **Good UV resistance**<br>o **Good mechanical properties** | o **High costs**<br>o Not broadly available<br>o Narrow processing window<br>o Odour during processing |
| **Synthetic monomers** | o Biodegradable<br>o **Good mechanical properties**<br>o **Good properties (comparable with conventional plastics)** | o **High costs**<br>o Synthetic raw material |

Table 7: property overview

The major disadvantage of Cellulose based plastics and PLA is the poor water vapour barrier. Leaf holds the water vapour transmission in great esteem because of the impact of vapour on their products. TPS has a poor water vapour barrier as well but it is still better than the water vapour barrier of PLA and cellulose based plastics.

Next to the disadvantage 'poor water barrier' has PLA also the disadvantage of being quite brittle. This property does not make the material very suitable as a packaging material for Leaf because of it feels breakable.

The previous table showed that the costs of TPS, PLA, and cellulose based plastics are relatively low. Graph 3 shows a more accurate overview of the costs. The costs that are displayed in this graph are partly conventional and partly biobased. The conventional plastics are displayed on the left side.




**Graph 3: Costs (EUR) source: CES EduPack 2009**

Graph 3 shows that polyhydroxyalkanoates (PHAs) are currently too expensive while their properties are rather good. The other bioplastics such as TPS, CA and PLA cost less than PHA but are still more expensive than conventional plastic. PLA scores the best when it comes to costs.

### *2.6. Summary*

Bioplastics can differ a lot from each other. Even when bioplastics have the same origin it is possible to produce different variations with different characteristics. There are four different categories based on their origin. The four different origins of the bioplastics are:

- Polymers directly extracted from biomass
- Polymers produced by biological derived monomers
- Polymers produced by microorganism
- Plastics produced by classical synthesis from synthetic monomers

The first three categories are biobased and the last one is based on synthetic monomers. There are multiple bioplastics per category with all their own unique specifications. Each bioplastics also differs in costs. The category 'polymers produced by microorganism' is the most expensive category while the other categories are rather low in comparison to the this category.

# Chapter 3: Leaf's packaging inventory

Leaf BV is an international company with departments in several countries. The department of the Netherlands operates under name Leaf Holland BV. The focus in this report will be on the brands and their packaging of Leaf Holland only.

Leaf's brands are subdivided into two different categories: Enjoyment and Refreshment.

## *3.1 Enjoyment: brands, products and packaging*

The enjoyment department is as the name already implicates specialized in confectionary that brings joy into your life. The brands that belong to this department are Red Band, Venco and Läckerol.

### *3.1.1 Red Band*

Red Band has a strong heritage in The Netherlands, were it roots go back to 1928. It has since build up a leading position in de Dutch and German candy markets with a brand promise to deliver pleasure and fun. Red Band was repositioned and given the same look & feel as its sister brand Malaco in 2006. Together with Malaco, Red Band forms the largest brand within Leaf, helped by the success of the innovative Truly concept (natural ingredients, fitting in a healthier lifestyle) under both brands (Leaf BV, 2009).

There are various types of Red Band confectionary on the market. A couple of them are:

- Winegums
- Dropfruit duo's
- Smullers
- Snoepmix original
- Snoepmix surprise
- Snoepwolken
- Perzikjes
- Flesjes
- Truly Juicy
- Truly Black.

See figure 9 for the most common types of Red Band packaging. Most of the products are packed in multiple types of packaging.


**Figure 9: Red Band**

There are more types of Red Band packaging , they be found in the packaging overview in appendix D.

### *3.1.2 Venco*

Venco is the number one in the Dutch liquorice industry. Venco has been delivering 'ultimate sensoric experience' through its promise of 'real liquorice' since it was established in 1878. At the end of 2007 Venco successfully launched the premium concept Venco Drop Twist. Venco is a household name in the country. There are also various types of Venco liquorices on the market (Leaf BV, 2009). A couple of them are:

- Droptoppers
- Dro Twist
- Honingdrop
- Tikkels
- Schoolkrijt
- Salmiakrondo's
- Katjesdrop
- Dropmix zoet
- Dropmix zout
- Dropmix gemengd

See figure 10 for the most common types of Venco packaging. Most of the products are packed in multiple packaging types, such as conical bags and transwraps.


**Figure 10 : Venco packaging**

There are more types of Venco packaging , they can be found in the packaging overview in appendix D.

### *3.1.3 Läckerol*

Läckerol is the company's iconic gum pastille brand established in 1909. The brand essence 'make people talk' indicates the benefit of lubricating your mouth to free your voice. The brand is targeting socially outgoing independent with a young adult life style (Leaf BV, 2009).

Products that are on the market with the brand name Läckerol are Läckerol split and Läckerol classics. Both of the products are available in various flavours and are packed in a different packaging. See figure 11 for the split and classic packaging. The Läckerol classic packaging is the packaging displayed on the left.


**Figure 11: Läckerol classic and split packaging**

## 3. 2 Refreshment: brands, products and packaging

The refreshment department has brands in the area of refreshing confectionary such as King, Sportlife and Xylifresh.

### 3.2.1 King

King was established in the Netherlands in 1902. It is a local jewel in the Netherlands, and is also sold in Belgium. The refresher brand is positioned within the activation pillar with a consumer benefit that evolves from throat pastille to breathe refreshment over time. (Leaf BV, 2009)

### 3.2.2 Sportlife

Sportlife was born in the Netherlands in 1981 as the first chewing gum in an innovative 'blister' packaging. It has since been a leader in the Dutch market, and also acquired a leading position in Belgium. Sportlife is a leader in the refreshment domain (based around its brand essence of 'unexpected freshness'), with an international brand profile and a strong appeal under youngsters. (Leaf BV, 2009)

### 3.2.3 Xylifresh

Xylifresh has been a leading dental brand in the Dutch chewing gum market since it was launched in the late eighties. Sweetened with hundred per cent xylitol the brand has set a new standard in the gum market. The Xylifresh brand is positioned in the "wellness" pillar delivering "fresh and clean teeth". (Leaf BV, 2009)

The three refreshment brands do not have a broad variation in packaging. See figure 12 for the most common packaging types of King, Sportlife and Xylifresh.


**Figure 12: refreshment's packaging**

A blister packaging is illustrated on the left side of the figure and is Leaf´s most common chewing gum packaging. They come in various designs and in different formats. The format is mostly dependent on the type of chewing gum and their form. Next to the blister there is the jar. This is a large jar but they are also available in smaller formats. King's bag and stick and Sportlife chewing gum bag are displayed on the right side of figure 12. See appendix D for a complete overview of Leaf´s packaging.

### 3.3. Packaging materials

The packaging types that are going to be investigated are: filmflexibles (commonly used for Leaf's bags) and rigids (commonly used for wine gum and chewing gum packaging). In this paragraph Leaf's current filmflexibles and rigids will be clarified. There has been chosen for filmflexibles and rigids because they are the most common packaging types of Leaf Holland BV.

#### 3.3.1. Filmflexibles

A filmflexible is a flexible plastic film. This film is commonly used for the production of Leaf's confectionary bags. Bags cover a broad field of Leaf's packaging and are mostly used for the brands Red Band and Venco.

Filmflexibles are on the market in various material combinations and various properties. For the selection of a 'good' filmflexible for a particular product a lot of different aspects need to be considered, such as barrier properties, seal strength and process ability.

It is important that a packaging contributes to a long shelf life and that the packaging does not affect the confectionary and production process in a negative way. So the material has to prevent the product from moulding, dehydrating and a lot of other aspects. Next to these aspects it is also important to take the look and feel into consideration.

Filmflexibles made of the materials Polyethylene (PE) and combinations of Oriented Propylene (OPP) and Cast propylene (CPP) are largely applied as a packaging material for Leaf BV. Film combinations of OPP and CPP are used for transwraps and stand pouches and PE is largely used for conical bags. The moisture barrier and seal strength of the combinations of OPP and CPP are high while the oxygen barrier is quite low. The moisture barrier of PE is also high. Conical bags have two seals on the sides while the upper part is closed with clip.

The most common combination of OPP and CPP are OPP20/CPP30, OPP20/OPP20/CPP30 and OPP40/CPP30. The number illustrates the thickness of the layer, so OPP20/CPP30 consists of a 20μm OPP layer on the outer side and a 30μm layer of CPP on the inside. The layer of CPP is added to OPP to improve the seal strength of the material.

A couple of important OPP20/CPP30 specifications are shown in table 8. Other specifications can be found in Appendix E

| **Material Properties** | | | | | |
|---|---|---|---|---|---|
| **Description** | **UoM** | **Value** | **Tolerance in UoM or %** | | **Method of analysis** |
| Heat seal strength (Inside - Inside)* | N/15mm | | min | 15 | ASTM F88 |
| Heat seal strength (Inside - Outside)* | N/15mm | | min | 8 | ASTM F88 |
| Laminate strength* | N/15mm | | min | 1,5 | ASTM F88 |
| WVTR (38°C/90% RH)* | g/m²/24h/atm | 4,1 | | | ASTM F1249 |
| OTR (23°C/0% RH)* | cm³/m²/24h | 1200 | | | DIN 16525 |
| **General Print Quality** | | | | | |
| Printing technique: | Gravure | | | | |
| **Reel Properties** | | | | | |
| Material is not allowed to block in any way. | | | | | |
| Winding must be regular, without folds, no curling, no telescoping. | | | | | |

Table 8: Specifications of OPP20/CPP30

### *3.3.2. Rigids*

Another packaging type of Leaf BV is a rigid. Rigids are plastics that stay in a fixed form after they are injection moulded or thermoformed. They come in various shapes and also with various properties. Some are more flexible than others and others are transparent while others are dull. There are different combinations possible but not every rigid is suitable for food packaging. Especially with food it is important to take a closer look at the material properties.

The most common rigids are Sportlife and Xylifresh jars and Red Band's autopack. The Sportlife and Xylifresh jars are made of Polypropylene (PP) and Red Band's autopack is a mixture of three different plastics: eighty per cent random copolymer, ten per cent LDPE and ten per cent homopolymer. The barrier properties of the mentioned rigids are unknown.

The difference between the rigids is that an autopack is relatively flexible and transparent and the Sportlife and Xylifresh jars are quite stiff and coloured.

### *3.3.3. Material Requirements*

Leaf BVdoes not have an exact list of requirement for their packaging material. They rate the moisture barrier and the seal strength of a material as an important aspect because they assume that it influences the shelf life of the product in a negative way. At the moment they are investigating how their products react to moisture and how sensitive they react to it. There is also no requirement for the oxygen barrier. The oxygen barrier of their current films is relatively poor. For that reason the oxygen barrier is not considered as an important aspect. This has to be investigated further because it could also be that a good oxygen barrier influences the product in a negative way. Thereby comes that the materials have to fulfil the requirements of food commodities.

## *3.4. Summary*

Leaf Holland's brands are subdivided into two different categories: enjoyment and refreshment.
The brands that belong to the enjoyment category are Red Band, Venco and Läckerol. The packaging material that is mostly used to pack the confectionary of these brands is filmflexibles (transwraps and stand pouches). Other packaging types are sticks, silo's and cups.
The brands that belong to the refreshment category are King, Xylifresh and Sportlife. The most common packaging for chewing gum is a blister but jars are also used to pack chewing gums. Other packaging types are bags and sticks.

The most common packaging types for Leaf BV are filmflexibles and rigids. Filmflexibles are flexible plastic films and rigids are plastics that stay in a fixed form after they are injection moulded or thermoformed. Most of Leaf's filmflexibles are combinations of the materials Oriented Propylene (OPP) and Cast Polypropylene (OPP). The rigids are made of polypropylene or a mixture of three different plastics (random copolymer (80%), LDPE (10%), homopolymer (10%)).

There is no explicit list of requirements for Leaf's packaging material. The moisture barrier and the seal strength are of high esteem because Leaf assumes that it influences the shelf life of the product in a negative way. Next to these aspects it is also important that the material meets the requirements of the food commodities. Otherwise it cannot be used as a packaging material for food products.

# Chapter 4: Suppliers

Bioplastics are a relatively new and upcoming type of plastic. Thereby comes that there are less suppliers and therefore harder to find than conventional plastic supplier.  For conventional plastics it is common to go to the supplier to order you preferred type of plastic, which is mostly the company at the end of the production process. With bioplastics is this different, because a lot of companies that operate at the end of the production process are not familiar with bioplastics. In this case it is more effective to start searching in an earlier phase in the production process.  Figure 13 shows the different phases in the production process of packaging materials.

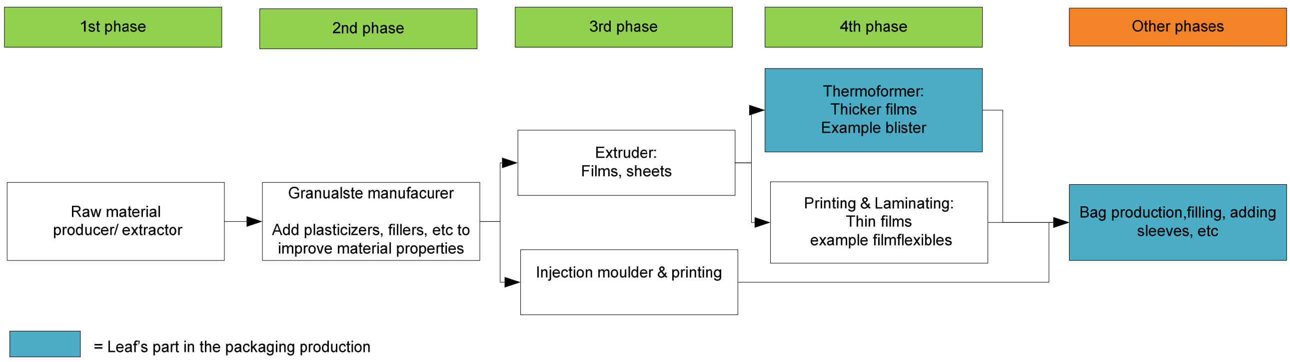



Figure 13: production process of packaging material (from raw material to Leaf)

Once the different phases of the production process are determined, it is possible to make a subdivision between the different types of bioplastic companies. The companies in the different phases have to work together to get to the final phase before Leaf takes it over. The granulate producer requires raw materials from the raw material producer and the converter needs granulate to produce films or injection moulded products from the granulate producer (phase two). In the fourth and final phase the films need to be printed and/or laminated.

