Research and choice of biodegradable materials that are used for production of food packages for the food industry

Mikko Ketonen

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Abstract:

Paroprint Oy is a company which makes food packaging applications made out of cardboard and plastic coated cardboard. With the help of co-operators Lamican Oy and Loomans Group, different kind of tests were done from biodegradable bio plastic materials which could be used in their product list. The aim of the project was to find cost-effective and environmentally friendly substitution to the oil based plastics. Paroprint Oy made tests both in Finland and in Belgium to find out possibilities to produce packages of the bio plastics commercially available on the market. Therefore to gain wider product range and new markets beside the existing product range based on oil-based plastics. The world's bio plastic markets are in a high development and from different alternatives Paroprint decided to test a few materials for their own applications. Products were made using Injection Molding machines and Extrusion Coating machines. After the test results it was concluded, which materials were most suitable for their applications and decided of their use in future.

Keywords:	Paroprint Oy, biodegradable, research, food packaging
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Työn ohjaaja (Arcada):	Marko Voho
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Tiivistelmä:

Paroprint Oy on elintarvikepakkauksia kartongista ja muovipäällysteisistä kartongeista valmistava yritys. Yhteistyö kumppaneiden, Lamican Oy:n ja Loomans Groupin avulla Paroprint teki erilaisia testejä biomuovi sovelluksista, joita voisi hyödyntää heidän tuotevalikoimassaan tulevaisuudessa. Tutkimuksen tarkoituksena oli löytää tuotantotehokas ja ympäristöystävällinen vastike öljypohjaisille muoveille. Paroprint Oy teki testejä sekä Suomessa että Belgiassa kartoittaakseen mahdollisuuksia tuottaa markkinoilla olevista biomuoveista pakkauksia ja siten laajentamaan tuotevalikoimaa. Maailman biomuovi markkinat ovat kovassa kehityksessä ja eri vaihtoehdoista Paroprint päätyi testaamaan muutamaa sovellusta omissa tuotteissaan. Tuotteet tuotettiin ruiskupuriste koneita ja ekstruusio päällystys koneita hyväksi käyttäen. Testien jälkeen saadut tulokset vaikuttivat Paroprint:in päätökseen, mitkä ja millaiset biomuovi sovellukset toimivat heidän tuotteissaan parhaiten.

Avainsanat:	Paroprint Oy, biomuovi, tutkimus, elintarvikepakkaus
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EXAMENSARBETE	
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Sammandrag:

Paroprint Oy tillverkar förpackningar av kartong eller plast belagd kartongt för livsmedelindustrin. Med hjälp av samarbetspartnern Loomans i Belgien och Lamican i Finland utfördes tester av olika nedbrytbara bioplaster som kunde användas i framtiden vid tillverkning av livsmedelsförpackningar. Ändamålet av projektet var att hitta kostnadseffektiva och miljövänliga alternativ för plaster som baserar sig på olja. Paroprint Oy gjorde tester både i Finland och i Belgien för att få uppgifter om funktion och möjligheterna att använda råmaterial som finns på marknaden. Med hjälp av lyckade tester kan nuvarande produkt sortimentet utvidgas med miljövänliga produkter vid sidan om olja baserade. Bio plast marknaden växer starkt i hela världen och från olika alternativ valde Paroprint att testa några av dem som kunde anpassas för produkter ifråga. Produkterna tillverkades i formsprutnings maskin och extrusion beläggnings maskin. På grund av testresultaten valde Paroprint de materialen som skall användas i framtiden.

Nyckelord:	Paroprint Oy, bio plast, forskning, livsmedelsförpackning
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1 INTRODUCTION

Living in a high technology society gives a lot of possibilities to develop the old techniques used in the manufacturing of different goods. This works for everything; cars have been improved, houses are built in a more efficient way and plastic packaging materials for different applications are already approved for a wide range of packages. The world is changing constantly; old techniques and applications will be dislodged by the new innovations.

Plastics have taken their place in manufacturing and plastic is well known material for almost every kind of application. It has been used for many years and its use will continue to grow. Mostly, plastic materials are used in nearly every household product you can imagine. It is so common that people do not recognize how much plastics are used around them. A slightly new trend has become more relevant when talking about the environment, biodegradable materials, and the renewable raw materials are found in the nature. These materials can also be modified to become a part of plastic material, which is called bio plastics. This is a fast growing subject area which has a lot of research aimed at improve the natural polymers that we can use in the future. [12] [13]

In the food industry, the packaging materials often used are; paper and cardboard, plastic, metal, glass and foam. Food is stored in different packages depending on the shelf life of the product. There are certain things that have to be taken in consideration when choosing the right packaging material to right foodstuff. When the requirements are fulfilled, then it is possible to manufacture the right kind of package. [10]

The use of biodegradable plastics for food packaging is also a noteworthy option. The material is being used more and in the future it will be a competitor for the oil-based plastics. People from the food industries are more concerned that there should be more eco-friendly packages on the market. Plastic is the most commonly used packaging material and all the machines and technologies are developed for it. That is why it is challenging to use new eco-friendly biodegradable materials on the same production lines. Many companies manufacturing packaging materials are starting to use biodegradable materials and it will also cause changes in new machinery. Plastic machines and other equipments will be made dedicated for bio materials. This helps to become more competitive with new products. [11] [21]

1.1 Aims and Objectives

Paroprint's aim is to find out suitable bio plastic solutions beside the oil based plastics. For environmental reasons; both fast food chains and food industry, would like to use biodegradable materials but these have to fulfill the requirements and the costs has to be in a reasonable range. The materials have to work effective in existing production lines.

If the research and tests from chosen biodegradable materials are functional Paroprint will take them to their product lists and discuss with the customers that has shown interest for the biodegradable food packages.

First by studying different existing biodegradable materials and then by evaluation choosing the suitable ones that will be tested. The test will be made in Paroprint's co-operators in Finland and in Belgium. For the extrusion part Lamican in Valkeakoski will extrude the biomaterial on the cardboard. Results from process ability are given to Paroprint. Based on the test results Paroprint will choose the right material and will further test it with the customers. For the injection molding part Loomans Group in Belgium injection molded the biomaterial together with the cardboard. (Shown in the picture next page) Results from process ability are given to Paroprint. Based on the test results Paroprint will choose the right material and will further test it with the customers.

Paroprint wants to test the materials to 3 different kinds of products they are manufacturing.

1. Printed, laminated or extrusion coated cardboard plates. Disposable product.

Figure 9. Laminated plates top view (Photograph Mikko Ketonen. Paroprint 2011)
Figure 10. Laminated plates bottom view (Photograph Mikko Ketonen. Paroprint 2011)

2. Printed, laminated or extrusion coated cardboard sausage tray. Disposable, but industrially packed. No barrier properties required.

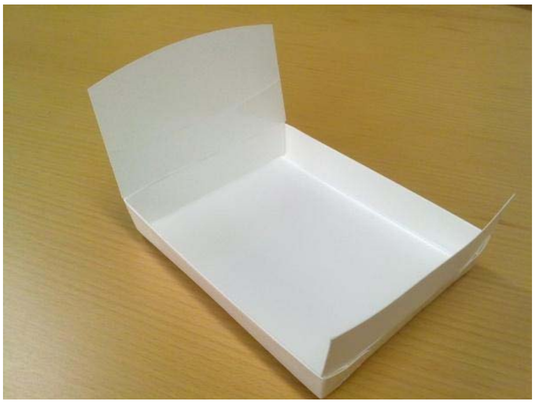

Figure 11. Sausage tray. (Photograph Mikko Ketonen. Paroprint 2011)

Figure 12. Sausage tray. (Photograph Mikko Ketonen. Paroprint 2011)

3. Printed, laminated or extrusion coated cardboard combined with injection molded sealing rims. Disposable, but industrially packed. Requires barrier properties.

Figure 13. Rectangular tray top and bottom view. (Photograph Mikko Ketonen. Paroprint 2011)

Figure 14. Rectangular tray side and top view. (Photograph Mikko Ketonen. Paroprint 2011)

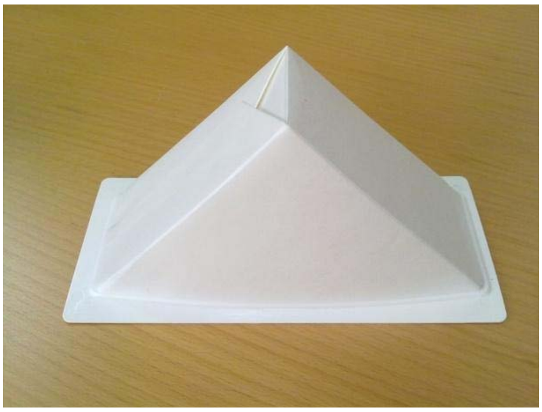

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Figure 16. Sandwich box side view. (Photograph Mikko Ketonen. Paroprint 2011)

Paroprint has chosen these three products because of their demand on the market. The results were important to give to Paroprint in a certain time limit. If the right suitable biodegradable material was found, in the future Paroprint will use the biodegradable material in other products too. The following objectives can be made:

- To determine that the material is environmentally friendly, biodegradable and suitable for food contact
- To determine that the material works effective on an existing production line
- To determine that the cost of the material is in a reasonable range

2 LITERATURE REVIEW

2.1 Materials used in food packaging

Food products can be stored in different kind of packages. It depends on in what purposes the packages are used and what the food product is. When talking about the traditional food packaging materials; glass, metal containers, paper & cardboard and plastic. They all have an important task; to provide a reliable barrier between the food product and the outside environment. A small introduction of the advantages and disadvantages for each package material;

<u>Glass</u>: Glass jars and bottles are leak proof for any kind of moisture, oxygen, microorganisms and pests. They do not have any harmful chemicals which could affect the food. They can be used in a microwave or in any kind of heat, they are reusable, they are transparent and they are hard enough that they can be stacked on each other. Disadvantages for the glass jars and bottles are that they are heavier than other packaging materials that are why the transport costs are higher. Also during the transport they have a possibility to break. Glass as a packaging material is widely used as bottles in different juices, beers, wines and medical applications, such as cough medicine. In the long run they are being replaced by plastic applications.

Figure 1. Glass jar, food package [I]

Figure 2. Glass jar, food package [II]

Metal containers: Metal containers act a lot the same like glass jars. Depending on the sealing mechanism on the metal containers, it gives a total protection to the foodstuff inside the can. Usually the material used to manufacture metal cans is tinplate steel or aluminium and the inside of the can is often coated with some specific lacquers depending on the food content. After a sealing process is made, the foodstuff inside the can is in a safe atmosphere. It cannot be touched without opening the sealed lid and the cans are made in a wide range of different shapes and sizes. Aluminium cans have a great leak proof against oxygen, moisture, light, gases and some micro-organisms. Anyhow, the high price of metal and high cost for manufacturing the cans makes the process more expensive and cheaper plastic containers will replace metal cans in the future.

Figure 3. Metal containers, food package [III]

Figure 4. Metal containers, food package [IV]

Paper & cardboard: Paper and cardboards are made out of wood pulp, cellulose and mixture of additives to give some properties to the material. Usually the paper and cardboard surfaces has been treated with wax or with a laminated plastic layer. The added layers give better properties to the package; more surface strength, protection to moisture and resistance to compression. When paper and cardboard are so light weighted, they are easy to transport and they are eco-friendly. Usually these packages are used to dry food, like biscuits, bread and for some fruits. It is used also for goods that do not need a long shelf life, salads, meat and fish. To different boxes which do not have to be in contact with the food, cereal boxes and so on. For disadvantages we can say that these packages are not gas tight, rigid and not for long term storage. With plastic packaging all of those are possible.