## 4.1. Film and rigid suppliers

Figure 14 shows an overview of bioplastic companies per phase.  The companies displayed in bold are Leaf's current suppliers.

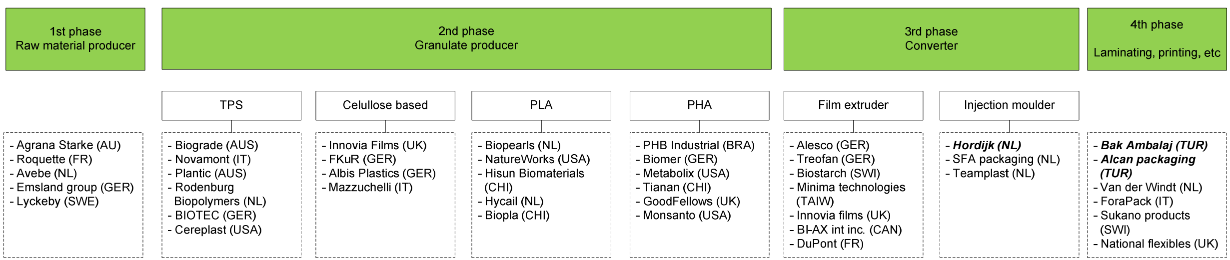


Figure 14: bioplastic company overview per phase (see appendix F for a larger picture)

In the first phase the companies that produce and/or extract raw materials are shown and in which country they are located. The second phase is subdivided into four different types of granulate that can be produced: TPS, cellulose based, PLA or PHA. The third phase is subdivided into the two processing types, extruding and injection moulding. The fourth and last phase before Leaf steps into the production process is laminating, printing, cutting, etc.

The selection of bioplastics takes place by looking at the companies in the second and third phase, because most of the fourth phase companies did not have much knowledge about bioplastics. The companies in phase two and three are experienced in their own field and have contact with companies in the up following phases.

### *4.2. Component and constituent suppliers*

Next to the basic packaging materials such as films and rigids there are also components and constituents. Components and constituents can be used to improve the packaging's quality and looks. The difference between a constituent and a component is that a constituent is an element that may be easily separated from the rest of the packaging and a constituent not. Figure 15 shows an overview of bioplastic components and constituents.

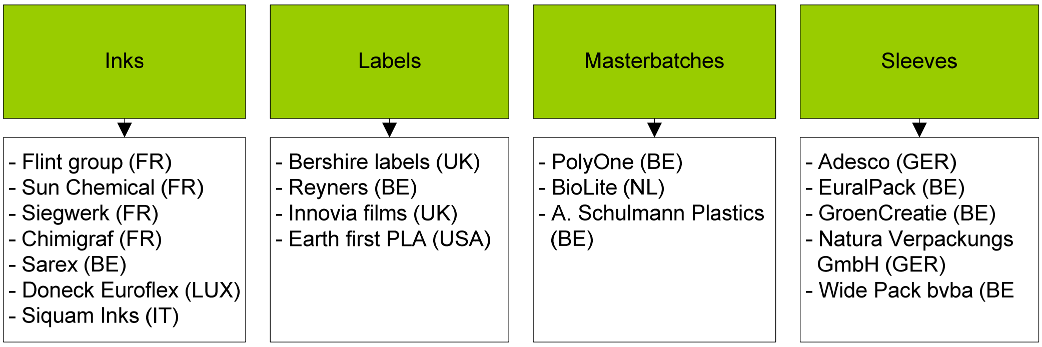



**Figure 15: component supplier (source: Vincotte, 2009)**

Labels and sleeves are component because it is possible to separate them from the rest of the packaging and the inks and master batches are constituents because they cannot be separated from the rest of the packaging.

### *4.3. Summary*

It is hard to find bioplastic suppliers in companies that operate at the final phase of the production process. Companies are mostly unknown with bioplastics and do not exactly know how to process it. It is therefore more effective to look for bioplastic suppliers in earlier phases of the production process of materials.

Next to packaging suppliers such as filmflexible or injection moulded jars suppliers there are also component and constituent suppliers. These suppliers are also hard to find, paragraph 4.2. shows an overview.

# Chapter 5: Tests

The previous chapters show what bioplastics are, where they can be found and what Leaf current packaging materials are. The information of these chapters has been used to execute tests on environmental impact, shelf life (of the product), process ability and costs of bioplastic packaging.

As mentioned earlier, bioplastics are a relatively new type of material and there is a lot of information unknown. The material properties described in chapter two are the properties in general and are not specified to a maybe already upgraded material. There are also a lot of different TPS producers which produce they granulate in another way than their competitors.

The tests that will be described in this chapter will give more in-depth information about bioplastic packaging itself and in comparison to Leaf's current packaging materials.

## 5.1 Tested bioplastic

Several tests and in-depth views have been accomplished in this chapter. The materials that have been used to perform these tests and to get more knowledge about bioplastics are shortly described below.

### 5.1.1. Filmflexibles – blow moulding

**Innovia films**- Innovia film is company specialised in the film industry. They are an innovative company with an unbeatable depth of knowledge in both its product and its markets. One of their relatively new innovations is focussed on biodegradable and renewable packaging material. Innovia films' NatureFlex is renewable and biodegradable and has proved a rapid success through the technical properties they provide. Key properties include very good dead-fold, excellent transparency & gloss, a wide heatseal range and static-free machinability (Innovia Films, 2009).

Two NatureFlex films with a relative high water vapour transmission rate are going to be tested in this chapter. The first film is *NatureFlex N913* which is a transparent, high barrier, heat-sealable and compostable film and the second film is *NatureFlex NM* which is a high performance metallised and compostable film. See appendix G for the specifications of both N913 and NM.

**Cropac-** Cropac is a flexible packaging manufacturer. They are specialised in environmental friendly printing. The biodegradable film line is named CropacEco. These biodegradable films are not made from renewable resources. An additive is added make it possible for the material to break down by biological means. This material is not certified by the EN 13432 but they say that the film is biodegradable. The biodegradable film that has been selected is CropacEco OPP20/CPP30. See appendix H for the specifications of CropacEco OPP and CPP.

### 5.1.2. Rigids- injection moulding

**Rodenburg biopolymers**- Rodenburg is a Dutch company specialised in biopolymers. Their biopolymer Solanyl is a starch based polymer. Currently they are also working on an upgrade of Solanyl, a biopolymer with better properties. Rodenburg's application area is in the thermoforming and injection moulding industry.

**Naturework LCC**- Natureworks LCC is the first company to offer a family of commercially available low carbon footprint polymers based on renewable resources with costs and performance that compete with oil based plastics and fibres. Their biopolymer Ingeo™ is the first commercially available polymer, with significantly reduced greenhouse gas emissions. Their biopolymers are poly lactic acids, also known as PLA. Natureworks' PLA can be processed with thermoforming, injection moulding and also with blow moulding.

## *5.2 Life Cycle Assessment*

A life cycle assessment (LCA) is a compilation and evaluation of the inputs, outputs and the potential environmental impact of a product system throughout its life cycle. Life cycle assessments are very useful as a comparison tool. They can be used to compare product with each other on behalf of their environmental impact. See paragraph 1.2 for a more elaborated description.

A report written by the imperial college of London and the National Non-Food crops centre (2004) summarizes approximately hundred reports, articles and standards to create a detailed review of the current availability of LCA and complementary information on biodegradable polymers.

The findings are that available LCA usually show that biodegradable polymers have advantages over petro chemical based polymers in several environmental impact categories (including fossil energy consumption and greenhouse gas emissions), but are less favourable and poorer in other categories (eutrophication, ozone layer depletion and in some cases acidification).

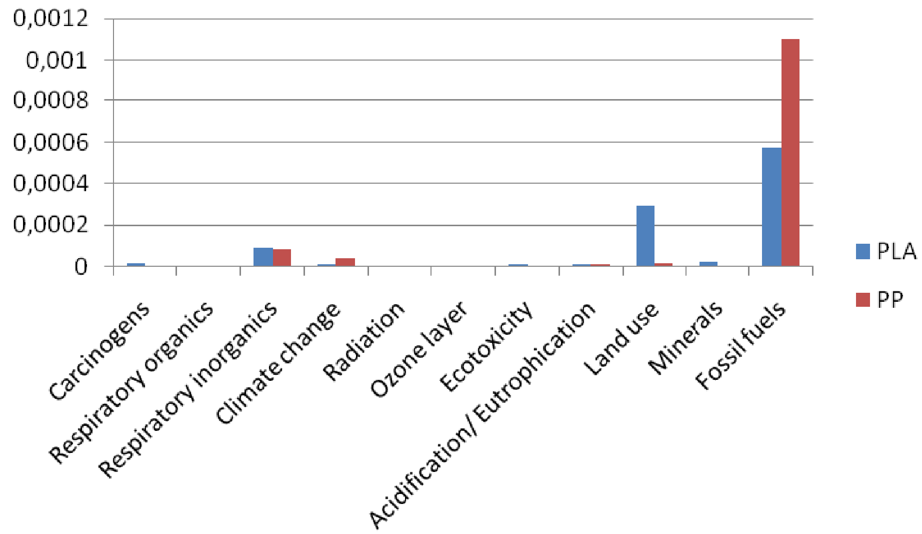
A life cycle assessment performed by the University of Utrecht (2009) also verifies the same results as the summarized report. It shows that biobased polymers score low on greenhouse emissions but on the other and have a relatively high score on ozone precursors, acidification and eutrophication.

### *5.2.1. Test*

A bioplastic is going to be compared in a cradle to gate life cycle assessment to the plastic polypropylene. The cradle to gate assessment focuses on the environmental impact of a product from raw material to film. The life cycle will be executed with the software SimaPro. The (bio)plastics that will be assessed and compared are polylactic acid (PLA) from Natureworks and Polyproylene (PP).

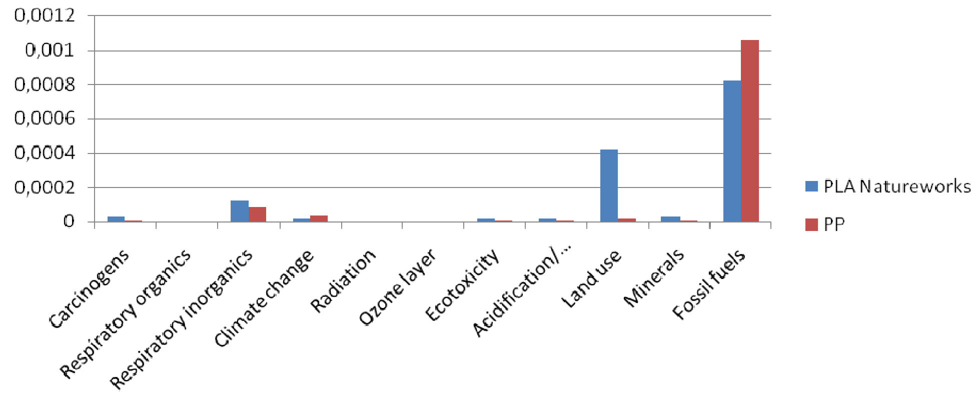
The first life cycle assessment is executed with the same mass for both plastic. To gain a better understanding of the size of the effect, a normalisation step is required. This step normalizes the overall impact to the impact caused by the average European during a year. The calculation method eco indicator 99 is used to calculate the impacts. The results are displayed in graph 4.

Graph 4 shows that PLA has less impact than PP on fossil fuels and climate change. On the other hand has PLA more impact than PP on carcinogenic, respiratory inorganic, ecotoxicity, acidification/ eutrophication, land use and minerals.




**Graph 4: Normalized PLA and PP (1 kg PLA and 1kg PP)**

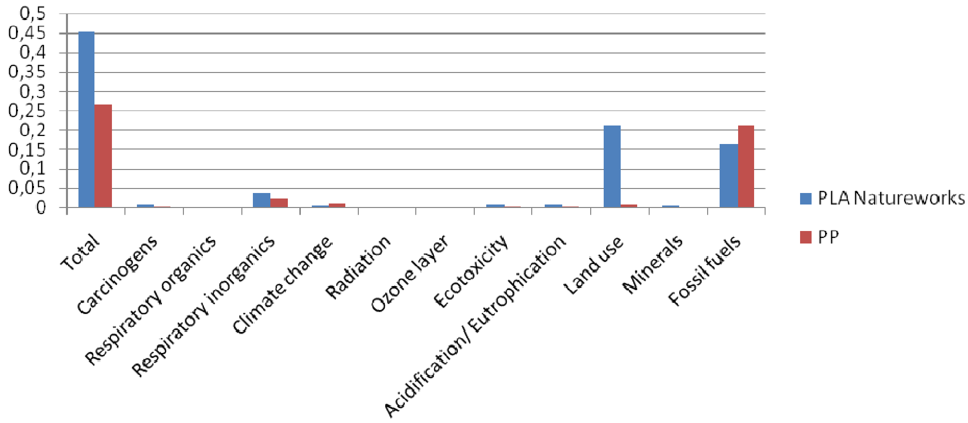
The second life cycle assessment is executed with the same plastics but not with the same weight per plastic. PLA has a higher density than PP. This means that more kilogram material is needed to obtain the same surface and thickness as a PP film. See graph 5 for the normalized results of this assessment.




**Graph 5 : Normalized PLA and PP (1,44 kg PLA and 0,96 kg PP)**

In comparison to the first LCA scores PLA less good on fossil fuels and climate change. PLA still scores better than PP but it shows that the impact on fossil fuels and climate change differs less from PP when the same thickness and surface of film is taken into account. The impact increase is probably caused by the higher quantity of PLA.

Some impacts are nowadays more important than other impacts. It can for example be said that the impact 'climate change' is ten times more important than the impact 'ozone layer'. The impact assessment method, Eco indicator 99, has a set of 'weighing factors'. These weighing factors 'weigh' the impact. An important impact weighs heavier than a less important impact. A note on the weighing factors is that those factors are subjective. The weighed results the second LCA are shown in graph 6.




**Graph 6: Weighed impacts**

After the impacts have been weighed, it seems that the total impact of PLA is bigger than PP. This difference in total impact is mostly caused by PLA's impact on land use. Climate change and fossil fuels are still the only two impacts where PLA scores better than PP.

### *5.2.2. Conclusion*

- PLA has less impact on the climate change and fossil fuels than PP.
- PLA scores lower on other impacts such as acidification/ eutrophication and land use.
- PLA has a higher density than PP. More kilogram material is needed to obtain a film with the same thickness and surface as PP. The increase in kilograms results in more emissions and higher impacts.
- The overall impact score of PLA is higher than PP after it has been weighed with the eco indicator 99 weighing set.

### *5.3 Shelf life*

The essence of a packaging can be summarised into three P's: Protect, Preserve and Promote. The second P stands for the preservation part, the shelf life of a product. A packaging can be used to extend the shelf life of a product by blocking or guiding moistures and odours.

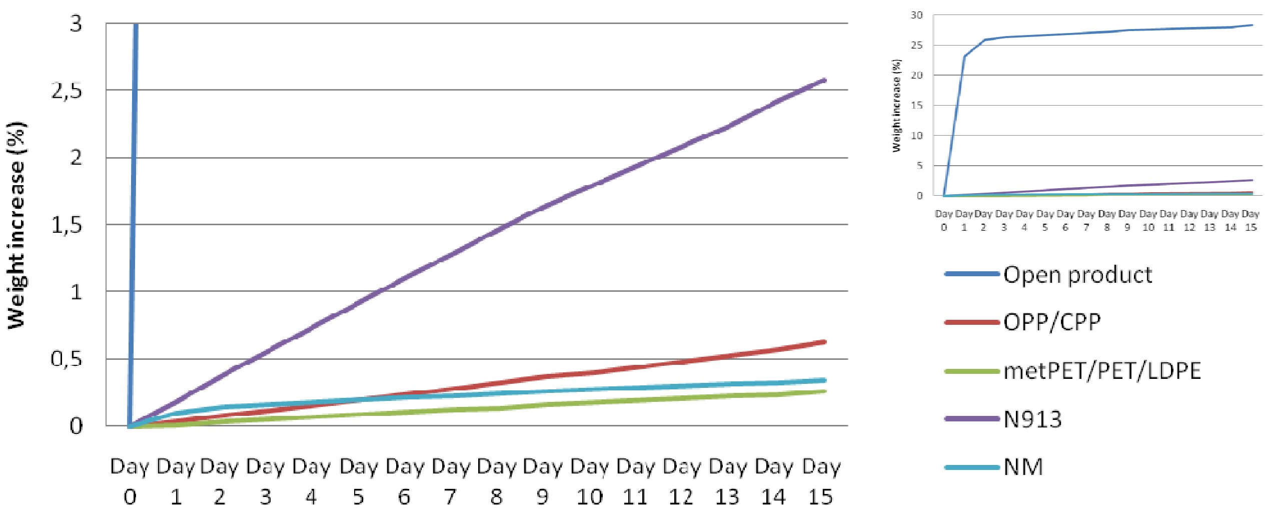
An important factor that influences the shelf life of Leaf's products is the moisture. A common Leaf packaging film is made of OPP20 and CPP30 which has a water vapour transmission (WVTR) of 4.1. This is the amount (in grams) of water that goes through one square metre of film in twenty four hours. This value is particular low and therefore good as a packaging material for confectionary.

The bioplastics have a WVTR just like the conventional plastics, but to determine the moisture transmission other aspects like seal strength and amount of seals have to be taken into account as well.

#### *5.3.1. Tests*

The first test is executed to determine the moisture absorption of a product packed in a transwrap. The test bags have three seals, two on the sides and one on the top. The films OPP20/CPP30, NatureFlex N913, NatureFlex NM and metallised PET/PET/LDPE are tested under the same circumstances. An open product is also tested to compare the moisture absorption of a product with packaging to a product without any packaging. See appendix I for the complete test plan.

The test is executed with the product silica gel because this material has a strong hygroscopic character what was expected to result in clearer results than a material with a weaker hygroscopic character. The bags are tested in circumstances of thirty degrees and seventy five per cent of humidity for fifteen days. See graph 7 for the results. The graph in the right upper corner shows an overview and the larger graph on the left takes a closer look at the plastics. Complete results can be found in appendix J.




**Graph 7: moisture absorption of bioplastics, OPP20/CPP30 and metPET12/PET12/LDPE50**

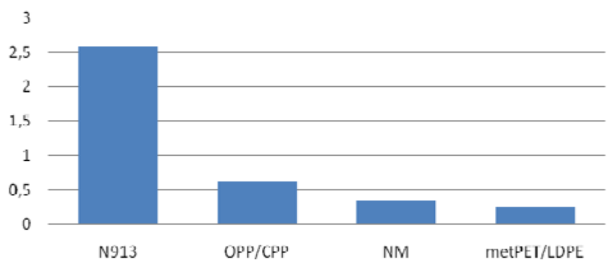
The graphs show that a packaging made of mettalised PET/LDPE has the lowest moisture absorption. NatureFlexNM absorps less than OPP/CPP but still more than mettalised PET /LDPE. NatureFlex N913 absorps the most of all plastics. It can also be concluded that all plastics protect the product in a strong way because an open product absorbs ten times more moisture than a product packed in NatureFlexN913.

The moisture barrier of a film is also dependent of the thickness of the film. See table 16 for the film thickness.

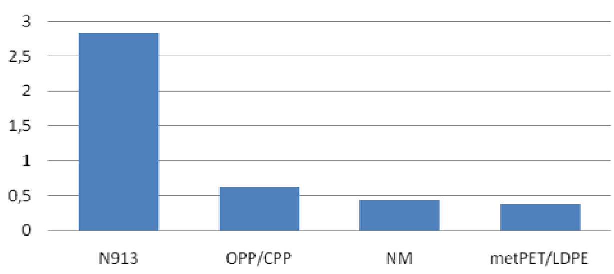
| Film | Thickness |
|---|---|
| OPP20/CPP30 | 50 µm |
| N913 | 55 µm |
| NM | 65 µm |
| PET12/MetPET12/LDPE50 | 74 µm |

Table 16: Material thickness

The moisture absorbtion of the films without paying attention to the film thickness are displayed graph 8. The second graph, graph 9 takes the thickness into account. The numbers on the Y axis indicate the weight increase (in %).



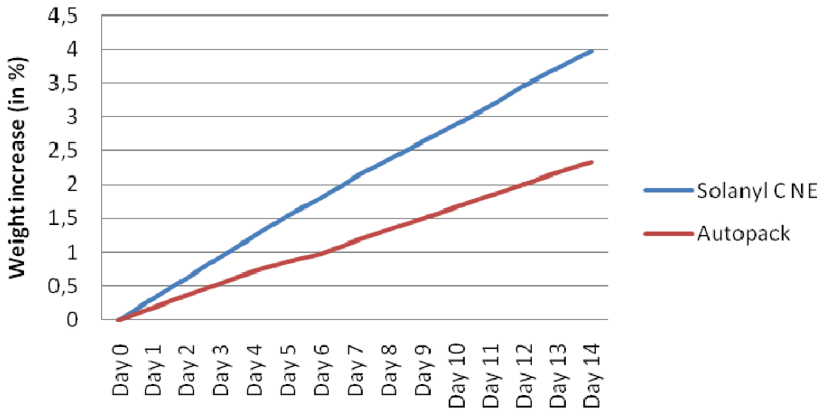

Graph 8: moisture absorption




Graph 9: taking the thickness into account

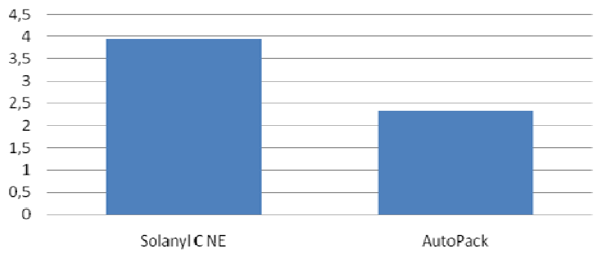
It can be concluded that N913 absorbs most of the moisture and that OPP/CPP, NM and mettalised PET/LDPE score almost the same.

Another test has been executed to determine the moisture absorbtion of a rigid. A thermoformed Solanyl C NE rigid with a NatureFlexN913 film sealed to the top is compared to the autopack rigid. The packs are both tested under the same circumstances (30°C; 75% humidity; 14 days). The results are shown in graph 10. Complete result can be found in appendix J.

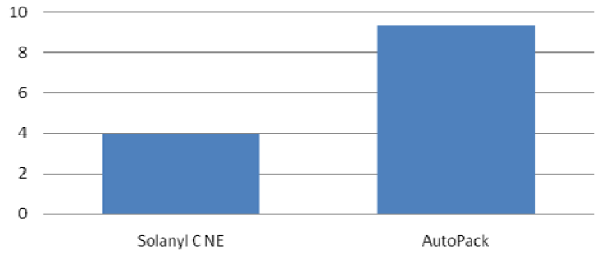



**Graph 10: moisture absorption of the Solanyl rigid and Autopack**

From the graph can be concluded that the Autopack absorps less moisture than the Solanyl rigid. The materials thickness of Solanyl is one fourth of the autopack's thickness. See graph 11 for the results of the test and see graph 12 for the results after the material thickness is taken into account. The numbers on the Y axis indicate the weight increase (in %).




**Graph 11 : moisture absorption**




**Graph 12: taking the thickness into account**

From graph 12 can be concluded that the moisture absorbtion of Autopack (when they have the same thickness) is higher. This result is probably not caused by the material itself but by the lid. The Solanyl rigid has a seal closure while the autopack has a lid closure. It is expected that the moisture enters the Autopack through the closure and not through the material itself. The only conclusion that can be made from this test is that a Solanyl rigid with the same thickness as the Autopack and a NatureFlex N913 seal will have a lower moisture absorbion than an Autopack.

### *5.3.2. Conclusion*

- MetPET/PET/LDPE has the best moisture barrier compared to the other tested material.
- NatureFlex N913 has the weakest moisture barrier.
- Bioplastic NatureFlex NM has a better moisture barrier than the OPP20/CPP30.
- All plastic packaging score at least ten times better than without packaging.
- Solanyl N CE rigid with a seal closure scores better than an autopack with a lid closure on moisture barrier.
- It is expected that the autopack's moisture absorption is caused by the closure.

### 5.4 Look & Feel

The appearance of a packaging is determined by its look & feel. One of the three packaging P's is Promote. A product can be promoted by the packaging look & feel. Colours, prints, surface texture and other material properties have a big influence on the look & feel of a packaging.

Bioplastics have a different look & feel than conventional plastics but this does not necessarily needs to be a negative aspect. The 'Look & Feel' of the materials described in paragraph 5.1 is shortly described in the tables 17 and 18. Table 17 describes the look of filmflexibles and table 18 describes the look of the rigids. Leaf's current material is also included in these tables to make a distinction between the bioplastics and the conventional plastic. '+' means that the material is flexible in the case of flexibility and the '-' that a material is not flexible. In the case of transparency does the '+' mean that a material is transparent and the '-' that it is not transparent. See appendix K for bioplastic sample material of filmflexibles.

| Films | NatureFlex N913 | Natureflex NM | MaterBi | CropacEco OPP/CPP | PLA | OPP20/CPP30 |
|---|---|---|---|---|---|---|
| **Flexibility** | + | + | ++ | + | - | + |
| **Surface look** | Glossy | metallic | Dull | Glossy | Glossy | Glossy |
| **Transparency** | +- | - | - | + | ++ | + |

Table 17: Filmflexibles's look

| Rigids | PLA (NatureWorks) | Solanyl C NE | Autopack |
|---|---|---|---|
| **Flexibility** | - | +- | + |
| **Surface look** | Glossy | Dull | Glossy |
| **Transparency** | ++ | -- | + |

Table 18: Rigid's look

It is not possible to say something about the positive or negative character of bioplastics with regards to their look & feel without further research. The look & feel is dependent of more factors than only the material's look & feel. Printing has a big influence on the look and it also dependent of the packaging's area of application to determine if a material is suitable for application or not.

### 5.5. Process ability

Conventional plastics are mostly easy to process on machines, because there is a lot of experience in that field. Most plastics have different properties and processing temperatures what influence the process ability on the machines. Thereby comes that bioplastic differ even more in material properties from conventional plastics what could influence the process ability in negative way.

#### 5.5.1. Test

The bioplastics Solanyl C NE from Rodenburg Biopolymers and PLA from Natureworks have been tested on process ability. They have been injection moulded by the company Hordijk into the AutoPack form. Hordijk reported the following results:

**Solanyl C NE**- Autopacks produced out of this material are opaque. Rodenburg advised a processing temperature of 135 °C but it was not possible to fill the mould completely. After an increase of the temperature into 190 °C it was possible to fill the mould. This temperature is beyond the advised temperature what resulted in a degeneration of the material and weaker material properties. Rodenburg Biopolymers wants to improve its process ability in the future by adding additives.

This materials is not (yet) suitable for this rigid.

**PLA-** Autopacks produced from this material are transparent and brittle. This material can be processed with higher temperatures (200 °C). It is more stable with high temperatures and longer 'stay-in' periods. The material degenerates by a stagnation longer than ten minutes. It is also not possible to fill the mould completely with the advised temperature. Higher processing temperatures made it possible to fill the mould completely.

Higher pressures in the mould cause that the parts move sideways with regard to each other. Different material thicknesses and wear of the mould will be result of this problem.

The material does not shrink what makes is harder to detach the product from the mould. Special supplies are needed and the mould needs to be adapted to prevent this problem. This will result a longer cycle period, twice as long.

This material could be suitable if the quality of the product will be accepted

See figure 13 for the injection moulded bioplastics.

**Figure 13: Solanyl C NE pack (left) and PLA pack (right)**

Hordijk's representative also reported that the cycle time of a bioplastics is twice as long as the cycle time of conventional autopacks. The granulate costs are also twice as much as the conventional granulate's cost.