Figure 5. Cardboard, food package [V]

Figure 6. Cardboard, food package [VI]

Plastic: When talking about food containers, there is a wide range of plastic packages; bottles, jars, trays, tubes and boxes. Plastic packages have numerous advantages compared to glass, metal or paper and cardboard. Low weight, easy to stack, saving in transports, low production costs, rigid almost unbreakable and easy to seal, good barrier properties, can be formed in any shape wanted and the packages can have many different colours. But on the other hand they have also disadvantages, oil is not renewable resource and therefore some alternatives must be found. Plastic packages can be re-used or used as energy but new bio based materials are more eco-friendly but cannot tolerate high or very low temperatures. [14], [15], [16], [17]

Figure 7. Plastic food package [VII]

Figure 8. Plastic food package [VIII]

2.2 Different plastic materials

There are several different types of plastic materials which are used widely in food packaging industry in the world. The polymers have been developed by time from the past and nowadays the materials used in packaging are meeting the standards. Here are examples of the most commonly used materials what are used in the food packaging industry. [1], [7]

Polyethylene (PE): Both HDPE (high-density polyethylene) and LDPE (low-density polyethylene) are used in the field in the food packaging industry. HDPE is used for rigid trays, like ice cream boxes and are made by injection molding technique. LDPE are basically used as films, like a thin transparent film layer wrapped on a meat box. Polyethylene is also used for shelf-stable foods, which means dry food products that have high oil, salt, acid or sugar content. It also has a good moisture barrier.

Polypropylene (PP): Polypropylene is a multifunctional plastic which is used in rigid and flexible packages. Polypropylene is used more or less in the same applications that PE products also, the material is even possible to use in the microwave.

Polystyrene (PS): There are three different kind of polystyrene material with different properties; clear and brittle crystal polystyrene, the high-impact styrene which is used for thermoformed trays and heat insulating, protective foamed polystyrene. These materials are mostly used in cups, trays and containers.

Polyvinyl chloride (PVC): Polyvinyl chloride is a general plastic which is used in rigid packaging. PVC is also used for food oils because of its relatively low oxygen permeability.

Polyethylene terepthalate (PET): Polyethylene terephtalate is mostly used in bottles to store, lemonade, juice ciders and other liquid drinks. PET can also be used in normal food trays. A modified PET; Crystalline polyester (CPET) can be used also in a conventional oven to heat up the food.

These packaging materials will be used in the future as they have been used for now. Even though the materials will improve to a better way to reach the need of households. Materials get better to stand up more heat and the packages can be more durable. [1], [7]

2.3 Different biodegradable materials

Biopolymers, as it can be said instead of biodegradable plastics, may be naturally occurring materials. Most of the raw material to biodegradable materials comes from the nature; green plants, bacteria or even from the eatable vegetables. The natural synthesis is very complex process and it is not yet practical as a complete production for commodity plastics. In the food industry the margin of biodegradable materials are yet quite small but here are a few examples of the most used materials in this field. [2], [3], [4], [5]

Polylactic acid (PLA): Polylactic acid is the most used biodegradable material, because of its wide use range. It can be used for single use cutlery, cups, short-shelf life trays and even in bottles.

Polybutylenes succinate (PBS): Polybuthylenes succianate has been used almost for the same purposes than the PLA. Food packaging film wrapping applications.

Poly3-hydroxybutyrate (PHB): It has very similar physical properties than Polypropylene so it can be used in different kind of food packaging applications such as bottles, bags and wrapping films.

Polycaprolactone (PCL): It is widely used in medical purposes for now but in the future it can be possible that this material will be one of the packaging materials.

Plastarch material (PSM): Starch based material which is chemically derived to become a biodegradable plastic material. Are used in food trays, cups and single use cutlery.

As when these materials are not yet a common view in the food packaging industry, the cost of the raw materials for biodegradable plastics are quite high. But they'll have a huge potential to become a huge market segment when these materials are researched and developed more that they'll reach the oil-based plastics properties. Then they can compete with them. [2], [3], [4], [5]

2.4 Material requirements

All plastic materials are not suitable for food packaging or in other words, the material cannot be in contact with the foodstuff. “The package should not contaminate the food or adversely affect its organoleptic properties.” [1] It is the food packager’s responsibility to construe the information on migration. The overall migration from the packaging has to be evaluated that all the specific migration limits are met.

Migration; in general the food diffuses to the plastic package and changes the migration of unreacted monomers and additives from the plastic to the food. This means that the plastic material can spread its material to the foodstuff if the migration is too big. If this happens the foodstuff can be spoiled. The migration can be modeled mathematically by using Fick’s Law of Diffusion. “In which the rate of diffusion increases with the concentration of the diffusing substance, and both diffusion coefficients depend on the extent of penetration of food into the plastic.” [1] It is very important not to underestimate the migration in the food packaging, because the objective of the food packaging legislation is to protect the consumers. They control the contamination of food by chemicals transferred from the packaging.

When looking at different kind of plastic and biodegradable packages. The first thing that has to reach the standard is that it is not hazardous material for food and humans. Common sense says that the material should be pure and clean without any harmful additives and other contaminants that can harm the health. That is why in the Europe there are certificates and standards, European Food Safety Authority (EFSA), for materials that can be used in touch with food. In the USA they call it The U.S. Food and Drug Administration (FDA) certification.

Different materials have different properties. For example others can hold gases better than others; others are more suitable against moisture and so on. The packages requirements can be listed like this: Has to withstand moisture of the food, if package is sealed it has to be gastight, for products like meat, fish and chicken. It is possible to freeze, in some occasions it can be used in microwave, if the foodstuffs are oily or has fats on it the package has to have low oxygen permeability. There are different properties which the packages have to have, but the main reason why the requirements have to fulfill is that the foodstuff is in a good protection during the storage time. [1], [3], [5], [6], [18], [19]

2.4.1 Food contact certificate

Packaging materials have to have a food contact certificate if the material is in a direct contact to the food. For both European market and U.S. market exists own certificates, although they have similar legislations to each other's. European Food Safety Authority (EFSA) and Food and Drug Administration (FDA). Both are valid in the whole world.

With different type of certifications it is easier to maneuver when producing food packages to the food industry. When the material has been approved by this kind of certificate, packaging manufacturer can be sure that the material will not include any toxic materials, it is safe to produce and it is easy to sell further without any problems due to the material. [18], [19], [25]

A few example of different certificate: The certificate has a certain number which has a specific meaning. The list is available on the U.S. Food and Drug Administration web page. When reading through the list, there are listed a lot of substances what the plastic material can consist of. There are levels of approvals depending on shelf-life of the product, if the foodstuff is dry, fatty or aqueous. [18], [19], [25]

3 METHOD

Before using the materials in practice, it is important to know their properties and process abilities, which can be found in the materials Technical Datasheets and manufacturer's description of the material. By collecting the data of different biodegradable plastics on the market was rather easy because of the world wide known internet page called ides.com. From there it was possible to collect the right information about the biodegradable plastics what Paroprint could use in their applications in the future.

The criteria for the search of right material were that the material had to be biodegradable and it could be processed with injection molding and extrusion methods. The material should also have EFSA or FDA certificate. Most important criteria is that the material has to have good process ability, if the material is hard to process in the machine or it gives more problems than benefits it is no idea to use the material.

On the next page there are lists of biodegradable materials. On the left hand side is the manufacturer of the material, in the middle material description, materials product name and on the right hand side four rows that shows what properties the material has; FDA is food contact approval, IM means it is suitable for Injection Molding, EXT means it is suitable for Extrusion and FILM means that the material can be purchased as a ready film roll. Red X on the FDA row means that the material is approved to non-specific food applications.

Table 1. List of biodegradable plastic materials collected from different data sheets. (Technical data sheets 2011, ides.com)

Manufacturer	Material	Product name	FDA	IM	EXT	FILM
Grenidea	Biodegradable fiber composite	**Agro-Resin**		**x**	**x**	
API	Biodegradable bio plastic Synthetic and renewable raw material	**Apinat**		**x**	**x**	
Futuramat	Biodegradable polymers (Wheat flour-based material)	**BioCeres**		**x**		
Futuramat	Biodegradable polymers (wood fibers spruce-based material)	**BioFibra**		**x**		
Biocycle	Biodegradable material	**Biocycle**		**x**	**x**	
Biograde	Biodegradable plastic TPS + AP Resin is based on corn starch	**Biograde**		**x**	**x**	**x**
DuPont	Partially biodegradable 37% bio content	**Biomax**		**x**		
Biomer	Biodegradable plastic PHB	**Biomer**	**x**	**x**	**x**	
BIOP	Bio-plastic resin consisting: TPS, Synthetic copolyester and additives	**BIOpar**			**x**	**x**

Table 1. (Continue)

Manufacturer	Material	Product name	FDA	IM	EXT	FILM
R.O.J. Jonboom Holding B.V	Biodegradable material Starch based PLA	**Biopearls**		**x**		
Heritage Plastics	Mineral-containing compound based on a blend of biodegradable resins (Non-Specific Food Applications)	**BioTuf**	**x**		**x**	**x**
Cardia Bioplastics	TPS + Copolyester Based on corn starch	**Cardia Compostable**	**x**	**x**	**x**	**x**
Cereplast	Biodegradable materials Derived from starch (PLA) and other renewable materials	**Cereplast Compostable**	**x**	**x**	**x**	
Perstorp	PLA + Calcium Carbonate filler 40%	**CAPA**			**x**	**x**
Ecolgreen	Biodegradable materials derived from starch	**Ecol-Green**		**x**	**x**	**x**
BASF	Biodegradable copolymers	**Ecoflex**	**x**	**x**	**x**	**x**
BASF	Biodegradable resins blended to PLA	**Ecovio**	**x**	**x**	**x**	**x**
Eco-Tech Environment	Biodegradable materials	**EcoPure**	**x**	**x**	**x**	**x**

Table 1. (Continue)

Manufacturer	Material	Product name	FDA	IM	EXT	FILM
Natureworks	Biodegradable materials derived from starch (PLA)	**Ingeo**	**x**	**x**	**x**	**x**
Jamplast	Biodegradable material (PLA)	**Jam-plast**	**x**		**x**	**x**
Novamont	Biodegradable materials	**Mater-Bi**	**x**	**x**	**x**	**x**
NatureP-LAST	Biodegradable material PBS (succinic acid and butanediol) Blend able to other bio plastics	**Nature-PLAST**		**x**	**x**	**x**
Natur-Tec	Biodegradable materials Approved to short shelf-life products	**Natur-Tec**	**x**	**x**	**x**	**x**
Plantic Technologic	Biodegradable material derived from corn starch	**Plantic**	**x**	**x**	**x**	**x**
Polyone	Combine of; Thermoplastic resins with bio-derived polymers: PLA, PHB, PHVB and bio polymers	**re-Sound**		**x**		
Teknor Apex Com-pany	Biodegradable materials TPS + Copolyester (Thermoplastic Starch)	**Terra-loy**		**x**	**x**	**x**
Transmare	Biodegradable materials PLA	**Trans-mare**	**x**	**x**	**x**	**x**

3.1 Chose of materials to be tested

From the list Paroprint and co-operators decided to test a few potential materials which could be good for the products Paroprint will manufacture. Basically the materials were chosen from the datasheets. Which materials had the best properties, Food Contact Approvals, the materials availability in Europe and material price. All the data sheet information is more likely to be estimations of the materials behavior because the materials have been tested in a laboratory conditions at the manufacturer. Paroprint Oy did not give the information about the prices of the materials but the price difference to PE and PP is shown as index. PE=100 for Extrusion and PP=100 for Injection Molding.