### *5.5.2. Conclusion*

- Solanyl C NE cannot be processes in injection moulding machines.
- High pressure needed to process the material into the mould.
- Cycle period is two times longer that the cycle period of an autopack.
- New moulds are needed because there is almost no shrink.
- Solanyl C NE is not a suitable material and PLA could be suitable.

## 5.6. Costs

Costs are an important issue when it comes to profit. Companies want to make profit purchase packaging materials for the lowest price as possible.

### 5.6.1 Calculations

The Graph 3 in chapter 2 shows that the prices of bioplastics are relatively higher than the prices of conventional plastics. In this paragraph the prices of two bioplastics will be compared to the prices of OPP20/CPP30 .

Table 19 shows the prices of the plastics per kilogram and per metre. The prices per meter* give a better indication because the buyer wants to know how many bags he can make for a particular price. The amount of kilogram does not really say anything about number of bags that can be made with it. See appendix L for the calculations.

*Reel width is 230 mm

| Film type | Minimum order quantity (m) | €/kg | €/m$^2$ |
|---|---|---|---|
| **OPP20/CPP30** | 27.750 | 7,28 | 0,07 |
| **CropacEco OPP20/CPP30** | 96.153,8 | 5,65 | 0,06 |
| **NatureFlex N913** | 50.000 | 20,87 | 0,32 |
| | 75.000 | 19,5 | 0,299 |
| | 100.000 | 18,26 | 0,28 |

Table 19: Film thickness

### 5.6.1. Conclusion

- The costs of OPP20/CPP30 and CropacECO OPP20/CPP30 are around the same price.
- NatureFlex N913 is five times more expensive than OPP20CPP30.

### *5.7. Summary*

This chapter contains the tests that has been executed to gain more knowledge about bioplastics. The tests include a life cycle assessment, shelf life test (of the packed product), look & feel analysis, process ability analysis and costs calculations.

The life cycle assessments in combination with literature showed that bioplastic have less impact on climate change and fossil fuels than conventional plastics. On the other hand they have more impact on other environmental issues such as carcinogenic, respiratory inorganic, ecotoxicity, acidification/ eutrophication, land use and minerals than conventional plastics.

The shelf life of products packed in bioplastics is not as good as packed in conventional plastics. There is just one bioplastic, NatureFlex NM that can provide a good shelf life of the product. This is probably caused by the aluminium content in the material. This small part of aluminium is accepted in the testing method and therefore it is allowed to name this material a bioplastic. A pack made of the bioplastic can also provide a better shelf life of the product but this is probably caused by the closure (seal versus lid) that has been used and not the barrier properties of the material itself.

The look& feel of bioplastics is different from conventional plastics but this does not necessarily has to be a negative aspect. Some bioplastics are less flexible, transparent than conventional plastics and some are more. They also differ from each other in surface finish.

The machine ability is a problem for bioplastics. It's is harder to process them and it takes twice as much time to process them. Improvements are required before they become suitable as a replacement of the current materials. Bioplastics have almost no shrink what means that news mould are required to make to pack and the lid fit to each other. The bioplastic PLA from NatureWorks could be suitable as a replacement if the look & feel will be accepted by Leaf.

Thereby also comes that the costs of biobased plastics are considerably higher than the costs of conventional plastic. There is one type of plastic, the biodegradable plastic CropacECO that is comparable to the costs of the conventional plastics of Leaf BV.

# Chapter 6: Application options

The previous chapters give an overview of the different bioplastics and their properties. The tests in chapter five give even more depth into the properties of a couple of available bioplastics. The conclusion in chapter five is that most of the bioplastic do not have a moisture barrier as good as the moisture barrier of current packaging materials. This does not mean that bioplastics cannot be used as a substitution of Leaf current packaging plastics.

The market potentials for bioplastics are high and it is expected that the cost will decrease as a result of an increased market. Bioplastic are interesting when it comes to the carbon footprint. They score better on carbon footprint what means that is has less impact on climate change. Big stores like Wal-Mart are pushing suppliers to reduce their carbon footprint by introducing scorecards. Wal-Mart's packaging scorecard is a measurement tool that allows suppliers to evaluate themselves to other suppliers, based on specific metrics. Asda, the United Kingdom subsidiary of Wal Mart will introduce Wal-Mart's scorecard next year as well. It is not out of the question that this scorecard will eventually end up in the Netherlands and other countries where Leaf operates.

Movies like 'the inconvenient truth' and the 'age of stupid' are also making people aware of the human influence on climate change. People are starting to know that the climate change is an important and threatening matter, and that they have to try to stop it before it is too late.

Another reason to choose for bioplastics is because of the competitors. Coca Cola and FritoLay are starting to come with bioplastic packaging and other big companies are investing in bioplastic research to eventually apply it as well. As company you do not want to be the last company to follow.

As stated above, there are many reasons for Leaf to choose for bioplastics. This chapter shows five options for application. The options that are described in the upcoming paragraphs are recommendations and are not tested. It functions as an overview for bioplastics options for Leaf, to show them where and how they can use bioplastics instead of conventional plastics.

## *6.1 Options*

The five options that will be elaborated further in this chapter are the following options:

Plastics that are:

1. Biobased and biodegradable (primary packaging)
2. Biobased and biodegradable (secondary packaging and components)
3. Partly biobased; not biodegradable
4. Biodegradable; not biobased
5. Biodegradable and partly biobased

Figure 14 illustrates the options stated above. The first column shows the material types that Leaf currently uses. They are all synthetic based. The next column shows the bio solution for this packaging and the last column shows that the material is biodegradable or not. For example, the first option is completely biobased (two layers are green) and is biodegradable. The second option is synthetic, but the material packed around it (secondary packaging) is biobased and biodegradable.

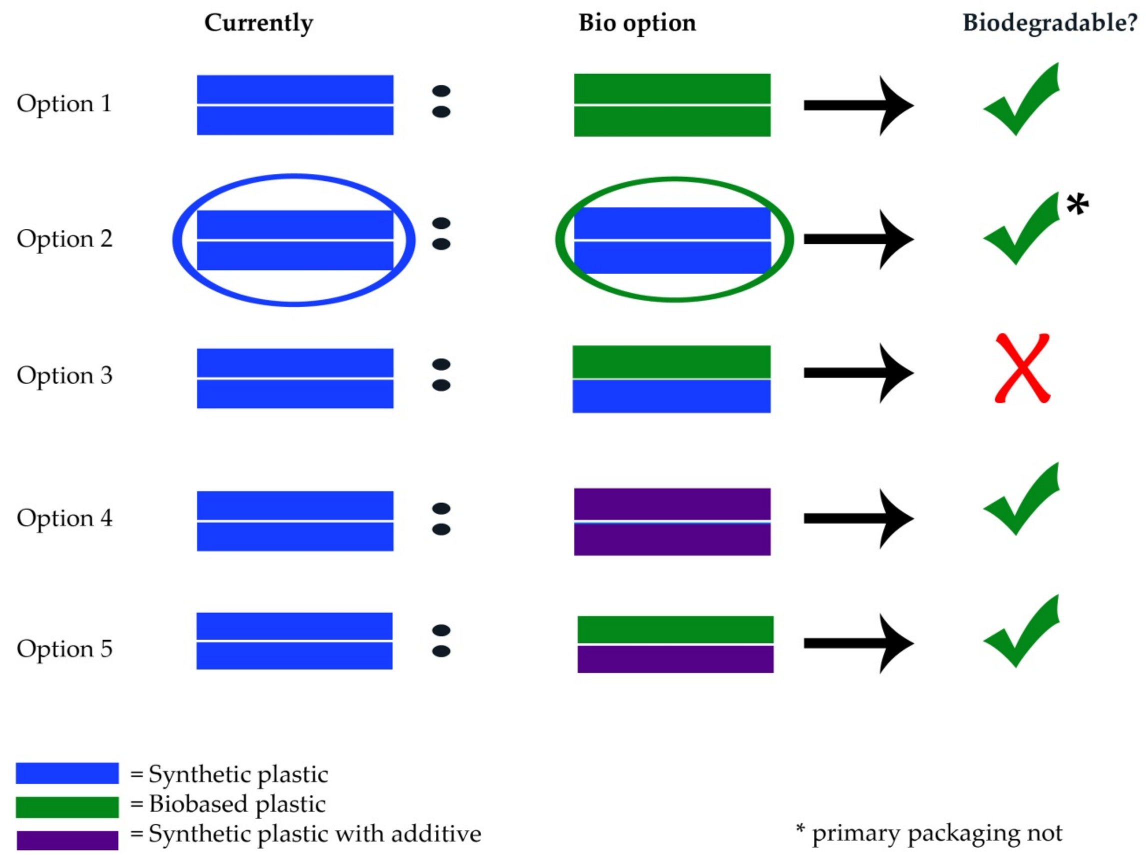



**Figure 14: overview of the options**

The options will be elaborated further is the following paragraphs. Examples of packaging that could be suitable for the replacement of the plastics are described in the paragraphs and how to communicate the options to the consumer will also be amplified in the paragraphs. The topic 'how to communicate' shows the selling points of these options in comparison to conventional plastics. The way that this message needs to be transferred to the consumer needs to be investigated further in a market research. This could for example be done by logos, slogans or by commercials.

## 6.2 Option 1: Biobased and biodegradable

Bioplastics can be both biobased and biodegradable or just biobased or biodegradable. This option is based on plastics which are both biobased and biodegradable with the focus on primary packaging. The advantage of this option is that it is produced on the basis of renewable resources and that the packaging will also break down by biological means. So there is an environmental profit at the beginning and the end of the packaging's life cycle. See figure 15 for an illustrated version of option one.

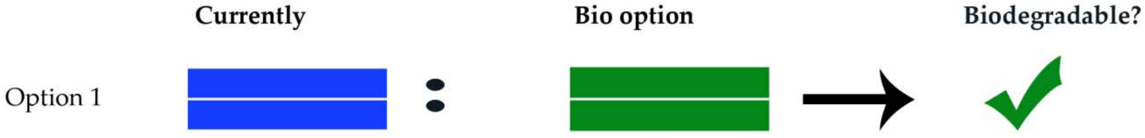



Figure 15: option 1

### *6.2.1 Substitution of current plastics by bioplastics ( same barrier properties)*

The shelf life test in chapter five shows that this application area is not possible for most of the bioplastics.

- Chewing gum bag and Läckerol zipper bag (figure 16)
  The NatureFlex NM has a good moisture barrier and a metallic look. This material could be used as a subtraction of the metalized PET and LPDE laminate.
- Twist wraps
  The good barrier properties of NatureFlex could make the suitable as a replacement of twistwraps.


Figure 16: Läckerol and Sportlife

### *6.2.1 Substitution of current plastics by bioplastics ( other barrier properties)*

Products that do not need a high moisture barrier packaging

- King, Venco and Stophoest packaging (figure 17)
  Bioplastic layer with a biodegradable paper wrapped around. The bio(plastic) is illustrated on the right side of figure X is the bioplastics alternative illustrated. The green layers are the bio materials and the red part is the product.


Figure 17: King, Venco and stophoest stick and bio option

- Conical PE bag  (figure 18)
  The conical PE bag has a clip closure. This means that it is not closed with seals on all sides but with a clip at the top. It is expected that the clip closure is not as moisture proof as a seal. For this reason it is expected that the products packed in this packaging will also maintain their shelf life with a lower moisture barrier packaging. The bag can be substituted by a single or multiple laminated bioplastic.

Figure 18

- Carton box (Venco)
  Biodegradable carton with a bioplastic laminate on the inside

### *6.2.3 How to communicate*

- Reduction of carbon dioxide in comparison to conventional plastics
- No fossil resources; Renewable resources
- Sustainable and innovative packaging
- Compostable/ biodegradable

### 6.3 Option 2: Biobased and biodegradable (secondary packaging and components)

The second option is just like the first based on plastics that are both biobased and biodegradable. The only difference is that this option is focussed on secondary packaging instead of primary. The difference lies in the material properties. Primary packaging is quite strict when it comes to barrier properties because it has to secure a certain shelf life of the product without influencing the taste in a negative way. Secondary packaging is less dependent of barrier properties because they are the packaging around the primary packaging. So the primary packaging does the job when it comes to barrier properties and the secondary packaging has to pack the primary packaging together. It works the same for components. Components are not the packaging itself but a decoration of it. Components are just like secondary packaging easy to separate from the rest of the packaging. A disadvantage of this option is that only the secondary packaging and/or the components are made from bioplastic and the primary packaging not. See figure 19 for an illustrated version of option two.

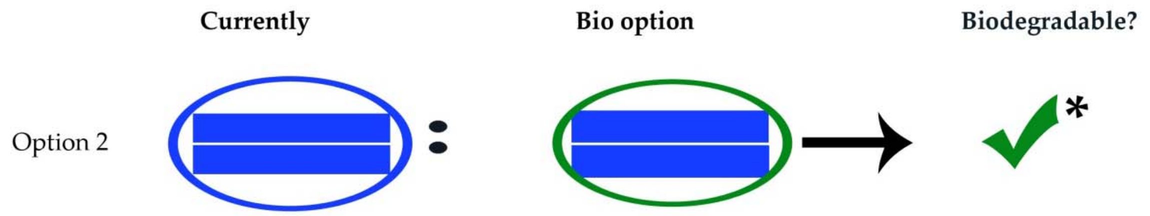



Figure 19: option 2

* only the secondary packaging

#### *6.3.1 Substitution of a secondary packaging by a bioplastic.*

- Kids multi pack (figure 20)
  A kids pack is a pack filled with multiple little kids packs. The outer pack can be made out of a bioplastic because the little bags are already packed with a good barrier packaging.

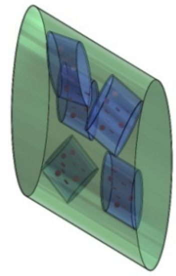


*Figure 20: Kids pack*

- Chewing gum multipacks
  A chewing gum multi pack is a transwrap filled with two or more blisters, see figure 21.


Figure 21

- Other multipacks (figure 22)
  Transwraps meant for multipacks can be replaced by bioplastics. These transwraps are secondary packaging and therefore not expected to have good barrier properties. Their function is to keep the multiple packs, bag or blister together


Figure 22: Venco and Red band multipacks

- Red band's autopack
  Autopacks can be replaced by a bioplastic pack if the pack functions as a secondary packaging. This can be accomplished by packing the confectionary individually.

### *6.3.2 Bioplastic components*

- Bioplastics sleeves (figure 23)
  - King, Venco and Red Band Sticks The paper around the aluminium layer can be replaced by a bioplastics sleeve
  - Bioplastic sleeves can be used to decorate an autopack or a jar instead of inks.


Figure 23: Sportlife and Xylifresh jars with sleeves

- Bioplastic labels
  - All labels can be substitutes by bioplastic labels. See figure 24 for consumer silo's and their label.


Figure 24: consumer silo's

### *6.3.3 How to communicate*

- Reduction of carbon dioxide in comparison to conventional plastics
- No fossil resources; Renewable resources
- Sustainable and innovative packaging
- Compostable/ biodegradable

## *6.4 Option 3: Partly biobased; not biodegradable*

The third bio option is based on plastics that are based on synthetic and renewable resources. This means that it is a combination of conventional plastics and biobased plastics. A disadvantage is this option is that the material cannot be called a bioplastic with conviction because it is just partly biobased and it is not biodegradable.

The advantage is that the conventional plastic has a positive influence on the barrier properties and the biobased plastic has a positive influence on the reduction of carbon emissions. So this option contributes to the reduction of carbon emissions but cannot be called a bioplastic with conviction. This is because a bioplastic has to be biobased and/or biodegradable. It is not stated how big the renewable percentage has to be. See figure 25 for an illustrated version of option three.

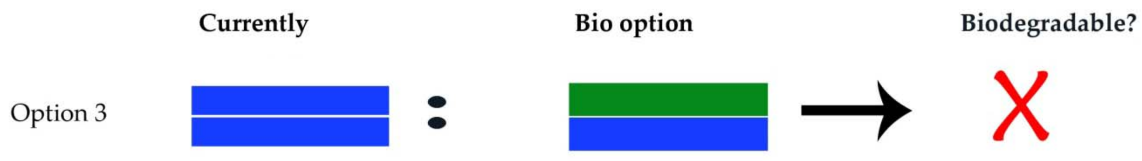



**Figure 25: Option 3**

### *6.4.1 Combination of a synthetic and a biobased layer*

- Transwraps/ stand-up pouches (figure 26)
  Transwraps and standpouches are mostly made from OPP and CPP film combinations. A layer of OPP or CPP can be substituted by bioplastic layer. It is also possible to make a new combination of a synthetic plastic and bioplastic layer.


**Figure 26: stand-up pouches and transwrap**

- Carton box (figure 27)
  Venco's carton box can be partly produced from bioplastics. The carton can be laminated with bioplastic to improve the barrier properties of the carton. This laminate could make the plastic bag for the confectionary that is placed on the inside unnecessary.


**Figure 27: Venco carton box and bio option**

- Jars & autopack
  The synthetic plastics that are used to injection mould jars and autopacks can be partly be substituted by bioplastics

- Zipper bag
    A layer of the Sportlife and Läckeroll zipper bags can be replaced by a bioplastic layer. The bioplastic layer will be laminated to a synthetic layer. The synthetic layer provides the good barrier properties.
- Others
    Blisters, consumer silo's, sticks and conical bags

### 6.4.2 How to communicate

- First step to reduce the environmental impact of the packaging
- Reduce amount of non renewable material in the packaging
- Based on renewable resources

## 6.5 Option 4: Biodegradable; not biobased

The fourth option is based on synthetic plastics that are biodegradable. There are bioplastics on the market that are biodegradable but not produced on the basis of renewable resources, see paragraph 2.1.4. for more information about these bioplastics. Next to these bioplastics there are also synthetic plastics that 'become' biodegradable after the addition of a particular additive. The disadvantage of first mentioned bioplastic is that the price is relatively high. The price of the second bioplastics, the plastic with additive, is comparable with conventional plastics and therefore more attractive. This paragraph will focus on synthetic plastics with an added additive. See figure 28 for an illustrated version of the plastic with an additive.

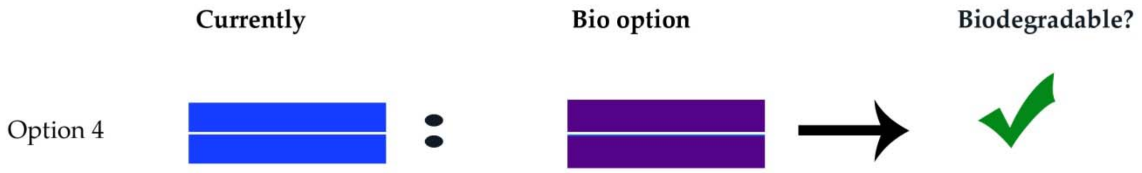



**Figure 28: biodegradable synthetic plastic with additive**

### 6.5.1 Substitution of plastics by biodegradable plastics

- Transwarps and stand up pouches
  Most of the transwraps and stand-up pouches are made from OPP and CPP combinations. It is possible to add an additive to OPP and CPP and to process it into a biodegradable laminate.
- Blisters (figure 29)
  Blisters are currently made from PolyVinylChloride and aluminium. An additive can be added to change the structure of polyvinylcholide into a biodegradable structure. Aluminium can also be substituted by a biodegradable plastic.


**Figure 29: blisters**

- Autopack and Jars
  An additive can be added to the autopack and jar granulates. The autopacks and jars that will be injection moulded from granulate and will have a biodegradable structure.
- Others
  All other primary and secondary packaging can be substituted by this biodegradable plastic.

### 6.5.2 How to communicate

- Biodegradable

### *6.6 Option 5: Biodegradable and partly biobased*

This option is a combination of option three and four. The materials is partly made from bioplastics and partly made from a biodegradable synthetic plastic. The advantage of this option is that the good barrier properties from the synthetic and biodegradable plastic will be combined with a bioplastic. Other benefits are that it reduces the impact of the packaging on climate change, it is less dependent of non-renewable resources and that it is biodegradable. See figure 30 for an illustrated version of option five.

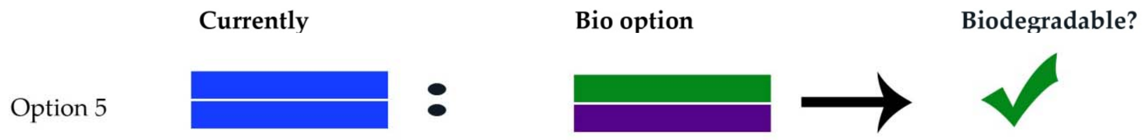



**Figure 30: option 5**

This option can be used for all the options that are stated in option three and four. The only difference with option three is that the synthetic part will be replaced by a biodegradable synthetic part and the difference with option four is that a biodegradable and synthetic part will be replaced by a bioplastic. See figure 31 for some packaging that could be substituted by this option.


**Figure 31: Packaging that could be substituted by material option 5**

#### *6.6.1 How to communicate*

- Reduction of carbon dioxide in comparison to conventional plastics
- Based on renewable resources
- Reduce amount of non renewable material in the packaging
- Biodegradable

## 6.7. Summary

There are many reasons for Leaf BV to choose for bioplastics. The tests in the previous chapter show that bioplastics do not have such a good moisture barrier as Leaf's conventional plastics. This does not mean that is not possible to use them as a packaging material. Five different application options have been developed to illustrate that it is possible for Leaf BV to make use of bioplastics. The options are:

Plastics that are:

1. Biobased and biodegradable (primary packaging)
2. Biobased and biodegradable (secondary packaging and components)
3. Partly biobased; not biodegradable
4. Biodegradable; not biobased
5. Biodegradable and partly biobased

These five options show different possibilities for bioplastic application. The options have been elaborated with possible ways to communicate it the consumer and examples have been given of possible packaging that could be replaced by the (bio)plastics described in the options. Appendix M shows an overview of the five options with their application areas, examples of packaging that could be substituted by these options and ways to communicate the options to the consumers.

# Conclusion

A packaging made of bioplastic is not better for the environment than a packaging made of conventional plastics. Bioplastics have less impact on climate change and fossil fuels but they have more impact on the other impact such as eutrophication, land use and the ozone layer. The total impact of a bioplastic ends up higher than the total impact of conventional plastics.

Bioplastics cannot maintain the shelf life of a product as good as their current packaging material. One material, NatureFlex NM has a good moisture barrier and is able to protect the product's shelf life. All bioplastics that are on the market have a relatively low moisture barrier.
The look and feel of bioplastics differs from conventional plastics but this does not necessarily needs to be a negative aspect.

The costs of bioplastics are relatively higher that the costs of conventional plastics. The bioplastic NatureFlex N913 is three time more expensive than the filmflexible oriented propylene 20/ cast propylene 30. CropacEco oriented propylene 20/cast propylene 30 cost the same as the conventional filmflexible oriented propylene 20/ cast propylene 30.
The market potentials of bioplastics are high and it is expected that the market will grow. The competitiveness and the production size will increase and it is expected that the costs will decrease.

Bioplastics are not suitable as a replacement of the primary packaging material of transwraps and standpouches, OPP20/CPP30. There a multiple other options to apply bioplastics in Leaf's packaging. These other options keep the shelf life, look & feel and the costs into consideration.

# Recommendations

The bioplastic market keeps on growing every year. It is a relatively new market and it keeps on developing. A recommendation is to keep up to date with all the new developments.
Products do not necessarily need to have highest barrier packaging possible. The type of barrier that is needed is depended of the product. A recommendation is to investigate the product properties so that the packaging material with other barrier properties can maybe be applied as well.

The shelf life of the product has been tested in this report. It is also a recommendation to test the shelf life of the packaging material itself.

The most effective way for marketing needs to be investigated. This report only informs how the materials look like and what their strong selling points are. More information needs to be gained about what the best way is to communicate the bioplastics message to the consumers.

There are multiple options for bioplastic applications. It is recommended to investigate these options, because these options are based on assumptions and are not tested.

Leaf BV has to make decisions about whether they want to continue with bioplastics. There are several feasible options available which could all contribute to lower impact on climate change.

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# Glossary

| | |
|---|---|
| Biobased | Based on renewable resources |
| Biodegradable | Degradable from the action of naturally occurring microorganism, |
| Bioplastics | plastics that are biobased and/or biodegradable |
| Carbon footprint | A life cycle assessment with the analysis limited to emissions that have an effect on climate change |
| Compostable | capable of undergoing biological decomposition in a compost site as part of an available program, such that the plastic is not visually distinguishable and breaks down to carbon dioxide, water, inorganic compounds, and biomass, at a rate consistent with known compostable materials (e.g. cellulose). and leaves no toxic residue |
| Degradable | will undergo a significant change in its chemical structure under specific environmental conditions resulting in a loss of some properties |
| European Bioplastics | European branch association representing industrial manufacturers, processors and users of bioplastics and biodegradable polymers (BDP) and their derivative product |
| Filmflexibles | Flexible plastics film |
| Life cycle assessment | compilation and evaluation of the inputs, outputs and the potential environmental impact of a product system throughout its life cycle |
| Rigids | Plastics in a stiff form |
| Primary packaging | packaging that is in direct contact with the product |
| Secondary packaging | Packaging to pack primary packaging. Material used primarily to give additional physical protection to the outside of a proximity package. |
| Tertiary packaging | Packaging to pack secondary packaging. Material used primarily to give additional physical protection to the outside of a proximity package. |
| SimaPro | Life cycle assessment software |
| Sustainability | development that meets the needs of the present without compromising the ability of future generations to meet their own needs. |
| Eco indicator 99 | Environmental performance *indicator* method for life cycle assessment and ecodesign. |

# Appendices

# A to L

# Appendix A: Project plan

## *Initiator analyses*

*The initiator, Leaf Holland BV, is a confectionary company located in Roosendaal. They own a lot of national and international brands, like Redband, Venco, Sportlife, Läckerol , etc. The mission of Leaf is to create value for its shareholders through its brands and customers. Their vision is to become the most admired company within the European confectionary industry; admired by consumers, costumers, competitors and employees.*

*Leaf develops confectionary to impress their costumers, costumers, competitors and employees. To stay admired and to impress the people around them it is important for Leaf to stay ahead of the market. A big upcoming trend is sustainability. Leaf is taking a closer look at this trend and how they can contribute to it. Sustainability is very broad and deals with a lot of different aspects on the environmental, social and economic field. One of the aspects that also have to do with sustainability is packaging. Leaf is interested in the new upcoming material built up out of biopolymers. They would like to know if this new material which sounds quite environmental friendly is environmental friendly and if it is possible to replace their existing packaging material.*

## *Project scope*

*The Dutch ministry of agriculture, nature and food quality is financial supporting a big project based on the development and improvement of bioplastics. This is just one project that has recently started but all over the world the interest in bioplastics is increasing. The attention to the upcoming plastics calls the interest of the consumer and costumers. People start to have an opinion about the topic without really knowing if it contributes to a better world or not. In America, Wal Mart is asking their suppliers to measure and report the greenhouse gas emissions incurred in the making of their products. It has not reached that level yet in The Netherlands but it would be interesting to look at the possibilities to reduce the greenhouse gas emissions before it has a change to reach that level.*

*For packaging it would be interesting to take a closer look at bioplastics. There are several ways to improve the sustainability of packaging, like reducing the amount of material used in a packaging which is already done with most of the packaging. To take one step further it could be possible to replace the current material by a more sustainable friendly material. Bioplastics are quite new and the consumer's feeling with bio products and/or materials associates with environmental friendliness. As said before, the material is quite new which also comes with the fact that is not really clear if they can fulfil their task the way that the current packaging is doing and if they really contribute more to sustainability than the current packaging.*

## *Objective*

*The objective of the assignment is to show if a packaging made of bioplastic(s) is better for the environment than the current packaging material without influencing the shelf life, costs, look & feel and process ability of a packaging in a negative way, focussing on filmflexibles and rigid materials.*