3.1.1 Table of chosen biodegradable materials

For Injection Molding tests we chose these materials;

Table 2: Biodegradable materials which were chosen to the Injection Molding tests. (Paroprint Oy, Mikko Ketonen 2011)

Manufacturer	Material	Product name	Price / kg	FDA	IM
Cereplast	PLA; starch-based resins	**Cereplast Composta-ble**	**140**	**x**	**x**
Natureworks	PLA; starch based resins	**Ingeo**	**130**	**x**	**x**
Transmare Compounding	PLA; starch based resins	**Transmare**	**135**	**x**	**x**

All these PLA materials are derived from wheat, corn, potato and tapioca starches. But they all have different properties due to their manufacturing processes.
[20] [21] [22] [29]

For Extrusion tests we chose these materials;

Table 3. Biodegradable materials which were chosen to Extrusion coating tests, (Paro-print Oy, Mikko Ketonen 2011)

Manufacturer	Material	Product name	Price / kg	FDA	EXT	FILM
BASF	Blend of biodegradable copolyester Ecoflex and PLA	**Ecovio**	**155**	**x**	**x**	**x**
BASF	Biodegradable copolyester	**Ecoflex**	**156**	**x**	**x**	**x**

Both Extrusion materials were from the same manufacturer because the data sheets showed us the best properties what we were looking for.
[23] [24] [29] [Appendices]

3.2 Tests

Paroprint Oy have been co-operating with two different kinds of companies to manage to do the required tests to the products. Using biodegradable plastic material for injection molding and extrusion methods. The idea of the whole project was to collect information about different suitable biodegradable plastic materials that could be used in Paroprint Oy products in the future. With these actual production line tests we can conclude which materials would be the most suitable for these manufacturing processes. The prices of the materials were also on acceptable level.

3.3 Tests in Belgium, Loomans Group

Loomans Group in Belgium is a company which makes products out of plastics with injection molding machines. Paroprint Oy has been now for a few years co-operating with Loomans Group because of the new market idea of combining cardboard and plastics together to get more environmentally friendly food package. Both companies want to reduce the greenhouse emissions and that is why it was easy to maneuver to the right path to choose bio plastic coated cardboard and biodegradable bio plastics.

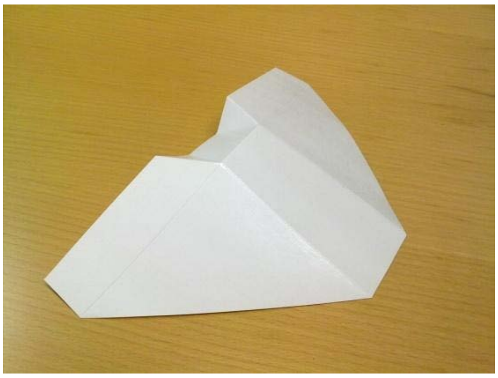
The idea of the dividing tasks was that Paroprint makes the cardboard blanks and Loomans makes the plastic part in injection molding machine.

Loomans plastic parts:

Figure 17. Plastic rim to sandwich box (On the left side). (Photograph Mikko Ketonen 2011)

Figure 18. Plastic rim to rectangular tray (On the right side). (Photograph Mikko Ketonen 2011)

Paroprint cardboard blanks:



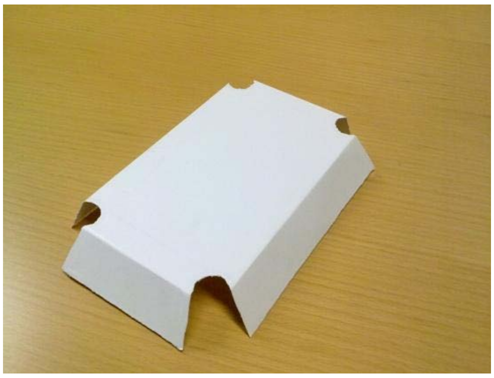


Figure 19. Cardboard blank to sandwich box. (Photograph Mikko Ketonen 2011)

Figure 20. Cardboard blank to rectangular tray. (Photograph Mikko Ketonen 2011)

Ready product when manufactured:

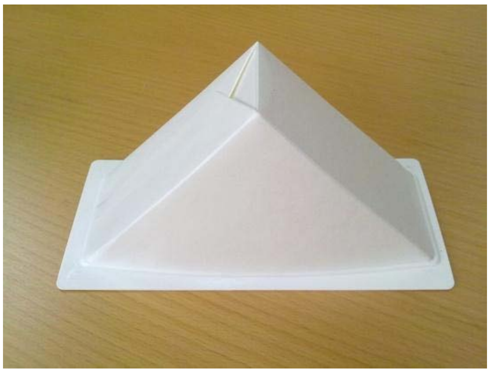


Figure 21. Sandwich box. (Photograph Mikko Ketonen 2011)

Figure 22. Rectangular tray. (Photograph Mikko Ketonen 2011)

Loomans have done two different test molds for these products; Sandwich box and Rectangular tray.

Sandwich box mold is planned so that the cardboard blank is placed in the middle of the mold to the cavity side and when the mold is closed the plastic material is injected from two corners of the mold to attach the plastic on the cardboard. For faster production the mold has HASCO hot runner system which provides the manufacturing without any material loss. The picture down shows roughly how the core side of the mold looks like and the injection point where the plastic is injected to the mold.

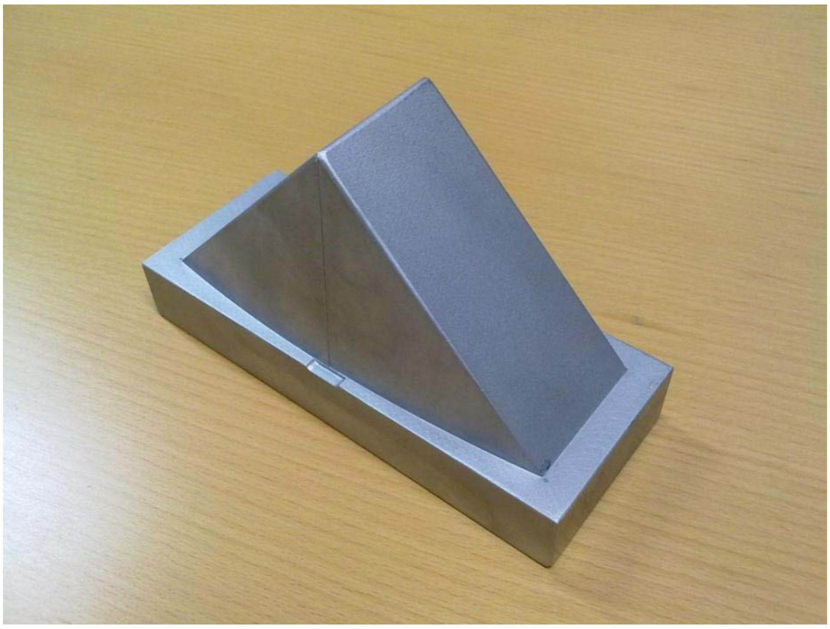


Figure 23. Directional copy of the sandwich box mold (Photograph Mikko Ketonen 2011)

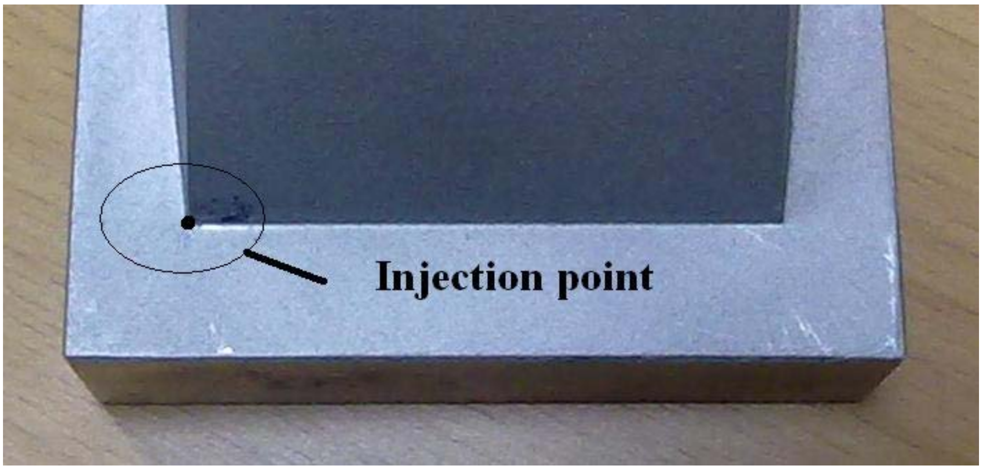


Figure 24. Directional copy of the sandwich box mold injection point. (Photograph Mikko Ketonen 2011)

Both sandwich box and rectangular tray molds are used in an injection molding machine which is the most commonly used plastic machine to manufacture solid food trays or food packages.

Figure 25. Injection molding machine. (Photograph Mikko Ketonen 2011)

Figure 26. Injection molding machine. (Photograph Mikko Ketonen 2011)

In the following picture are shown how the sandwich box is placed in the mold and ready products stacked on top of each other to show how the products are delivered to the end customers.

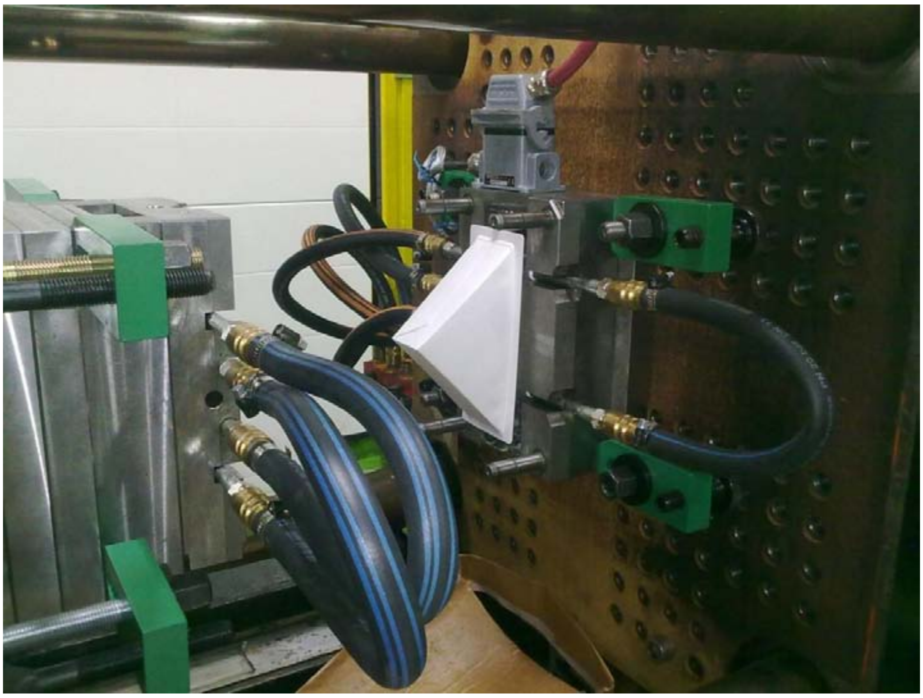


Figure 27. Directional picture of the sandwich box production from the machine. (Photograph Mikko Ketonen 2011)

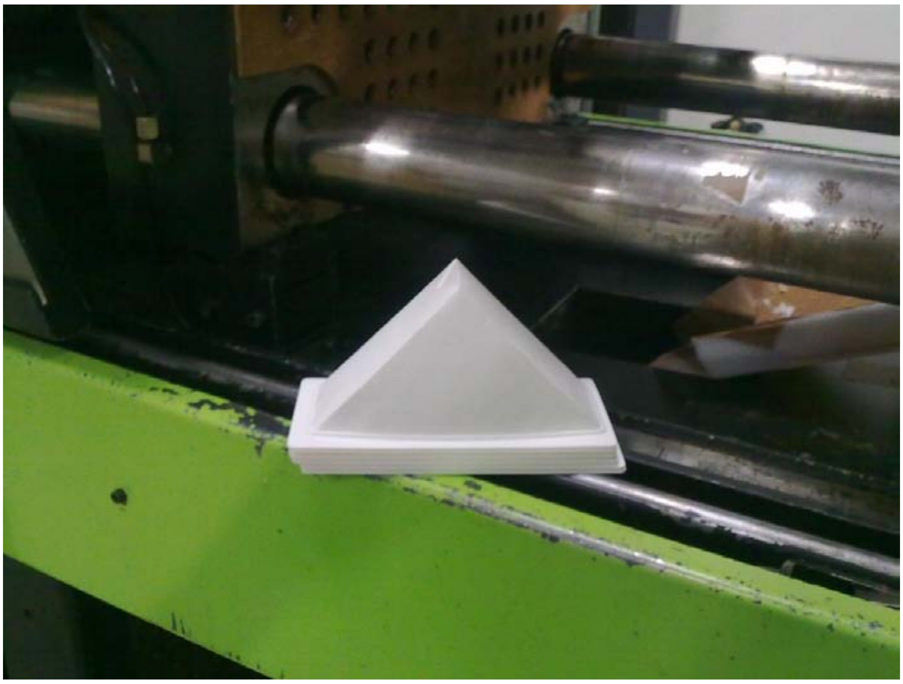


Figure 28. Stacked sandwich boxes. (Photograph Mikko Ketonen 2011)

Another product tested in Belgium at Loomans was the rectangular tray. The rectangular tray mold was planned with the same principles than the sandwich box mold. Although rectangular tray mold had four injection points instead of two. From each bottom corner, as shown in the picture.