*This will be done by giving an overview of different bioplastics that can replace the current packaging of filmflexible and rigid material that Leaf uses. Subsequently decisions can be made about the most appropriate bioplastic to replace the current filmflexible(s) or rigid material(s)*. After that, the analyse starts by comparing the bioplastic packaging with the current packaging on shelf life, environmental impact, costs and look and Feel. A factory run will be accomplished with this material to ensure that the material runs on the existing machines in the way that the current packaging material does.*

*This assignment will be accomplished in a period of three months and will give advice about the bioplastic packaging as a replacement of their current packaging material.*

** a material and suppliers overview will be made for bioplastic filmflexibles and rigid materials. After that, decisions will be made about whether to analyse a filmflexibles or rigid materials. This will be done by taking a look at Leaf's products and its packaging and by making a decision together with Leaf about which packaging would be the most appropriate to replace by a bioplastic material.*

### *Questions*

*Step 1: scope and definition*

*1. In which way can bioplastics contribute to the sustainability of packaging?*

*What is the role of packaging in sustainability?*

*What is a bioplastic?*

*What are the pros and cons of bioplastics?*

*What is the consumer's attitude to bioplastic packaging?*

*Step 2: inventory of available biobased packaging materials (focussing on max. 5 suppliers)*

*2. Which bioplastic filmflexibles are on the market and are suitable for replacement of the current filmflexibles?*

*What are the properties of Leaf's current filmflexibles?*

*Which bioplastics filmflexibles are on the market and what are their properties?*

*3. Which bioplastic rigid materials are on the market and are suitable for replacement of the current rigid materials?*

*What are the properties of Leaf's current rigid materials?*

*Which bioplastics rigid materials are on the market and what are their properties?*

*Step 3: Quick scan leaf products*

*4. For which product of Leaf is it reasonable to replace the existing packaging for a bioplastic packaging?*

*What are Leaf's products?*

*What type of confectionary properties belong to the product?*

*What are the images of those products?*

*What kind of packaging materials does belong to those products?*

*Step 4: application of biobased packaging materials for leaf. (At this stage a bioplastic has been choosen to analyse: samples of this materials are going to be tested and the properties and materials of the bioplastic are known)*

*5. What is the impact of the bioplastic packaging on the environment, costs, shelf life, look and feel and the production ?*

*What is the environmental impact of the bioplastic in comparison to the current packaging material?*

*What is the cost impact of the bioplastic in comparison to the current packaging material?*

*What is the shelf life impact of the bioplastic in comparison to the current packaging material?*

*What is the impact on look and feel of the bioplastic in comparison to the current packaging material?*

*What is the impact on the production of the bioplastic in comparison to the current packaging material?*

## *Project strategy*

*The information that will be needed during my assignment will be collected by (see planning for when):*

*Question 1 : literature and interview*

*Question 2 : market analysis: literature, interviews, company visits and trade fair*

*Question 3 : literature, interviews, company visits and trade fair*

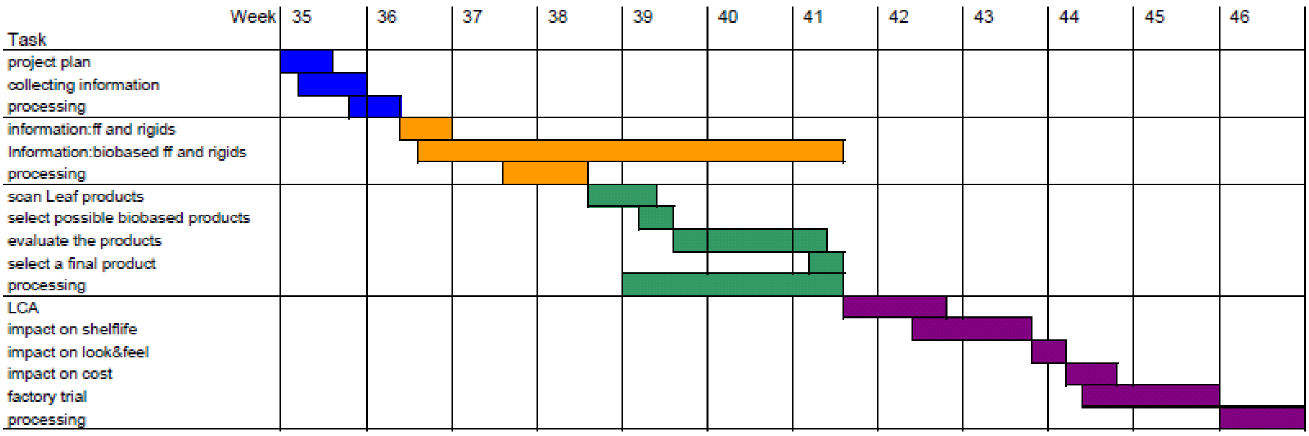
*Question 4 : data, interview*

*Question 5 : analysis*

*Stage 1 is for the introduction of the subject and to gain more inside information about bioplastics. In stage 2 (question 2 and 3) information and sample material of the bioplastics will be collected. After* *stage 3 (question 4) it is clear which packaging of Leaf is going to be analysed in comparison to the bioplastic that meets the same (or almost the same) characteristics. In stage for the 4 the packaging will be analysed on environmental, cost, shelf life, look and feel and production impact. This will be done by making a life cycle assessment, a sample packaging to test it on look & feel and shelf life, calculations and a factory run.*

*The analyses will be used to advice Leaf about the bioplastic packaging in comparison to the current packaging on environmental impact, shelf life, costs, look and feel and production.*

## *Planning*



# Appendix B: Logo's

American logo for compostability

Other logo's:

**This logo meets The European and American standard**

**Canadian logo**

**Oxo- biodegradable logos**

# Appendix C: Fees for the certification of compostable products

TÜVRheinland®
DIN CERTCO
Genau. Richtig.

## Schedule of fees for the certification of products made of compostable materials

valid with effect from 01.02.2009

| | | |
|---|---|---|
| **1** | **General** | |
| | The following fees apply to the normal services provided by DIN CERTCO. The charges for these services take the form of fee units (FU), the current rate per unit being **EUR 42.00** plus VAT. | |
| | Payment of fees falls due immediately the account is rendered. | |
| **2** | **Initial certification of products** | |
| 2.1 | Processing of application | **2 FU** |
| 2.2 | Technical examination<br>Invoice from testing laboratory plus 10 % additional fee, at least **8 FU** | **at cost** |
| 2.3 | Conformity assessment<br>- per product and type<br>- per subtype/model<br>- per product family | <br>**30 FU**<br>**5 FU**<br>**20 FU** |
| 2.4 | Issue of certificate including permission to use the Compostability Logo<br>- in a CEN-language (German, English, French)<br>- in other languages | <br><br>**5 FU**<br>**7 FU** |
| **3** | **Verification of products** | |
| 3.1 | Technical examination (transmission spectrum)<br>- per additional spectrum (e.g. product family) | **10 FU**<br>**5 FU** |
| 3.2 | Conformity assessment<br>- per product and type or verification process | <br>**10 FU** |
| **4** | **Renewal of products** | |
| 4.1 | Conformity assessment<br>- per product and type<br>- per subtype/model<br>- per product family | <br>**15 FU**<br>**3 FU**<br>**12 FU** |
| 4.2 | Issue of certificate<br>- in a CEN-language (German, English, French)<br>- in other languages | <br>**5 FU**<br>**7 FU** |

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| | | |
|---|---|---|
| **5** | **Registration of materials, additives and intermediates** | |
| 5.1 | Processing of application | **2 FU** |
| 5.2 | Technical examination<br>Invoice from testing laboratory plus 10 % additional fee, at least 8 **FU** | **at cost** |
| 5.3 | Conformity assessment<br>- per product and type<br>- per subtype/model<br>- per family | <br>**40 FU**<br>**5 FU**<br>**20 FU** |
| 5.4 | Issue of notice of registration<br>- in a CEN-language (German, English, French)<br>- in other languages | <br>**5 FU**<br>**7 FU** |
| **6** | **Sublicences** | |
| | Evaluation and Documentation | **4 GE** |
| 6.1 | Issue of certificate including permission to use the Compostability Logo<br>- in a CEN-language (German, English, French)<br>- in other languages | <br>**5 FU**<br>**7 FU** |
| **7** | **Annual fee for use** | |
| 7.1 | Certification of products<br>Annual fee for licence to use the Compostability Logo<br>(charged per calendar year from the year following the issue of the certificate) | <br>**5 FU** |
| 7.2 | Registration of materials, additives and intermediates<br>Annual fee for licence to use<br>(charged per calendar year from the year following the issue of the notice of registration) | <br>**5 FU** |
| **8** | **Amendment of certificates with conformity assessment (incl. Issuing of certificate in German language)** | |
| 8.1 | Registration | **20 FU** |
| 8.2 | Certification | **15 FU** |
| **9** | **Flat rate fee for administrative costs** | |
| 9.1 | Flat rate fee for administrative costs is charged e.g. for amendments/ extensions of certificates without conformity assessment , etc.<br>- per action taken | <br>**8 FU** |
| 9.2 | Other services, where not specifically mentioned, e. g. test costs and costs of sampling, visits to production sites, will be charged for on the basis of the actual costs plus a flat rate fee for administrative costs. | |

# Appendix D: Leaf's packaging overview

### *Transwraps/ Pillowbags*


### *Stand pouches*


### *Stick pack*


### *Stick 4 pack*

### *Blister*



### *3 pack blister*




### *Other gum packs*



## *Jars*


## *Cups*


## *Consumer silo*

### *Others*





### *Other multi packs*


# Appendix E: OPP20/CPP30 specifications

| | | | |
|---|---|---|---|
| **Specification number:** | 2D0003 | **Version:** | 2 |
| **Product description:** | OPP20/CPP30 | | |
| **Product class:** | 2D Polymer flexibles | **Releas e date:** | 22-7-2009 |
| **Reason modification:** | Internationalise this specification. | | |

| **Description** | |
|---|---|
| Polymer flexible for use on form-filling-machine to produce packages for products in direct contact with the material. Products: sugarcontaining and sugarfree confectionary, sugarfree chewing gum, chocolate. These product may contain/be covered with oil/wax, powder or cristals of starch, acid, salt, liquorice or sugar. | |
| Packaging meant for direct food contact: | Yes |
| Packaging has incidental direct food contact: | Yes |

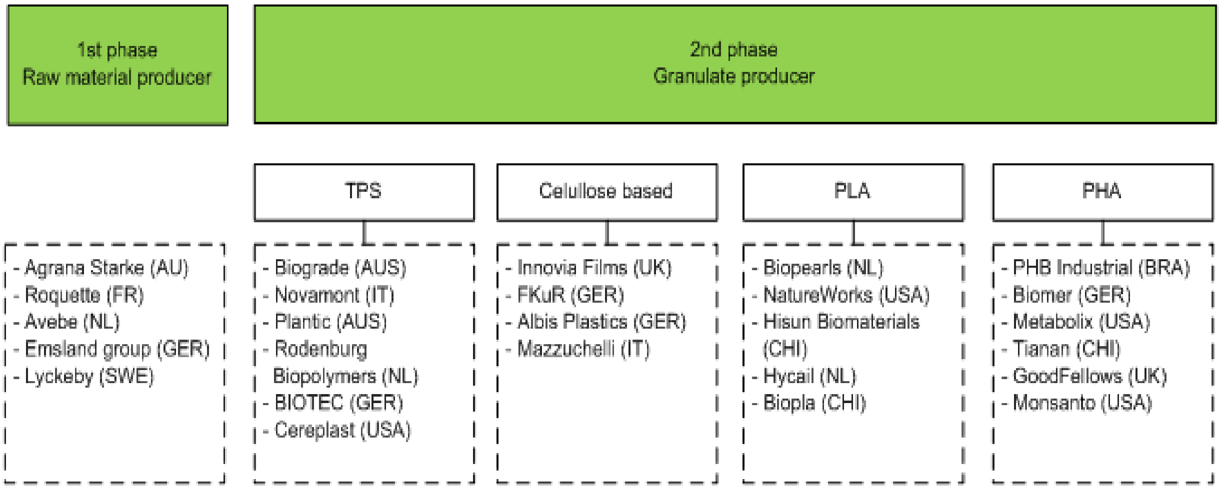
| **Material Composition (outside to inside)** | | | | | | |
|---|---|---|---|---|---|---|
| **Description** | **Supplier** | **Type** | **Thickness (µm)** | **Weight (gsm)** | **Weight (%)** | **Functional Description** |
| Lacquer | | n.a. | | | | |
| Outerlayer: COPP20 Co-extruded Oriented Poly Propene | | | 20,0 | | | Printing, transparency, barrier properties, stiffness, sealing medium, look and feel. |
| Ink: Foodgrade NC or PVB | | | | | | Product presentation and legal information. It should not change the properties of the other components of the laminate. |
| Adhesive: PU-based solvent free | | | | | | Lamination of the films. It should not change the properties of the other components of the laminate. |
| Middle layer | | n.a. | | | | |
| Adhesive | | n.a. | | | | |
| Inner layer: CPP30 Cast PolyPropene | | | 30,0 | | | Sealing medium, stiffness, transparency, barrier properties. |
| Remarks | | | | | | |

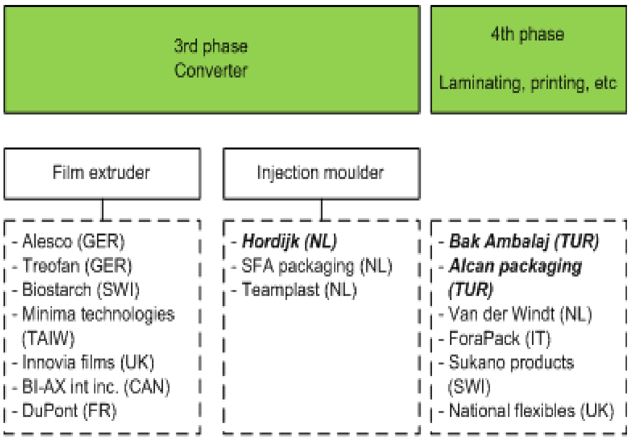
| **Material Properties** | | | | |
|---|---|---|---|---|
| **Description** | **UoM** | **Value** | **Tolerance in UoM or %** | **Method of analysis** |

| | | | | | |
|---|---|---|---|---|---|
| Total Weight* | g/m² | | ± | 5% | ASTM D2673 |
| Total Thickness* | µm | | ± | 5% | ASTM D2673 |
| Coefficient of Friction Dynamic, outside - outside* | -- | | min - max | 0,2 - 0,4 | ASTM D1894 |
| COF Dynamic, inside - inside* | -- | | min - max | 0,11 - 0,25 | ASTM D1894 |
| Heat seal strength (Inside - Inside)* | N/15mm | | min | 15 | ASTM F88 |
| Heat seal strength (Inside - Outside)* | N/15mm | | min | 8 | ASTM F88 |
| Laminate strength* | N/15mm | | min | 1,5 | ASTM F88 |
| Shrinkage LD* | % | n.a. | | | ASTM D1204 |
| Shrinkage CD* | % | n.a. | | | ASTM D1204 |
| Shrink temperature* | ºC | n.a. | | | OPMA TC4a |
| Perforation strength* | N | n.a. | | | Equipment as ASTM F88 |
| Deadfold retention* | degree | n.a. | | | Angle of springback after folding |
| Rub resistance* | frequence | n.a. | | | ASTM D5264 |
| Lightfastness total laminate* | Wool scale | | min | 3 | DIN 16525 |
| WVTR (38°C/90% RH)* | g/m²/24h/atm | 4,1 | | | ASTM F1249 |
| OTR (23°C/0% RH)* | cm³/m²/24h | 1200 | | | DIN 16525 |
| Solvent Retention* | mg/m² | | max | 10 | ASTM F1884 |
| Remarks: | | | | | |

* must be based on the completed material composition.