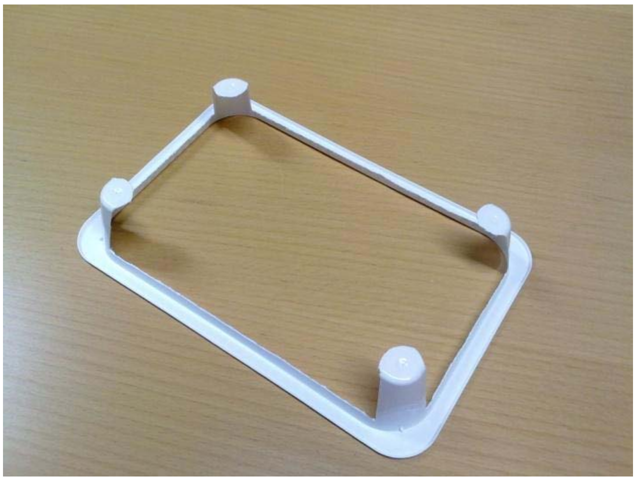


Figure 29. Rectangular tray injection points. (Photograph Mikko Ketonen 2011)

Figure 30. Closer view of one injection point. (Photograph Mikko Ketonen 2011)

Cardboard blank is placed in the middle of the mold to the cavity side and when the mold is closed the plastic material is injected form four corners of the mold to attach the plastic to the cardboard. Mould for rectangular tray has the HASCO hot runner system which provides the manufacturing without any material loss. The picture next page shows roughly how the rectangular tray is placed inside the mold and a few ready products stacked on top of each other's.

Figure 31. Directional picture of the rectangular tray production from the machine. (Photograph Mikko Ketonen 2011)

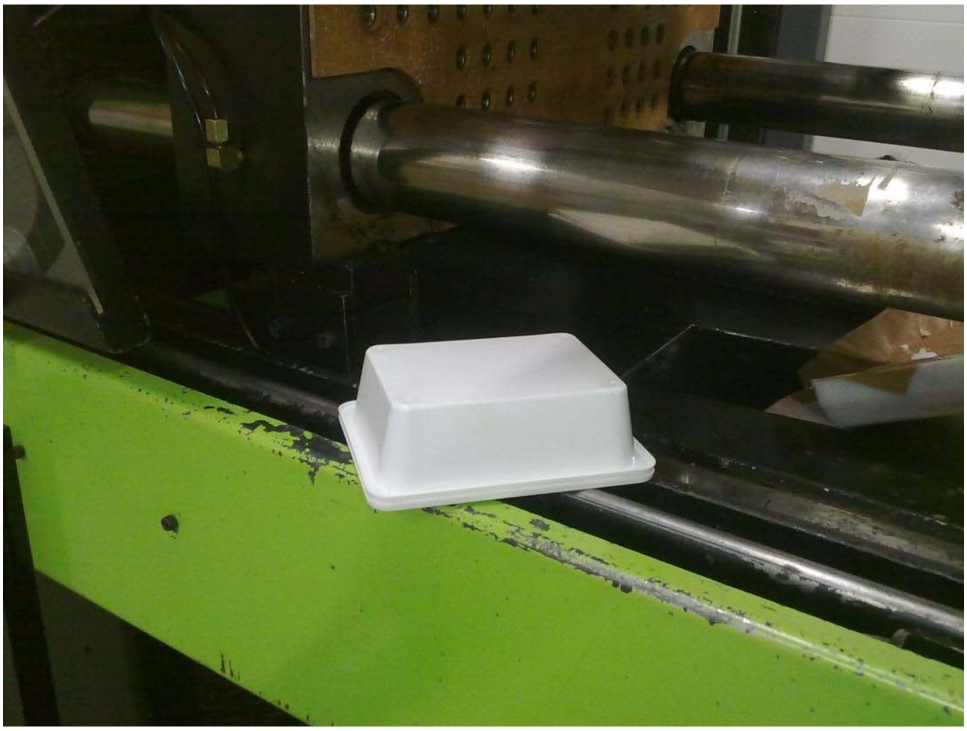


Figure 32. Stacked rectangular trays. (Photograph Mikko Ketonen 2011)

3.3.1 Materials

For these two tests we had chosen three different biodegradable PLA materials and they were tested at Loomans in Belgium;

CEREPLAST, Cereplast Compostable 1001:

Figure 33. Cereplast bag of granulates. (Photograph Mikko Ketonen 2011)

Figure 34. Cereplast granulates. (Photograph Mikko Ketonen 2011)

NATUREWORKS, Ingeo PLA Polymer 3001D:

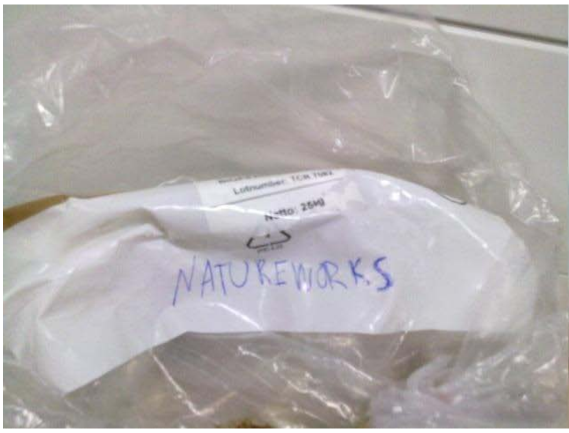


Figure 35. Natureworks bag of granulates. (Photograph Mikko Ketonen 2011)

Figure 36. Natureworks granulates. (Photograph Mikko Ketonen 2011)

TRANSMARE COMPOUNDNIG, Transmare Bio 35 LA-0.001:

Figure 37. Transmare bag of granulates. (Photograph Mikko Ketonen 2011)

Figure 38. Transmare granulates. (Photograph Mikko Ketonen 2011)

3.4 Tests in Valkeakoski, Lamican Oy

Lamican Oy in Valkeakoski is a company which makes different kind of plastic coatings on the cardboards with cardboard roll extrusion coating machines. Paroprint Oy has been co-operating with Lamican almost five years. Mostly Lamican has been doing PE-extrusion coatings to the cardboard rolls, but now the biodegradable bio plastic coatings have been done because of the tests Paroprint were making.

Figure 39. Cardboard extrusion coating machine. (Photograph Lamican Oy 2008)

Cardboard roll extrusion coating machine is planned so that the plastic material is heated inside the screw which rotates the plastic with a help of friction to gain the needed temperature.

Figure 40. Extrusion coating machine screw and die. (On the left side). (Photograph Mikko Ketonen 2011)

Figure 41. Control panel of extrusion coating machine heat barrels. (On the right side) (Photograph Mikko Ketonen 2011)

Then the material is extruded on top of the cardboard while the roll is spinning through the production line. There can be 1-4 hoppers which feed the plastic to the die.

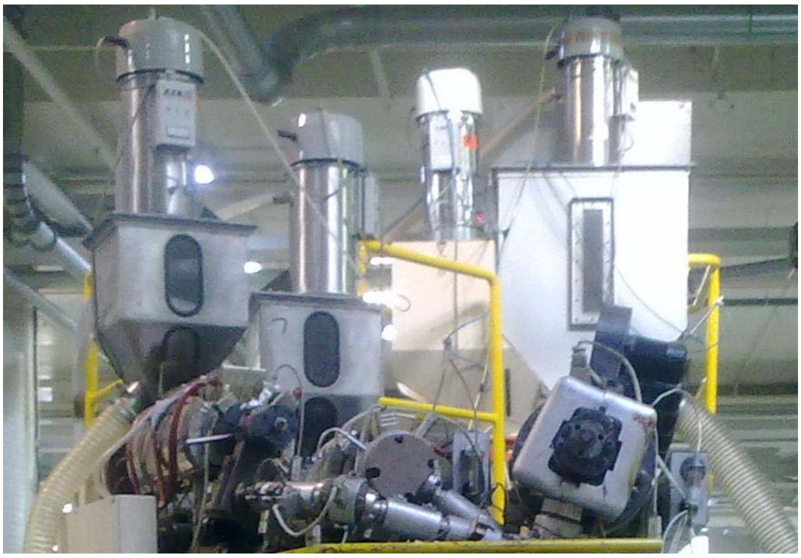


Figure 42. Extrusion coating machine hoppers. (Photograph Mikko Ketonen 2011)

Before the cardboard goes below the die, it goes through a corona unit, which treats the cardboard surface so that it get better adhesion properties, and the plastic material stick easier to the cardboard.

Figure 43. Extrusion coating machine specific view of corona unit. (On the left side) (Photograph Mikko Ketonen 2011)

Figure 44. Extrusion machine corona unit. (On the right side) (Photograph Mikko Ketonen 2011)

After corona treatment the cardboard goes through the die where the melt plastic is poured on top of the cardboard. Immediately after the melt plastic is on the cardboard it is cooled down rapidly with a cooler roll.

Figure 45. Extrusion coating machine cooler roll. (Photograph Mikko Ketonen 2011)

The plastic material can be around 180-300 degree Celsius, with a rapid cooling down to 10-15 degrees Celsius, the plastic surface will stick on the cardboard hard and it gives a smooth plastic layer. The die is also a measuring unit, how much material is poured on the cardboard varies the thickness of the plastic material on the cardboard. (On the left side is the cardboard, in the middle is the die where the material is poured on the plastic and on the right side is the cooler roll.)

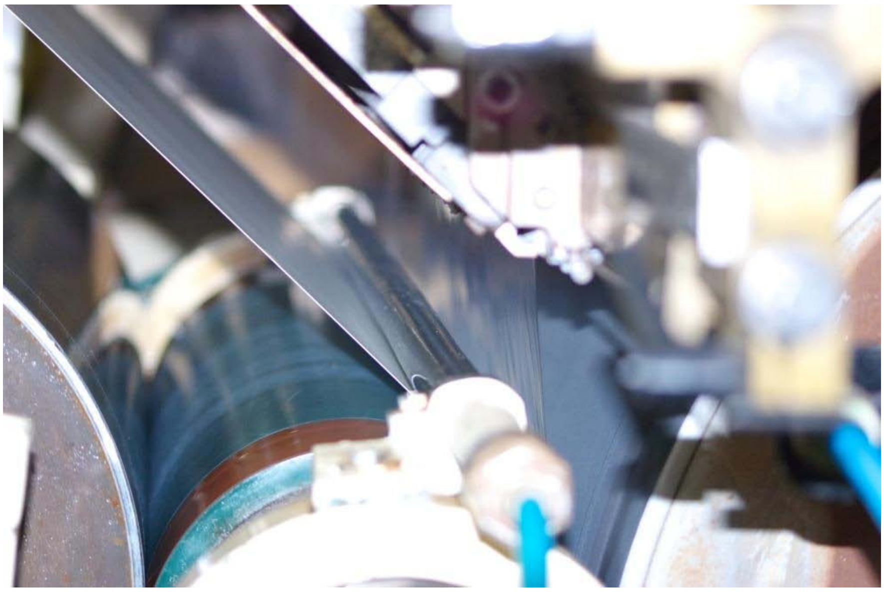


Figure 46. Extrusion coating machine in action, die pouring plastic on the cardboard. (Photograph Mikko Ketonen 2011)

After this production, the cardboard roll has a biodegradable plastic layer which can be used for diverse different purpose. In this case, the cardboard is used in food packages used in food industry.