# Appendix F: Bioplastic supplier overview



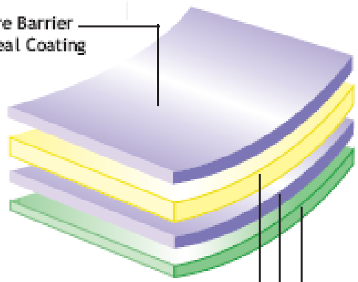
# Appendix G: NatureFlex N913 & NM specifications

innovia FILMS

## NatureFlex™ N913 Provisional Data

### Features - Transparent High Barrier Heat-sealable Compostable Film

- Based on renewable resources
- Currently undergoing certification process
- Excellent moisture barrier
- Heat-sealable on both sides
- Formulated for enhanced print and conversion receptivity
- Excellent transparency and gloss
- Superb dead-fold properties
- Inherent anti-static properties
- Controlled slip characteristics
- Good barrier to gases and aromas
- Resistant to oils and greases
- Cold-seal compatible
- Ultra strong heat-seal layer
- Hermetic seals




### Applications

N913 film has been formulated to provide enhanced moisture barrier by the addition of a small amount of PVdC. The addition of a proprietary heat-seal layer allows the film to be used in heavy pack applications; the heat-seal layer will form hermetic seals and is especially suitable for applcations requiring heat-seal through contamination or gas flushing. The film maintains good conversion receptivity as well as heat-sealability on both sides. Target applications include VFFS, flow-wrap and lamination for moisture sensitive products.

### Technical Properties (Typical Values)

| Property | Test Basis | Test Conditions | Units | N913<br>55µ |
|---|---|---|---|---|
| Thickness | Innovia Films test | | micron | 55.0 |
| Yield | Innovia Films test | | m$^2$/kg<br>g/m$^2$ | 15.0<br>66.7 |
| Permeability to<br>Water vapour | ASTM E96 | 38°C 90% RH | g/m$^2$.24 hrs | <10 |
| Oxygen | ASTM F 1927 | 23°C 0-5% RH<br>23°C 50% RH | cc/m$^2$.24 hrs.<br>bar | 3.0<br>7.0 |
| Optical:<br>Gloss | ASTM D 2457 | 45° (NF side) | units | 95 |
| Haze (wide angle) | ASTM D 1003 | 2.5° | % | 20 |
| Coefficient of friction<br>(film to film) | ASTM D 1894 | Static<br>Dynamic | | 0.35<br>0.30 |
| Tensile strength | ASTM D 882 | | MN/m$^2$ MD<br>TD | 125<br>70 |
| Elongation at break | ASTM D 882 | | % MD<br>TD | 22<br>70 |
| Elasticity modulus<br>(1% secant) | ASTM D 882 | | MN/m$^2$ MD<br>TD | >3000<br>>1500 |
| Sealing range | Innovia Films test | 0.5 secs;<br>69 kN/m$^2$ | °C | 100->170 |
| Seal strength | Innovia Films test | 135°C; 0.5 secs;<br>69 kN/m$^2$ (B/B) | g(f)/25mm | >1000 |

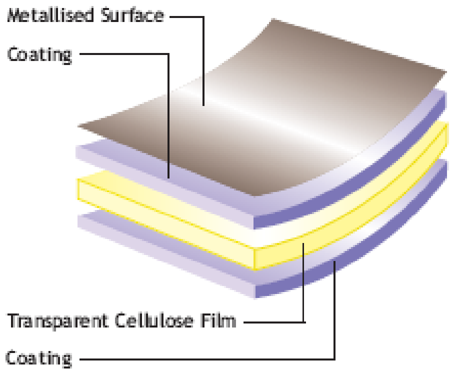
All properties are tested under standard laboratory conditions: 23± 2°C; 50±5% RH, unless otherwise stated.
MD Machine Direction TD Transverse Direction

Ref N913 - 1 of 2 - Edition UK - 0709

# NatureFlex™ NM Data

## Features - High Performance Metallised Compostable Film

- Based on renewable resources
- Certified as compostable in key biodegradation environments (including anaerobic digestion, home and industrial composting)
- Superb dead-fold and twist capability
- Highly receptive surfaces for ease of conversion
- Ultra high lustre and sparkle
- Excellent barrier to UV/visible light transmission
- Heat-sealable on non-metallised surface
- High moisture barrier
- Inherent anti-static properties
- Controlled slip characteristics
- Barrier to gases and aromas
- Resistant to oils and greases
- Cold-seal compatible




## Applications

NM film combines excellent optical properties with enhanced barrier and deadfold capabilities. Target applications include twistwrap and flow-wrap of confectionery, bakery and non-food products.

## Technical Properties (Typical Values)

| Property | Test Basis | Test Conditions | Units | NM 23µ |
|---|---|---|---|---|
| Thickness | Innovia Films test | | micron | 23.3 |
| Yield | Innovia Films test | | m²/kg<br>g/m² | 29.9<br>33.5 |
| Permeability to<br>Water vapour | ASTM E96 | 38°C 90% RH | g/m².24 hrs | 10 |
| Oxygen | ASTM F 1927 | 23°C 0-5% RH | cc/m².24 hrs. bar | <3 |
| Optical:<br>Optical density | Innovia Films test | | | 2.5 |
| Coefficient of friction (film to film) | ASTM D 1894 | Metallised surface<br>Non-metallised surface | | 0.4<br>0.22 |
| Tensile strength | ASTM D 882 | | MN/m² MD<br>TD | 125<br>70 |
| Elongation at break | ASTM D 882 | | % MD<br>TD | 22<br>70 |
| Elasticity modulus (1% secant) | ASTM D 882 | | MN/m² MD<br>TD | >3000<br>>1500 |
| Seal strength | Innovia Films test | 135°C; 0.5 secs; 69 kN/m² | g(f)/25mm | 275 |

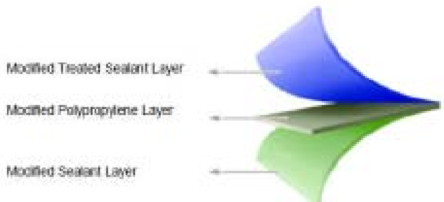
All properties are tested under standard laboratory conditions: 23± 2°C; 50±5% RH, unless otherwise stated.
MD Machine Direction TD Transverse Direction

Ref N500 - 1 of 2 - Edition UK - 0309

# Appendix H: CropacEco OPP & CPP

Cropac
MANUFACTURERS OF PRINTED PACKAGING

*Printing Green: "It takes more than Yellow & Cyan"®*




**CROPACECO**
***Datasheet***

CROPACECO is a transparent, one side treated, both sides sealable degradable & biodegradable film, biaxially oriented polypropylene film. It is specially designed for HFFS/VFFS packaging machines where strong seals and hot tack are needed. It can also be used in laminates and is also available in white and metalized.

CROPACECO films are rendered as degradable/biodegradable by combination of heat and UV as first step and absorption by micro-organisms naturally present in soil as second step. Film ends up as biomass in nature by a non-hazardous degradation and biodegradable process.

| PROPERTIES | TEST METHOD | UNITS | | 2011 MMB | | | | |
|---|---|---|---|---|---|---|---|---|
| THICKNESS | ASTM D 374 | micron | | 20 | 25 | 30 | 35 | 40 |
| | | Gauge | | 80 | 100 | 120 | 140 | 160 |
| YIELD | ASTM D 4321 | m²/kg | | 54,9 | 44,0 | 36,6 | 31,4 | 27,5 |
| | | in²/Lbs | | 38.600 | 30.900 | 25.700 | 22.100 | 19.300 |
| HAZE | ASTM D 1746 | % | | 1,6 | 1,9 | 2,2 | 2,5 | 2,8 |
| GLOSS (45° ) | ASTM D 2457 | % | | 90 | | | | |
| TENSILE STRENGTH AT BREAK | ASTM D 882 | MD | N/mm² | 160 | | | | |
| | | | lb/in² | 23.200 | | | | |
| | | TD | N/mm² | 290 | | | | |
| | | | lb/in² | 42.000 | | | | |
| ELONGATION AT BREAK | ASTM D 882 | MD | % | 180 | | | | |
| | | TD | | 65 | | | | |
| THERMAL SHRINKAGE (120 °C, 5 min, in air) | ASTM D 2732 | MD | % | 4 | | | | |
| | | TD | | 2 | | | | |
| COEFFICIENT OF FRICTION | ASTM D 1894 | Film/Film | | 0,30 | | | | |
| | | Film/Metal | | 0,25 | | | | |
| SURFACE TENSION | ASTM D 2578 | Dyne/cm | O | 36 | | | | |
| | | | I | - | | | | |
| HEATSEAL RANGE | ASTM F 88 | °C | | 105-145 | | | | |
| | | °F | | 221-293 | | | | |
| HEATSEAL STRENGTH (120 °C, 150 N/mm², 1 sec) | ASTM F 88 | N/15mm | | 2,5 | | | | |

THE ABOVE VALUES ARE TO BE CONSIDERED AS GUIDELINES ONLY AND NOT AS PRODUCT SPECIFICATION.

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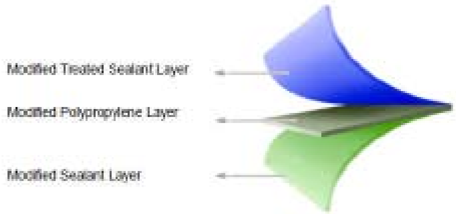
Cropac
MANUFACTURERS OF PRINTED PACKAGING

*Printing Green: "It takes more than Yellow & Cyan"®*




# CROPACECO *CPP* *Datasheet*

CROPACECO CPP is a transparent, one side treated, both sides sealable degradable & biodegradable film, cast polypropylene film. It is specially designed for all kind of pasta packaging. It can also be used in lamination substrate to itself or CROPAC ECO OPP.

CROPACECO CPP films are rendered as degradable/biodegradable by combination of heat and UV as first step and absorption by micro-organisms naturally present in soil as second step. Film ends up as biomass in nature by a non-hazardous degradation and biodegradable process.

| PROPERTIES | TEST METHOD | UNITS | | | | |
|---|---|---|---|---|---|---|
| THICKNESS | ASTM D 374 | micron | | 30 | 35 | 40 |
| | | Gauge | | 120 | 140 | 160 |
| YIELD | ASTM D 4321 | $m^2/kg$ | | 37,0 | 31,7 | 27,8 |
| | | $in^2/Lbs$ | | 26.000 | 22.300 | 19.600 |
| HAZE | ASTM D 1746 | % | | 2,5 | 3,0 | 3,0 |
| GLOSS (45°) | ASTM D 2457 | % | | 90 | | |
| TENSILE STRENGTH AT BREAK | ASTM D 882 | MD | $N/mm^2$ | 40,0 | | |
| | | | $lb/in^2$ | 5800 | | |
| | | TD | $N/mm^2$ | 25 | | |
| | | | $lb/in^2$ | 3600 | | |
| ELONGATION AT BREAK | ASTM D 882 | MD | % | 650 | | |
| | | TD | | 750 | | |
| THERMAL SHRINKAGE (120 °C, 5 min, in air) | ASTM D 2732 | MD | % | 1 | | |
| | | TD | | 1 | | |
| COEFFICIENT OF FRICTION | ASTM D 1894 | Film/Film | | 0,30 | | |
| | | Film/Metal | | 0,25 | | |
| SURFACE TENSION | ASTM D 2578 | Dyne/cm | O | 38 | | |
| | | | I | - | | |
| HEATSEAL RANGE | ASTM F 88 | °C | | 105-145 | | |
| | | °F | | 221-293 | | |
| HEATSEAL STRENGTH (120 °C, 150 $N/mm^2$, 1 sec) | ASTM F 88 | N/15mm | | 6,0 | | |

THE ABOVE VALUES ARE TO BE CONSIDERED AS GUIDELINES ONLY AND NOT AS PRODUCT SPECIFICATION.

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# Appendix I: Test plan (moisture absorption)

This test has been developed to determine the moisture transmission of a transwrap. Every film has a water vapour transmission rate (WVTR) given by its supplier. This transmission rate has been determined under particular circumstances like 38°C and a humidity rate of 90%. The WVTR is based on the film only and not on the final packaging, a transwrap. The film is not the only factor that influences the moisture transmission rate but there are also other factors like seal strength, amount of seals and the way of processing that contribute to the moisture transmission rate.

### *How does the test work?*

The product that is going to be packed in the test packaging is silicagel. There has been chosen for this material because it has a strong hygroscopic nature.

The films that are going to be tested will be compared to each other and to an 'open product'. The open product is there to show what the product would have done if there was not any packaging wrapped around it.

1. Firstly, bags will be made in the format 95 x 95 mm. Every 'to be' tested film will be processed into ten bag in this format (leave them open on one side)
2. After the bags are made they will be weighed.
3. The bags have to be filled with approximately twenty grams of silicagel.
4. After the bags are filled the last side can be sealed.
5. Weigh them again.
6. The exact amount of silicagel can be calculated by subtracting the bag's weight from the total weight.
7. Put them into a 30°C and 75% humidity cabin.
8. Weigh the bags every day for 15 days
9. Take the average weight of silicagel per day and compare them to the values of the other bags.

This will result in a comparison in moisture absorption of the transwraps. The moisture absorption tells us something about the moisture transmission through the transwrap.

With this information, films that are going to be processed into transwraps, can be compared with each other on their moisture transmission.

# Appendix J: Test results (moisture absorption)

## Film test

The test is executed with the following films:

- Open product
- Oriented Propylene 20 / cast polypropylene 30
- metPET/PET/LDPE
- NatureFlex N913
- NatureFlex NM

### Measurements

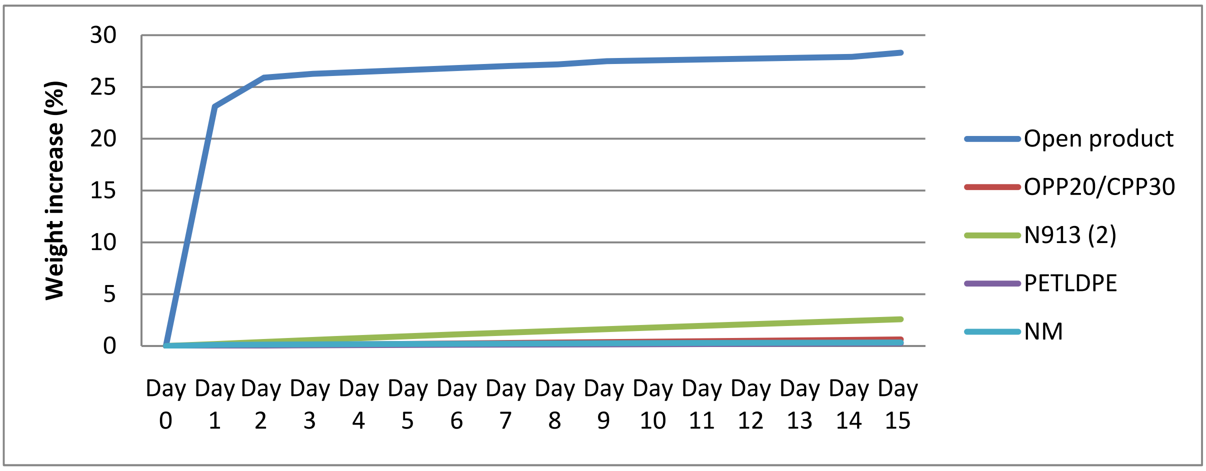
| | Open product | OPP20/CPP30 | N 913 | PETLDPE | NM |
|---|---|---|---|---|---|
| Day 0 (mo) | 20,38271 | 20,37161 | 20,4186 | 20,34404 | 20,43472 |
| Day 1 (Tu) | 25,095 | 20,37916 | 20,4562 | 20,34604 | 20,45571 |
| Day 2 (We) | 25,66168 | 20,38765 | 20,49596 | 20,35134 | 20,46347 |
| Day 3 (Th) | 25,73758 | 20,3965 | X | X | X |
| Day 4 (Fr) | X | X | X | X | X |
| Day 5 (Sa) | X | X | X | X | X |
| Day 6 (Su) | X | X | 20,64661 | #REF! | 20,47824 |
| Day 7 (Mo) | 25,89131 | 20,42955 | 20,68213 | 20,3702 | 20,48141 |
| Day 8 (Tu) | 25,9233 | 20,43898 | 20,71824 | 20,37202 | 20,48407 |
| Day 9 (We) | 25,98508 | 20,44771 | 20,75464 | 20,37584 | 20,48744 |
| Day 10 (Th) | X | 20,45424 | X | X | X |
| Day 11 (Fr) | X | X | X | X | X |
| Day 12 (Sa) | X | X | X | X | X |
| Day 13 (Su) | X | X | 20,87554 | 20,38968 | 20,49864 |
| Day 14 (Mo) | 26,07214 | 20,48947 | 20,9136 | 20,39202 | 20,50032 |
| Day 15 (Tu) | 26,15333 | 20,49981 | 20,94502 | 20,39667 | 20,50436 |

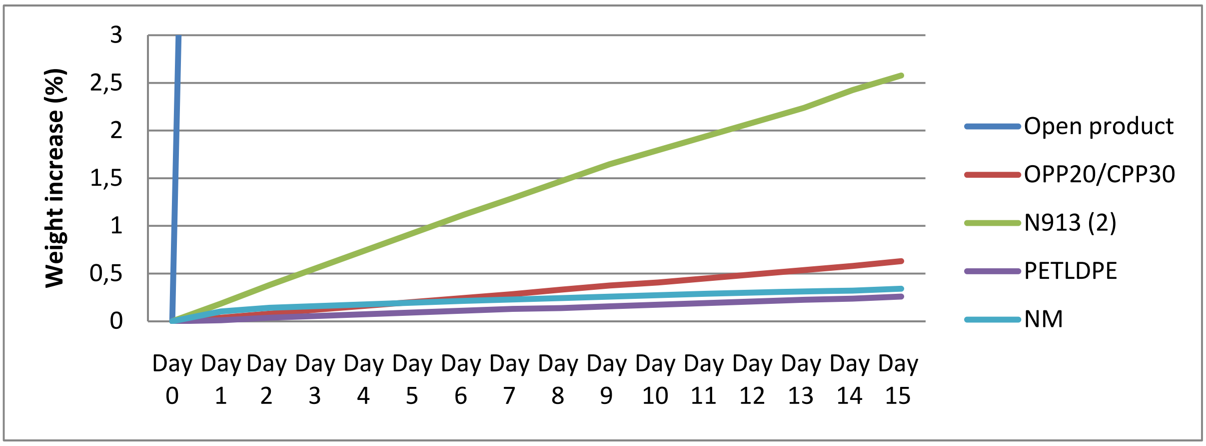
### Results

The measurements are dependent on the average amount of silicagel. Every transwrap contains around twenty grams of silicagel. The start weight is not exactly the same what makes it difficult to compare the films with each other. Therefore the values will be calculated in percentages. So the measurements start at the value 0 (0 per cent) and the other values indicates the increase in percentage in comparison to the first day.

| | Open product | OPP20/CPP30 | N913 | PETLDPE | NM |
|---|---|---|---|---|---|
| Day 0 | 0 | 0 | 0 | 0 | 0 |
| Day 1 | 23,11906 | 0,037061 | 0,184146 | 0,009831 | 0,102712 |
| Day 2 | 25,89923 | 0,078737 | 0,37887 | 0,035883 | 0,140665 |
| Day 3 | 26,2716 | 0,12218 | X | X | X |
| Day 4 | X | X | X | X | X |
| Day 5 | X | X | X | X | X |
| Day 6 | X | X | 1,116678 | X | 0,212982 |
| Day 7 | 27,02586 | 0,284415 | 1,290637 | 0,128566 | 0,228478 |
| Day 8 | 27,18279 | 0,330705 | 1,467486 | 0,137523 | 0,241474 |
| Day 9 | 27,48587 | 0,373559 | 1,645754 | 0,156311 | 0,258003 |
| Day 10 | X | 0,405613 | X | X | X |
| Day 11 | X | X | X | X | X |
| Day 12 | X | X | X | X | X |
| Day 13 | X | X | 2,237883 | 0,224308 | 0,312812 |
| Day 14 | 27,91301 | 0,57855 | 2,42426 | 0,235832 | 0,321022 |
| Day 15 | 28,31132 | 0,629307 | 2,57815 | 0,258662 | 0,34076 |

## *Graphs*



### *Rigid test*

The test is executed with the following rigids:

- AutoPack with an autopack lid
- Solanyl N CE with a NatureFlex N913 sealed to the top

#### *Measurements*

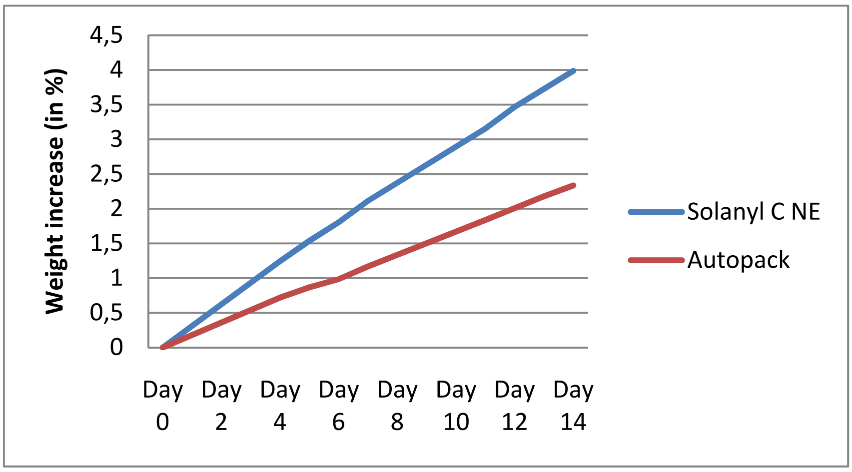
| | Rodenburg | Autopack |
|---|---|---|
| Day 0 | 70,0249 | 70,0899 |
| Day 1 | x | x |
| Day 2 | x | x |
| Day 3 | x | x |
| Day 4 | 70,8952 | 70,5938 |
| Day 5 | 71,1024 | 70,6975 |
| Day 6 | 71,2898 | 70,7809 |
| Day 7 | 71,5048 | 70,9077 |

| | | |
|---|---|---|
| Day 8 | x | x |
| Day 9 | x | x |
| Day 10 | x | x |
| Day 11 | 72,2351 | 71,3783 |
| Day 12 | 72,4527 | 71,4982 |
| Day 13 | 72,6353 | 71,6166 |
| Day 14 | 72,8164 | 71,7275 |

#### *Results*

The measurements are dependent on the average amount of silicagel. The rigids contain around  seventy grams of silicagel. The start weight is not exactly the same what makes it difficult to compare the films with each other. Therefore the values will be calculated in percentages. So the measurements start at the value 0 (0 per cent) and the other values indicates the increase in percentage in comparison to the first day.

| | Solanyl C NE | Autopack |
|---|---|---|
| Day 0 | 0 | 0 |
| Day 1 | X | X |
| Day 2 | X | X |
| Day 3 | X | X |
| Day 4 | 1,242844 | 0,718934 |
| Day 5 | 1,538738 | 0,866887 |
| Day 6 | 1,806357 | 0,985877 |
| Day 7 | 2,113391 | 1,166787 |
| Day 8 | X | X |
| Day 9 | X | X |
| Day 10 | X | X |
| Day 11 | 3,156306 | 1,838211 |
| Day 12 | 3,467052 | 2,009277 |
| Day 13 | 3,727817 | 2,178203 |
| Day 14 | 3,986439 | 2,336428 |



# Appendix K: Sample material

OPP20/CPP30

PLA (NatureWorks)

NatureFlex N913

NatureFlex NM

CropacEco OPP20/CPP30

MaterBI

# Appendix L: Cost calculations

The costs will be calculated per meter. The reel has a width of 230 mm=0,230 m. The surface of this area will be 0,230m x 1m= 0,23m$^2$

| OPP20/CPP30 | *CropacEco OPP20/CPP30* |
|---|---|
| ***Given data:***<br>€13,29 per 1000 pieces (bags) length of 1 piece = 185mm=0,185m<br>Minimum order quantity= 150.000 pieces with a weight of 274 kilograms.<br>***Calculations:***<br>€13,29 x 150= 1993,5 €/274 kg = 7,28 €/kg<br>1000 x 0,185= 185 m costs €13,29<br>13,19/185= 0,072 €/m<br>Minimum order quantity: 150.000 x 0,185= 27.750 meter<br>***Results:***<br>Price per kilogram 7,28 €/kg<br>Price per meter 0,07 €/m<br>Minimum order quantity 27.750 m | ***Given data:***<br>Minimum order quantity 1000 kg 5,65 €/kg<br>Yield OPP20: 54,9 m$^2$/kg<br>CPP30: 37 m$^2$/kg<br>***Calculations:***<br>***(0,23 m$^2$/ 54,9 m$^2$/kg)+ (0,23m$^2$/37 m$^2$/kg) = 0,0104 kg***<br>***0,0104 kg x 5,65 €/kg= €0,059***<br>***Price per meter €0,059***<br>***Minimum order quantity: 1000 kg / 0,0104 kg/m = 96.154 m***<br>***Results***<br>***Price per kilogram 5,65 €/kg***<br>***Price per meter 0,06 €/m***<br>***Minimum order quantity 96.154 m*** |

Natureflex N913

***Given data:***

| Order quantity | €/ 1,000m | €/m |
|---|---|---|
| 50.000 m | € 320,- | 0,32 |
| 75.000 m | € 299,- | 0,299 |
| 100.000 m | € 280,- | 0,28 |

Yield 15 m$^2$/kg

***Calculations:***

0,23m$^2$/15 m$^2$/kg= 0,01533 kg per 0,23m$^2$

0,32€/m / 0,01533kg/m= 20,87 €/kg

0,299€/m / 0,01533kg/m= 19,50 €/kg

0,28€/m / 0,01533kg/m= 18,26 €/kg

***Results:***

| Price per kilogram | Price per meter | Minimum order quantity |
|---|---|---|
| 20,87 €/kg | 0,32 €/m | 50.000 m |
| 19,50 €/kg | 0,29 €/m | 75.000 m |
| 18,26 €/kg | 0,28 €/m | 100.000 m |