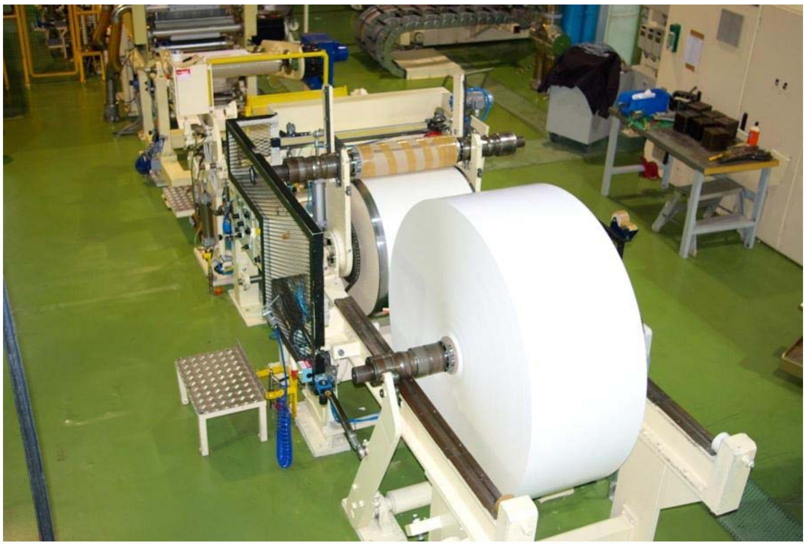


Figure 47. Extrusion coating machine ready product, coated roll. (Photograph Mikko Ketonen 2011)

In the end, the gram weight of the coatings depends on how thick the plastic layer is on the cardboard. For example if cardboard gram weight is 200g / m², and the plastic layer coated on the cardboard is 15g / m², the total thickness is cardboard thickness plus the thickness of the plastic, 215g / m².

[Appendices] [30] [31]

3.4.1 Materials

Lamican Oy has done tests with a few different bio plastic materials.

BASF, Ecovio L BX 8145:

Figure 48. BASF Ecovio material storage bag. (Photograph Mikko Ketonen 2011)

Figure 49. BASF Ecovio granulates. (Photograph Mikko Ketonen 2011)

BASF, Ecoflex F Blend 1200:

Figure 50. BASF Ecoflex material storage bag. (Photograph Mikko Ketonen 2011)

Figure 51. BASF Ecoflex granulates. (Photograph Mikko Ketonen 2011)

[30] [31] [Appendices]

4 RESULTS

When the tests were done, there were both positive and negative things that came up with the processes and with the materials. The results gave confirmation about what material could be used in the future. As when Paroprint did want to keep the PLA prices for their own information and did not want to publish them to a third part, the prices were shown as an index, compare to the oil-based plastics, PP and PE.

4.1 Results from Belgium, Loomans Group

Three different kind of PLA materials were tested at Loomans. Sandwich box and rectangular tray got three different bio plastic rims around it. Paroprint had shipped cardboard blanks there for both sandwich box and rectangular tray. Paroprint's requirements of the material were that the material has to have good process ability, so that it is easy to process, Food Contact Approval and it has to be biodegradable. Here is an overview of all the materials Paroprint and co-operators were testing.

Table 4. CEREPLAST, Cereplast Compostable 1001. Results from the tests. (Paroprint Oy and Loomans Group, Mikko Ketonen 2011)

Process ability	The material process temperatures; Feed zone 160 and nozzle 205 degrees Celsius.
	Screw speed: 50 – 100 RPM, If it was higher the plastic lose its strength, became brittle.
	Drying time and temperature: 40-50 Degrees Celsius four hours, if it was not dried the material became brittle, it broke too easily.
Advantages	The material had good adhesive to the cardboard, end product looked good, the bio plastic had even surface, no significant shrinkage of the plastic
Disadvantages	If the machine parameters were wrong the end result was not good, if material not dried end product too brittle, cooling time a bit longer compare to the oil-based plastics, if taken out from mold too early it had not stick to the cardboard hard enough
Fullfilled Paroprint's requirements?	The material fulfilled partially Paroprint's requirements. It had food contact approval, it had okay process ability when the machine had all parameters correct and the material is biodegradable, even though PLA had higher price compared to PE, it is still interesting Paroprint's customers

Paroprint and Loomans Group were slightly confused about how hard the material was to process. In the end the material functioned well, but more tests has to be done that the material works 100 % perfectly.

Table 5. NATUREWORKS, Ingeo PLA Polymer 3001D. Results from the tests. (Paroprint Oy and Loomans Group, Mikko Ketonen 2011)

Process ability	The material process temperatures; Feed zone 150 and nozzle 205 degrees Celsius.
	Screw speed: 100 – 175 RPM, If it was lower the plastic had too high viscosity, because of low friction and couldn't execute injection properly
	Drying time and temperature: 50 Degrees Celsius three hours, if it was not dried the material became more rigid and therefore the possibility to break was higher
Advantages	The material has not necessarily be dried before use but it is recommended, end product looked good, the bio plastic had even surface, no mold shrinkage
Disadvantages	Material had small problems to stick to the cardboard, but not significantly, if not dried the material eventually break if used more strength to bend it, worked better than Cereplast material, cooling time a bit longer compare to the oil-based plastics, if taken out from mold too early it had not stick to the cardboard hard enough
Fulfilled Paroprint's requirements?	The material fulfilled partially Paroprint's requirements. It had food contact approval, the material is biodegradable, even though PLA had higher price compared to PE, it is still interesting Paroprint's customers but the process ability were hard compared to PP

Same as with Cereplast material, Paroprint and Loomans Group were slightly confused about how hard the material was to process. In the end the material functioned well, but more tests has to be done that the material works 100 % perfectly.

Table 6. TRANSMARE COMPOUNDNIG, Transmare Bio 35 LA-0.001. Results from the tests. (Paroprint Oy and Loomans Group, Mikko Ketonen 2011)

Process ability	The material process temperatures; Feed zone 165 and nozzle 205 degrees Celsius.
	Screw speed: Medium (70-110) RPM, Worked also quite good when lower or higher
	Drying time and temperature: No need for drying, only in specific occasions
Advantages	No need for drying, material adhesive to the cardboard was good, end product looked good, the bio plastic had even surface, no mold shrinkage, the material was rigid but slightly elastic
Disadvantages	If used more strength to bend the plastic material it broke, cooling time a bit longer compare to the oil-based plastics, if taken out from mold too early it had not stick to the cardboard hard enough
Fulfilled Paroprint's requirements?	The material fulfilled partially Paroprint's requirements. It had food contact approval, the material is biodegradable, even though PLA had higher price compared to PE, it is still interesting Paroprint's customers but the process ability were hard compared to PP

All these three materials had advantages and disadvantages, but overall all these three materials could be used in sandwich box and rectangular tray products. Although the material was slightly hard to process but in the end the material functioned well, but there has to be done more tests that the material would function in the best possible way.

4.1.1 Comparison to oil-based plastics

When comparing three different PLA materials to the oil-based plastics we found some significant difference between them. There were only few things which make the oil-based plastics to be more effective on process ability.

The bio plastics were compared to the most used plastic material in the food packaging industry; PP, Polypropylene.

Table 7. POLYPROPYLENE (PP). Results from the test (Paroprint Oy and Loomans Group, Mikko Ketonen 2011)

Process ability	The material process temperatures; Feed zone 189-222 and nozzle 210-238 degrees Celsius.
	Screw speed: 50-100 RPM, functioned well in all cases
	Drying time and temperature: No need for drying
Advantages	No need for drying, very fast production, stiff and flexible, good adhesion on cardboard
Disadvantages	Mold shrinkage almost 2 %, bad surface finish on the sandwich box and rectangular tray,

Figure 52. PLA sandwich box on the left side and Polypropylene sandwich box on the right side. (Photograph Mikko Ketonen 2011)

When comparing these two materials; Oil-based Polypropylene and Starch based PLA. Both had their advantages and disadvantages, but the most significant difference with these materials was the cooling time of the materials. PLA needs approximately 3-5 seconds more time to cool down before it can be taken away from the mold. Polypropylene had benefit when talking about process ability, when the cooling time is lower the amount of end products can be produced faster and more by time. On the other hand PLA is better choice for these applications, when PLA have only 0,2-0,3 % mold shrinkage, compared to Polypropylenes 1,6-1,9 %. The end product looks very good and the plastic surface is even. [26] [29]

The picture shows the difference. Yellow plastic is Polypropylene and the white plastic is PLA.

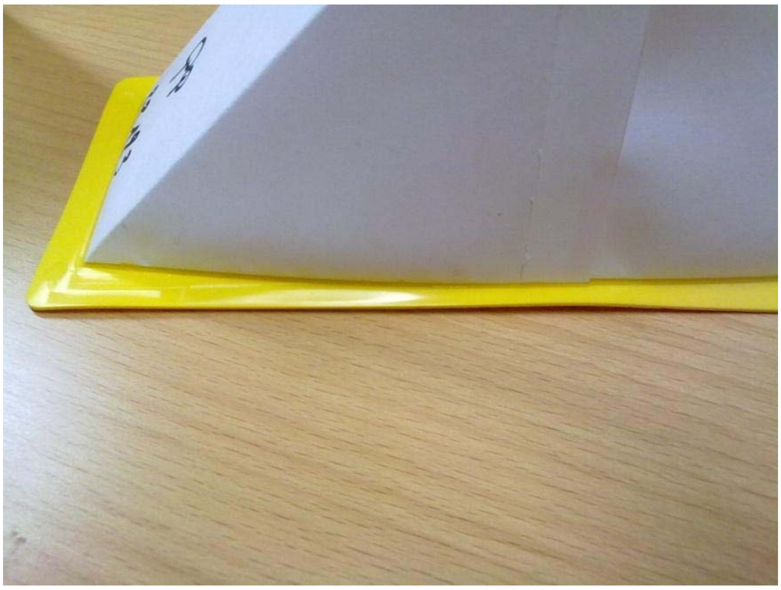


Figure 53. Polypropylene mold shrinkage effect. (Photograph Mikko Ketonen 2011)

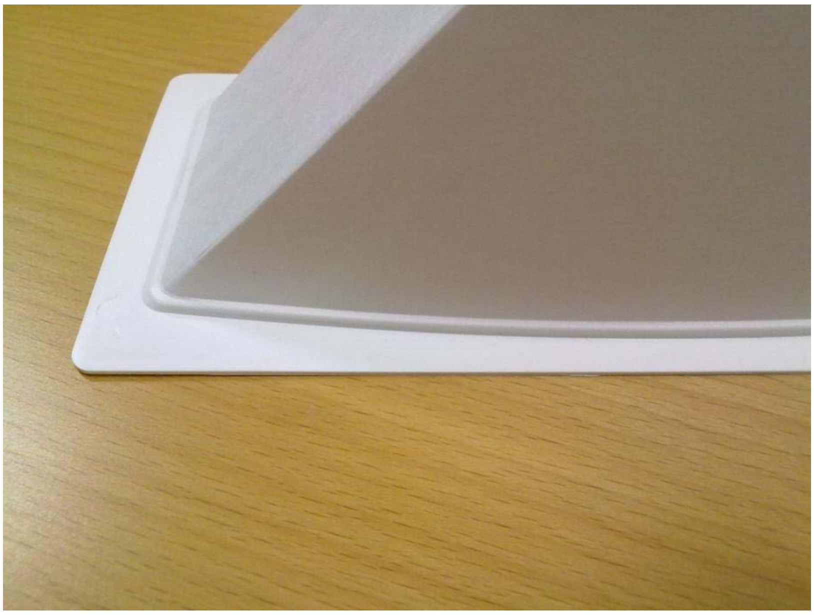


Figure 54. PLA mold shrinkage effect. (Photograph Mikko Ketonen 2011)

When the cardboard blank is inserted inside the mold and the plastic material is injected in to the mold and the plastic has a mold shrinkage the plastic will shrink but the card-board blank does not, that is why the result of this looks bad, when the cardboard is too “big” for the plastic rim. [26] [29]

4.2 Results from Valkeakoski, Lamican Oy

Two different kind of PLA materials were tested at Lamican Oy. One roll of cardboard was used to make the test. The roll was split to half that the two coatings could be done. Paroprint's requirements of the material were that the material has to have good process ability, Food Contact Approval and it has to be biodegradable and cost-effective.

Table 8. BASF, Ecovio L BX 8145. Results from the tests (Paroprint Oy and Lamican Oy, Mikko Ketonen 2011)

Process ability	The material process temperatures; Using two hoppers / barrels, 245 degrees Celsius.
	Screw speed: 40 RPM Machine speed: 100-180m / min
	Drying time and temperature: No need for drying
Advantages	Good surface finish
Disadvantages	Low machine speed, relatively hard to process
Fulfilled Paroprint's requirements?	The material fulfilled Paroprint's requirements. It had food contact approval, it had good process ability with low speed and the material is biodegradable

Table 9. BASF, Ecoflex F Blend 1200. Results from the test (Paroprint Oy and Loomans Group, Mikko Ketonen 2011)

Process ability	The material process temperatures; Using two hoppers / barrels, 245 degrees Celsius.
	Screw speed: 40 RPM Machine speed: 100-180m / min
	Drying time and temperature: No need for drying
Advantages	Good surface finish
Disadvantages	Low machine speed, relatively hard to process
Fulfilled Paroprint's requirements?	The material fulfilled Paroprint's requirements. It had food contact approval, it had good process ability with low speed and the material is biodegradable

Both PLA materials had problems with the process, because it was hard to find the right temperatures and speeds. The manufacturer of the material did not have exact parameters for the extrusion coating, so Lamican had to find them oneself. When processing with too low gram weight, the surface finish was not good and vice versa if the gram weight was too high it did the same thing. When thinking of production it would be much easier to manufacture big quantities rather than small quantities as we tested only two rolls of cardboard.

Lamican Oy had planned that they will continue testing and co-operating with the material manufacturer to get better results from PLA. When getting more experience of the material, PLA’s process ability will be improved.

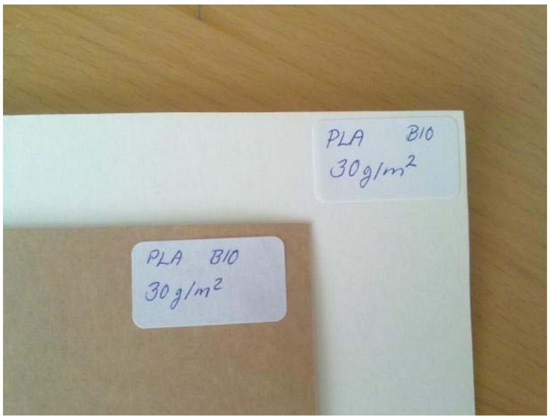


Figure 55. PLA coated cardboard. (Photograph Mikko Ketonen 2011)

Figure 56. PLA coated cardboard. (Photograph Mikko Ketonen 2011)

4.2.1 Comparison to oil-based plastics

With oil-based plastics the coatings have been done for many years so the process parameters are well known for these purposes. All properties of the PLA material are not yet on the right final technical standard. When comparing these materials to the oil-based plastics we found a few difference between them.

The bio plastics were compared to the most used coating material in the cardboard coating for food packaging industry; PE, Polyethylene.

Table10. POLYETHYLENE (PE). Results from the test (Paroprint Oy and Lamican Oy, Mikko Ketonen 2011)

Process ability	The material process temperatures; Using two hoppers / barrels, 270 degrees Celsius
	Screw speed: 50 RPM Machine speed: 400-500m / min
	Drying time and temperature: No need for drying
Advantages	No need for drying, very fast production, good adhesion on cardboard
Disadvantages	Not biodegradable

When comparing these two materials, PE has better process ability and it is possible to mix the machine parameters without bad results in the end product. PLA had quite limited values for processing, but in the end the result was good and it works well in the products Paroprint is using. [27] [29] [30] [31]

5 DISCUSSION

When studying the past years carbon dioxide levels charts, it shows that big changes have to be done before the climate will change for good. Everybody should make their own attempt to make it to be better. In the food packaging industry it could be a huge step forward to give up of the oil-based materials which are hard to get rid of. It is important to be green. To get things changed, everybody should make an effort but in the food packaging industry it is possible to come up with some new products that are eco-friendly, biodegradable and try to compete with the existing products. Majority of the people that are involved with the food plastic packaging industry says that the green plastics will be the future, it can take time before they are good enough to reach big market share but must happen.

Better products and more cost-effective productions can be reached by updating the existing methods and improving the techniques used in the food packaging industry. It is a normal life cycle; with the technology the final product has to cope with the others that it will function in the best way. Cars have been improved, due to the safety and environmental aspects, houses are built in an efficient way to restore energy, and the materials used in the food packaging industry improves to be more green and minimize the pollution consumption what comes when producing these materials. Making the recycling and getting rid of the package easier. When using nature's own resources, it gives more opportunities to the food packaging industry.

With small changes we help the future generations to live a happy and full life without a fear that pollution will destroy something nice and beautiful. Thinking green always counts. [17] [28] [29] [30]

6 CONCLUSION

Overall the tests went well without any bigger problems with the machines or the materials. The results were not as good as Paroprint thought they would get due to the good results got from oil-based plastics. It was known that the biodegradable materials are different from the oil-based materials but the lack of experience to produce these materials made it harder. In the end the materials showed that they have potential to become Paroprint's products if the process ability improves.

Three different PLA materials; Cereplast, Natureworks and Transmare, for sandwich box and rectangular tray products which were tested at Loomans Group in Belgium had very similar properties and process abilities when comparing them among themselves. All of them were biodegradable and were suitable for food contact. These PLA materials functioned well with the cardboard but the processes were hard to achieve with the injection molding machine. Also these materials were slightly more expensive compared to the Polypropylene. The price-functionality ratio was not good enough and therefore Paroprint will continue to do more tests to achieve the results they wanted.

Two different PLA materials; BASF Ecovio and Ecoflex, for cardboard extrusion coatings were tested at Lamican Oy in Valkeakoski. The properties of these two materials were similar among themselves. Both of the materials were biodegradable and they were suitable for food contact. Materials had limited process values which made it hard to use. Also the prices were more expensive when compared to PE. The price-functionality ratio was not good enough to reach Paroprint's needs.

The materials were not suitable for the needs of Paroprint's requirements. There have to be done more tests with the materials that the process can be 100% profitable. Manufacturers should also update and develop the materials more that they would reach the right level. The level was that the material is liable and its functionality is best possible. Biodegradable bio plastics are yet in the beginning of its journey and in the future it is possible to think that these materials are taking over in some extent the market from the oil-based plastic materials.

Paroprint Oy was pleased of the results they got and are going to take the next step further to co-operate more with the material manufacturers and carry out more tests regarding these applications. Lamican Oy will continue to do more tests with BASF to find out the right process parameters. Loomans Group will also continue to do more tests with their machines parameters and improve their mould designs.

By learning the right production parameters more cost-effective production can be achieved. Biodegradable raw-material producers will develop better products when demand grows.

This is a serious issue for the bio plastic manufacturers that they will get more competitive materials out on the market. It is an issue which is worth fighting for, to get more environmentally friendly products which reduce the pollution. Paroprint Oy will continue with the task to become more eco-friendly company among its co-operators.

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NatureWorks® PLA Polymer 3001D

Injection Molding Process Guide

NatureWorks® PLA (polylactide) polymer 3001D, a NatureWorks® product, is designed for injection molding applications.
It is designed for clear applications with heat deflection temperatures lower than 130ºF (55ºC). See Table 1 for properties.

Processing Temperature Profile		
Melt Temperature	390ºF	200ºC
Feed Throat	70ºF	20ºC
Feed Temperature (crystalline pellets)	330ºF	165ºC
Feed Temperature (amorphous pellets)	300ºF	150ºC
Compression Section	380ºF	195ºC
Metering Section	400ºF	205ºC
Nozzle	400ºF	205ºC
Mold	75ºF	25ºC
Screw Speed	100-175 rpm	
Back Pressure	50-100 psi	
Mold Shrinkage	.004 in/in. +/-.001	

Note: These are starting points and may need to be optimized.

Applications

The varieties of products made with NatureWorks 3001D grow every day. Applications include cutlery, cups, plates and saucers, and outdoor novelties.

Table 1 – Typical Material & Application Properties [1]	PLA Resin (General Purpose)	ASTM Method
Physical Properties		
Specific Gravity	1.24	D792
Melt Index, g/10 min (190ºC/2.16K)	10-30	D1238
Clarity	Transparent	
Mechanical Properties		
Tensile Yield Strength, psi (MPa)	7,000 (48)	D638
Tensile Elongation, %	2.5	D638
Notched Izod Impact, ft-lb/in (J/m)	0.3 (0.16)	D256
Flexural Strength (MPa)	12,000 (83)	D790
Flexural Modulus (MPa)	555,000 (3828)	D790

[1] Typical properties; not to be construed as specifications.

Processing Information

3001D polymer injection molding applications can be processed on conventional injection molding equipment. The material is stable in the molten state, provided that the drying procedures are followed. Mold flow is highly dependent on melt temperature. It is recommended to balance screw speed, back pressure, and process temperature to control melt temperature. Injection speed should be medium to fast.

Machine Configuration

PLA polymer 3001D will process on conventional injection molding machinery. A general purpose screw designed to minimize residence time and shear works well. Please refer to the PLA Injection Molding Guide for more information.

Process Details

Startup and Shutdown

PLA polymer 3001D is not compatible with a wide variety of polyolefin resins, and special purging sequences should be followed:

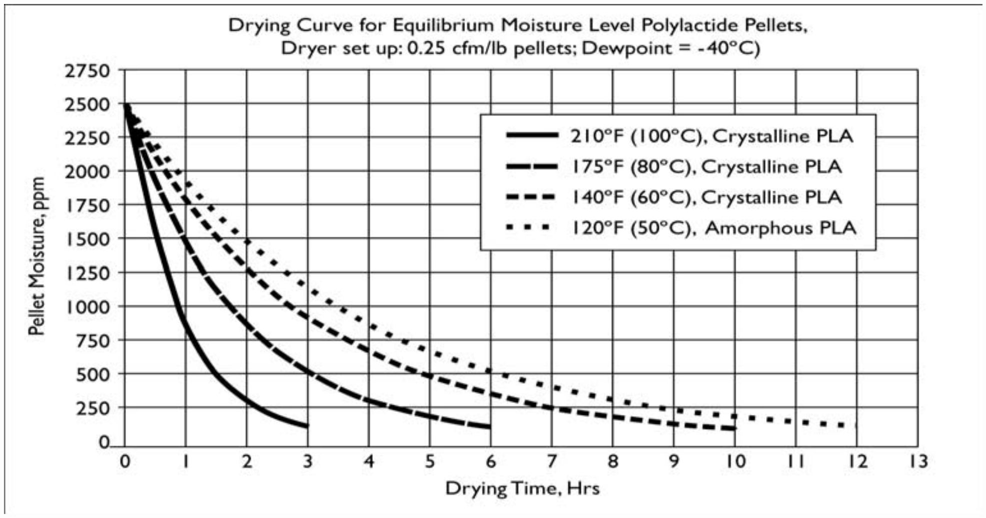
1. Clean extruder and bring temperatures to steady state with low-viscosity, general-purpose polystyrene or polypropylene.
2. Vacuum out hopper system to avoid contamination.
3. Introduce PLA polymer into the extruder at the operating conditions used in Step 1.
4. Once PLA polymer has purged, reduce barrel temperatures to desired set points.
5. At shutdown, purge machine with high-viscosity polystyrene or polypropylene.

NatureWorks® PLA Polymer 3001D

Drying

In-line drying is recommended for PLA resins. A moisture content of less than 0.025% (250 ppm) is recommended to prevent viscosity degradation. Polymer is supplied in foil-lined boxes or bags dried to <400 ppm. The resin should not be exposed to atmospheric conditions after drying. Keep the package sealed until ready to use and promptly dry and reseal any unused material. The drying curves for both amorphous and crystalline resins are shown to the right.

Note: Amorphous polymer must be dried below 120F (50C).



Compostability

Composting is a method of waste disposal that allows organic materials to be recycled into a product that can be used as a valuable soil amendment. PLA is made primarily of polylactic acid, a repeating chain of lactic acid, which undergoes a 2-step degradation process. First, the moisture and heat in the compost pile attack the PLA polymer chains and split them apart, creating smaller polymers, and finally, lactic acid. Microorganisms in compost and soil consume the smaller polymer fragments and lactic acid as nutrients. Since lactic acid is widely found in nature, a large number of organisms metabolize lactic acid. At a minimum, fungi and bacteria are involved in PLA degradation. The end result of the process is carbon dioxide, water and also humus, a soil nutrient. This degradation process is temperature and humidity dependent. Regulatory guidelines and standards for composting revolve around four basic criteria: Material Characteristics, Biodegradation, Disintegration, and Ecotoxicity. Description of the requirements of these testing can be found in the appropriate geographical area: DIN V 54900-1 (Germany), EN 13432 (EU), ASTM D 6400 (USA), GreenPla (Japan). This grade of NatureWorks® PLA meets the requirements of these four standards with limitation of maximum layer thickness of 1650 µm and for coating layers up to 37 µm thick

FDA Status

U.S. Status-

This is to advise you that on January 3, 2002 FCN 000178 submitted by NatureWorks LLC to FDA became effective. This effective notification is part of list currently maintained on FDA's website at http://www.cfsan.fda.gov/~dms/opa-fcn.html. This grade of NatureWorks® PLA may therefore be used in food packaging materials and, as such, is a permitted component of such materials pursuant to section 201(s) of the Federal, Drug, and Cosmetic Act, and Parts 182, 184, and 186 of the Food Additive Regulations. All additives and adjuncts contained in the referenced NatureWorks® PLA formulation meet the applicable sections of the Federal Food, Drug, and Cosmetic Act. The fin- ished polymer is approved for all food types and B-H use conditions. We urge all of our customers to perform GMP (Good Manufacturing Procedures) when constructing a package so that it is suitable for the end use. Again, for any application, should you need further clarification, please do not hesitate to contact NatureWorks LLC.

European Status

This grade of NatureWorks® PLA complies with EU Plastics Directive 2002/72/EC, which applies to all EU member states. The Plastics Directive is a consolidated version of the "Monomers Directive (Commission Directive 90/128/EEC) and its first 7 amendments. This grade of NatureWorks® PLA is also in compliance with "Bedarfgegenstände Gesetz", which is the German implementation of the EU Plastics Directive 2002/72/EC. Substances used in the manufacturing of this product which are not yet regulated by EU Plastics Directive 2002/72/EC, as amended, are in compliance with appropriate EU national regulations. NatureWorks

LLC would like to draw your attention to the fact that the EU-Directive 2002/72/EC, which applies to all EU-Member States, includes a limit of 10 mg/dm2 of the overall
migration from finished plastic articles into food. In accordance with EU-Directive 2002/72/EC the migration should be measured on finished articles placed into contact with the foodstuff or appropriate food simulants for a period and at a temperature which are chosen by reference to the contact conditions in actual use, according to the rules laid down in EU-Directives 93/8/EEC (amending 82/711/EEC) and 85/572/EEC Please note that it is the responsibility of both the manufacturers of finished food contact articles as well as the industrial food packers to make sure that these articles in their actual use are in compliance with the imposed specific and overall migration requirements. Again, for any application, should you need further clarification, please
do not hesitate to contact NatureWorks LLC.

Safety and Handling Considerations

Material Safety Data (MSD) sheets for PLA polymers are available from NatureWorks LLC. MSD sheets are provided to help customers satisfy their own handling, safety, and disposal needs, and those that may be required by locally applicable health and safety regulations, such as OSHA (U.S.A.), MAK (Germany), or WHMIS (Canada). MSD sheets are updated regularly; therefore, please request and review the most current MSD sheets before handling or using any product.

The following comments apply only to PLA polymers; additives and processing aids used in fabrication and other materials used in finishing steps have their own safe-use profile and must be investigated separately.

Hazards and Handling Precautions

PLA polymers have a very low degree of toxicity and, under normal conditions of use, should pose no unusual problems from incidental ingestion, or eye and skin contact. However, caution is advised when handling, storing, using, or disposing of these resins, and good housekeeping and controlling of dusts are necessary for safe handling of product. Workers should be protected from the possibility of contact with molten resin during fabrication. Handling and fabrication of resins can result in the generation of vapors and dusts that may cause irritation to eyes and the upper respiratory tract. In dusty atmospheres, use an approved dust respirator. Pellets or beads may present a slipping hazard. Good general ventilation of the polymer processing area is recommended. At temperatures exceeding the polymer melt temperature (typically 170ºC), polymer can release fumes, which may contain fragments of the polymer, creating a potential to irritate eyes and mucous membranes. Good general ventilation should be sufficient for most conditions. Local exhaust ventilation is recommended for melt operations. Use safety glasses if there is a potential for exposure to particles which could cause mechanical injury to the eye. If vapor exposure causes eye discomfort, use a full-face respirator. No other precautions other than clean, body-covering clothing should be needed for handling PLA polymers. Use gloves with insulation for thermal protection when exposure to the melt is localized.

Combustibility

PLA polymers will burn. Clear to white smoke is produced when product burns. Toxic fumes are released under conditions of incomplete combustion. Do not permit dust to accumulate. Dust layers can be ignited by spontaneous combustion or other ignition sources. When suspended in air, dust can pose an explosion hazard. Firefighters should wear positive-pressure, self-contained breathing apparatuses and full protective equipment. Water or water fog is the preferred extinguishing medium. Foam, alcohol-resistant foam, carbon dioxide or dry chemicals may also be used. Soak thoroughly with water to cool and prevent re-ignition.

Disposal

DO NOT DUMP INTO ANY SEWERS, ON THE GROUND, OR INTO ANY BODY OF WATER. For unused or uncontaminated material, the preferred options include recycling into the process or sending to an industrial composting facility, if available; otherwise, send to an incinerator or other thermal destruction device. For used or contaminated material, the disposal options remain the same, although additional evaluation is required. (For example, in the U.S.A., see 40 CFR, Part 261, "Identification and Listing of Hazardous Waste.") All disposal methods must be in compliance with Federal, State/Provincial, and local laws and regulations.

NOTICE: No freedom from any patent owned by NatureWorks LLC or others is to be inferred. Because use conditions and applicable laws may differ from one location to another and may change with time, Customer is responsible for determining whether products and the information in this document are appropriate for Customer's use and for ensuring that Customer's workplace and disposal practices are in compliance with applicable laws and other governmental enactments. NatureWorks LLC assumes no obligation or liability for the information in this document. **NO WARRANTIES ARE GIVEN; ALL IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR USE ARE EXPRESSLY EXCLUDED.**

Environmental Concerns

Generally speaking, lost pellets are not a problem in the environment except under unusual circumstances when they enter the marine environment. They are benign in terms of their physical environmental impact, but if ingested by waterfowl or aquatic life, they may mechanically cause adverse effects. Spills should be minimized, and they should be cleaned up when they happen. Plastics should not be discarded into the ocean or any other body of water.

Product Stewardship

NatureWorks LLC has a fundamental duty to all those that make and use our products, and for the environment in which we live. This duty is the basis for our Product Stewardship philosophy, by which we assess the health and environmental information on our products and their intended use, then take appropriate steps to protect the environment and the health of our employees and the public.

Customer Notice

NatureWorks LLC encourages its customers and potential users of its products to review their applications for such products from the standpoint of human health and environmental quality. To help ensure our products are not used in ways for which they were not intended or tested, our personnel will assist customers in dealing with ecological and product safety considerations. Your sales representative can arrange the proper contacts. NatureWorks LLC literature, including Material Safety Data sheets, should be consulted prior to the use of the company's products. These are available from your NatureWorks LLC representative.

NOTICE REGARDING PROHIBITED USE RESTRICTIONS: NatureWorks does not recommend any of its products, including samples, for use as: Components of, or packaging for, tobacco products; Components of products where the end product is intended for human or animal consumption; In any application that is intended for any internal contact with human body fluids or body tissues; As a critical component in any medical device that supports or sustains human life; In any product that is designed specifically for ingestion or internal use by pregnant women; and in any application designed specifically to promote or interfere with human reproduction.

For additional information in the U.S. and Canada,
call toll-free 1-877-423-7659
In Europe, call 31-(0)35-699-1344
In Japan, call 81-33-285-

NatureWorks

082415305 Minnetonka Blvd., Minnetonka, MN 55345

Cereplast Compostables®

Compostable 1001

Injection Molding Grade

Property Guide

Cereplast Compostables® resins are renewable, ecologically sound substitutes for petroleum-based plastic product, replacing nearly 100% of the petroleum-based additives used in traditional plastics. Cereplast Compostables® resins are using polymer and additives derived from starch and other renewable resources chemistry. These components are carefully blended together on state-of-the-art compounding equipments.

All Cereplast Compostables® resins, including **Compostable 1001**, are certified as biodegradable and compostable in the United States and Europe, meeting BPI (Biodegradable Products Institute www.bpiworld.com) standards for compostability (ASTM6400D99, ASTM6868) and European Bioplastics Standards (EN13432).

Compostable 1001 has been designed to have an excellent balance of toughness, rigidity and processability. Compostable 1001 can be processed on existing conventional electric and hydraulic reciprocating screw injection molding machines. Please see our processing guide for processing and material drying guidelines. This can be found at www.cereplast.com.

Physical Property	ASTM Test Method	Values	Values
Tensile Strength @ Max	D 638	7,190 psi	49.6 Mpa
Tensile Elongation @ Break	D 638	5.1 %	5.1 %
Tensile Modulus	D 638	520,000 psi	3,590 Mpa
Flexural Modulus	D 790	487,000 psi	3,360 Mpa
Flexural Strength	D 790	11,600 psi	80 Mpa
Gardner Impact	D 5420	10 In-lb	1.13 J
Notched Izod Impact Strength (23°C)	D 256	0.62 ft-lb/in	0.033 kJ/m
Temperature Deflection Under Load (0.45 Mpa)	D 648	112 °F	44 °C
Melt Flow Index 190°C @ 2.16 Kg	D 1238	8 g/10min.	8 g/10min
Density	D792 Method A	1.28	1.28

(Typical values, not to be construed as specifications)

Cereplast, Inc.
Tel. 310.615.1900 Fax 310.615.9800
300 North Continental Boulevard, Suite 100 El Segundo, CA 90245
Email: info@cereplast.com

Product Information

Apr 2011

Ecoflex F Blend 1200

BASF The Chemical Company

Product Description

A flexible plastic designed for film extrusion and extrusion coating. Ecoflex® F Blend 1200 comes closer than any other biodegradable plastic to the processing properties of LDPE and LLDPE. Blown film extrusion is a particular area where Ecoflex® F shows well-balanced processing properties, and the resin can also be used in extrusion coating applications. Ecoflex® F requires no predrying prior to extrusion. Antiblock and Slip additives are recommended and are available from BASF.

Applications

Ecoflex® F Blend 1200 can be used for applications such as compost bags, trash bags, carrier bags, bags for fruits and vegetables, general packaging films, agricultural films, and laminating films for trays made from natural materials.

PHYSICAL	Test Method	Property Value
Mass Density	ISO 1183	1.25 to 1.27
Melt Flow Rate (190 °C, 2.16 Kg), g/10min.	ISO 1133	2.7 to 4.9
Melt Volume Rate (190 °C, 2.16 Kg), ml/10min.	ISO 1133	2.5 to 4.5
MECHANICAL	**Test Method**	**Property Value**
ISO Hardness, Shore D	ISO 868	32
THERMAL	**Test Method**	**Property Value**
Melting Point, °C(°F)	DSC	110 to 120
Vicat (A/50), °C	ISO 306	80
PROPERTIES FOR BLOWN FILM, 50 m	**Test Method**	**Property Value**
Light Transmittance, %	D-1003	82
Tensile Strength, N/mm²	ISO 527	34
Ultimate Strength, N/mm²	ISO 527	34
Failure Energy (Dyna-Test), J/mm	DIN 53373	24
Ultimate Elongation (MD), %	ISO 527	560
Ultimate Elongation (TD), %	ISO 527	700
Oxygen Permeation Rate, cc/(m2d*bar)	DIN 53380	1,600
Water Permeation Rate, g/(m2*d)	DIN 53122	140

Note

BASF Corporation
Biodegradable Plastics
1609 Biddle Ave.
Wyandotte, MI 48192

General Information: InfoPoint: 1-800-238-4075
eMail: basf_infopoint@basf.com
Web address: http://www.plasticsportal.com/usa

BASF
The Chemical Company

Product Information

Version 2.1

Ecovio® L BX 8145 – Biodegradable polyester for compostable film containing 45 % of renewable resources

05.06.2009
G-KTS/BD – E 100
Gabriel Skupin
T:+49-621-60-41912

Product description

Ecovio® L BX 8145 is our new biodegradable film product containing renewable resources. It is basically a compound of our biodegradable copolyester Ecoflex® F BX 7011 and polylactic acid (PLA, NatureWorks®). Because of the PLA content Ecovio® L BX 8145 consists of 45% of renewable resources. Ecoflex® F BX 7011 is the coherent phase in the structure of Ecovio® L BX 8145 transferring the beneficial film properties of Ecoflex® F BX 7011 into the new film product:

Our new Ecovio® L BX 8145 exhibits the following properties compared to PE-LD:

- Translucent, semi-crystalline structure with DSC melting points in two ranges: 140-155 ℃ (PLA) and 110-120 ℃ (Ecoflex ® F BX 7011)
- High strength, stiffness and failure energy (dart drop)
- High, but controllable water vapour transmission rate (WVTR)
- High melt strength: MVR (190 ℃, 2.16 kg): < 2.5 ml/10 min.
  MVR (190 ℃, 5 kg): < 6.5 ml/10 min.
- Good thermostability up to 230 ℃
- Good processability on conventional blown film lines, e.g. for PE-LD, PE-MD
- Down gaging to 10 µm possible, typical thicknesses: 20 – 120 µm
- Weldable and printable in 8 colors by flexo printing

Ecovio® L BX 8145 exhibits an excellent compatibility to other biodegradable polymers e.g. in dry blends with Ecoflex® F BX 7011, PLA or aliphatic biodegradable polyesters (e.g. Poly-caprolactone PCL, Polybutylenesuccinate PBS or Polyhydroxyalkanoates PHA), if their MVR is close to the MVR of Ecovio® L BX 8145. Because of the moisture sensitivity of PLA at melt temperatures in the order of 170 – 180 ℃ we have to assure a maximum moisture content of below 1000 ppm prior to film blowing.

The processing of Ecovio® L BX 8145 on extrusion lines depends on the formulation, the extrusion technology and processing conditions. Trials are always recommended to assess the quality of the final product. Ecoflex® masterbatches have to be used as required to tailor the slip and antibloc properties of the final product as well as the barrier to water vapour. Detailed information concerning our Ecoflex® masterbatches will be sent upon request.

Ecovio® L BX 8145 fulfils the requirements of the European standard DIN EN 13432 for compostable and biodegradable polymers, because it can be degraded by micro-organisms.

The biodegradation process in soil depends on the specific environment (climate, soil quality, population of micro-organisms).

Ecoflex® L BX 8145 is one of the few biodegradable plastics, which complies in its composition with the European food stuff legislation for food contact (EU: Directive 2002/72/EC). Specific limitations and more details are given on request. The converter or packer has to check the suitability of the article for the application.

Form supplied and storage

Ecovio® L BX 8145 is supplied as pearl- or cylinder-shaped pellets in 1 t big bags. Temperatures during transportation and storage may not exceed 70 °C at any time. Storage time in an unopened bag may not surpass 12 month at room temperature (23 °C).

Quality Control

Ecovio® L BX 8145 is produced as a standard material in a continuous production process according to DIN EN ISO 9001: 2000. The melt volume rate, MVR, at 190 °C, 5 kg, according to ISO 1133 has been defined as specified parameter for quality control. A certificate of the MVR value can be provided with each lot number (5 t) upon request. Other data given in our literature are typical values, which are not part of our product specification for Ecovio® L BX 8145.

Applications

Ecovio® L BX 8145 has been developed for the conversion to flexible films using a blown film process. Typical applications are packaging films, hygienic films, carrier bags and compost bags. In view of numerous factors influencing functionality and shelf life of Ecovio® films and finished articles made thereof the production parameters have to be tested by the converters before utilisation. Additionally sufficient field tests are required to ensure the right functionality of the articles made from Ecovio® L BX 8145.

We supply technical service information concerning the blown film process with Ecovio® L BX 8145 on demand.

Intellectual Property

It is the responsibility of those to whom we supply our products to ensure that any proprietary rights and existing laws and legislation are observed. Some uses of Ecovio® and product obtained by use of Ecovio® are subject of intellectual property rights. Purchase of Ecovio® does not entitle the buyer or any third to produce, offer or use any blends of Ecovio® protected under property rights and all their equivalents as listed here:

EP-B 937120
EP-B 947559
EP-B 950689
EP-B 965615

Typical basic material properties of Ecovio® L BX 8145

Property	Unit	Test Method	*Ecovio® L BX 8145*	Lupolen 2420 F
Mass density	g/cm³ g/10	ISO 1183	***1.24 – 1.26***	0.922 – 0.925
Melt flow rate MFR 190 °C, 2.16 kg	min. ml/10	ISO 1133	***< 2.5***	0.6 – 0.9
Melt volume rate MVR 190 °C, 5 kg	min.	ISO 1133	***3.0 – 6.5***	-
Melting points	°C °C	DSC DSC	***110 – 120*** ***140 – 155***	111
Shore D hardness	-	ISO 868	***59***	48
Vicat VST A/50	°C	ISO 306	***68***	96

Typical properties of Ecovio® L BX 8145 blown film, 50 µm

Property	Unit	Test Method	*Ecovio® L BX 8145*	Lupolen 2420 F
Haze	%	ASTM D 1003	***85***	8
Tensile modulus	MPa	ISO 527	***750/520***	260/-
Tensile strength	MPa	ISO 527	***35/27***	26/20
Ultimate strength	MPa	ISO 527	***35/27***	-
Ultimate Elongation	%	ISO 527	***320/250***	300/600
Failure Energy (Dyna Test)	J/mm	DIN 53373	***38***	5.5
Permeation rates:				
Oxygen (23°C, dry) Water vapour (23°C, 85% r.h.)	cm³/(m² d*bar) g/(m²*d)	ASTM D 3985 ASTM F-1249	***860*** ***98***	2900 1.7

TRANSMARE® BIO 35LA-0.001

TRANSMARE® BIO 35LA-0.001 is a PLA **INGEO™** based biopolymer with good flow.

Specific properties	Testmethod	Units SI	Typical Value
Density:	*ISO 1183*	*kg/m³*	***1250***
Melt Flow Index:	*ISO 1133*		
at 190℃ and 2,16 kg		*g/10 min*	***35***
at 210℃ and 2.16 kg		*g/10 min*	***81***

Mechanical properties *1)*		Testmethod	Units SI	Typical Value
Charpy impact strength:				
unnotched, at +23 ℃		*ISO 179/1U*	*kJ/m²*	***17.6***
unnotched, at -40 ℃		*ISO 179/1U*	*kJ/m²*	***25.1***
notched, at +23 ℃		*ISO 179/1A*	*kJ/m²*	***1.5***
notched, at 0 ℃		*ISO 179/1A*	*kJ/m²*	***1.6***
notched, at -20 ℃		*ISO 179/1A*	*kJ/m²*	***-***
notched, at -40 ℃		*ISO 179/1A*	*kJ/m²*	***1.6***
Izod impact strength:				
unnotched, at +23 ℃		*ISO 180/1U*	*kJ/m²*	***16.3***
unnotched, at -40 ℃		*ISO 180/1U*	*kJ/m²*	***-***
notched, at +23 ℃		*ISO 180/1A*	*kJ/m²*	***2.7***
notched, at 0 ℃		*ISO 180/1A*	*kJ/m²*	***-***
notched, at -20 ℃		*ISO 180/1A*	*kJ/m²*	***-***
notched, at -40 ℃		*ISO 180/1A*	*kJ/m²*	***-***
Tensile test:		*ISO 527-2*		
tensile modulus	*2)*		*MPa*	***3415***
tensile stress at yield	*3)*		*MPa*	***72***
tensile stress at break	*3)*		*MPa*	***70***
elongation at yield	*3)*		*%*	***2.8***
elongation at break	*3)*		*%*	***3***
Flexural test:	*4)*	*ISO 178*		
flexural modulus			*MPa*	***3460***
maximum flexural stress			*MPa*	***100***
Hardness:		*ISO 868*		
Shore D			-	***82***

Thermal properties	Testmethod	Units SI	Typical Value
Heat deflection temperature:			
at 1.80 MPa (HDT/A)	*ISO 75/A*	*ºC*	***48***
at 0.45 MPa (HDT/B)	*ISO 75/B*	*ºC*	***51***
Vicat softening point:	*ISO 306*		
at 10 N (VST/A)		*ºC*	***62.5***

1) Determined at injection molded test specimen
2) Test speed 1 mm/min, test specimen 4 mm thick
3) Test speed 50 mm/min, test specimen 4 mm thick
4) Three point bending; test speed 2mm/min

Version date: August 17, 2009

TRANSMARE® BIO 35LA-0.001

TRANSMARE® BIO 35LA-0.001 is a PLA **INGEO™** based biopolymer with good flow.

PROCESSING GUIDELINES

Pre-drying
In specific cases pre-drying of this material might be required.

Injection moulding parameters
The following injection moulding parameters should be used as a guideline:

Temperature profile:	165 - 185 - 195 - 205ºC
Mould temperature:	25 ºC
Injection speed:	Medium

STORAGE AND HANDLING

This material should be stored in a dry place and should be protected from moisture and direct UV light.
Do not stack pallets.

Improper storage can cause degradation of the material, which results in colour changes and odour generation. It can have negative effects on the physical properties of the material.

SAFETY

This material is not classified as a dangerous preparation.
Visit our website **(www.compounding.nl)** for the latest version of this materials Safety Data Sheet (MSDS/SDS), or contact your representative at Transmare Compounding BV.

RECYCLING

Recyclable:	Yes
Remark:	-