TAMPERE UNIVERSITY
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BIODEGRADABLE PACKAGING MATERIALS

Case: PLA

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ABSTRACT

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Biodegradable Packaging Materials
Case: PLA

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The main aim of this bachelor thesis was to investigate the possibility of biodegradable packaging materials. Plastics and other non-degradable packaging materials have been used for many years and they have a negative impact on the environment since they do not degrade. Different research methods are used to get authentic results, which simplifies using biodegradable packaging materials.

There were two biodegradability testing methods, which has been applied to this task:-, testing biodegradability in TAMK laboratory and Paroprint and Loomans Group research for biodegradable materials that are used for the production of food packaging.

Nowadays a large amount of the packaging waste is recycled within the industry, especially of in the United kingdom due to the United Kingdom Packaging Waste Regulations. Some industries in the UK had a packaging recycling level of 42 % and the lowest target is 15% set within the set of laws was exceeded for all materials.

Biodegradable packaging materials are green living and it is environmentally friendly to change traditional materials. This is increasing nowadays with high negative environmental impacts. Packaging materials touch every part of our daily life from food packaging to medicine and its consumption is increasing. Non biodegradable packaging materials ends up in the landfills, because they cannot be reused and recycled and they will never decompose.

Keywords: biodegradable, biopolymer, composting, packaging, environment, compostability, biodegradable film, biodegradation

CONTENTS

GLOSSARY

APME	Association of Plastics Manufacturers in Europe
ASTM	American Society for Testing and Materials
CEN	European Standardization Committee
DIN	German Institute for Standardization
LCA	Life Cycle Assessment
ISO	International Standards Organization
PAS	Publicity Available Specification
PBAT	Polybutylene Adipateco-terephthalate
PBSA	Polybutylene Succinate Adipate
PCL	Polycaprolactones
PEA	Polyesteramide
PE	Polyethylene
PET	Polyethylene Terepthalate
PGA	Polyglycolic Acid
PLA	Polylactic Acid
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl Chloride

1 INTRODUCTION

There are many different materials, which are used for packaging like metals, glass, wood, paper pulp, plastic and the additions of more than one substance. At the end of their service life, these items go to the municipal waste streams. More than 67 millions of packaging waste are generated yearly in the EU, and it contains one third of total MSW. Due to strict food packaging regulations and also the drive to promote the appearance and increase product sales, food packaging are a major component of packaging waste. (Song et al., 2009)

Food packaging materials become one of the major sources of household, which should be put in landfills. In the European Union there are directives on packaging and packaging waste and they are adopted in the United Kingdom and other EU countries to decrease the formation of packaging waste and enhance reuse recycle of packaging materials. These directives of waste (94/62/EEC) and its amendments in 2004 and 2005 was commonly implemented appropriately and recycling goals are achieved. (Petelj et al., 2010)

According to the ISO/DIS 17088 definition degradable plastic material is a plastic designed to undergo a significant change in its chemical structure under particular environmental conditions resulting loss of some properties that may vary as measured by standard test methods. Japanese Plastic Society states biodegradable plastic as a plastic which could be used as conventional plastic and they decompose to water and carbon dioxide by the action of microorganisms, which is generally obtainable in the natural environment. Definition of biodegradation is based on many things such as the action of microorganism on the material and its conversion into carbon dioxide or methane and water. (Rudnik, 2008, 12-13)

Humans have been using polymers for thousand of years. In the ancient years natural plant gum was used to fix pieces of wood for accomodation building. Natural gum was also applied as a waterproof coating to boats at the beginning of ocean explorations. At that time people didn’t know the amount of polymers, which could be used and there were no modification to improve them. Leo Hendrik Baekeland invented the first synthetic polymer in 1907. (Sin et al., 2012)

Polymers are molecules made up of a combination of small materials called monomers.Polymerizations is the process of connecting these monomers to make large macromolecules. These monomer colonies are similar as a large building, which contains same type of concrete blocks.

Polylactic Acid or PLA is a semi-crystalline polymer, which has basic raw materials such as starch, cellulose, soya or sugar. It is thermoplastic with linear or branched polymer chains, which allows the plastic to melt and re-design. Naturally PLA breaks down into water, carbon dioxide and humus and this shows it is bioplastic. There are several advantages of PLA materials, including that it is eco-friendly produced from agricultural sources and has high tensile strength. (Juuri, 2016)

PLA was discovered by Carothers in 1932. Initially he was going to produce a low molecular weight PLA by heating it under vacuum and also removing the condensed water. Comparing to other bio-polymers, PLA production has numerous advantages, including: production of the lactide monomers from lactic acid and it is taken from the fermentation of renewable agricultural source corn; major energy saving and recycling ability of lactic acid. (Mehta et al., 2015)

Several different types of plastic materials are used for food and other packaging industry in the world. They have been developed from past to current time and these materials are applied into certain standards.Below is shown some of the most known used materials for food packaging.

Polyethylene (PE): is the most popular plastic in the world. It is a polymer made grocery bags, detergent bottles, toys, and etc. They are divided into high density polyethylene (HDPE) and low density polyethylene (LDPE) and used as in the food and other packaging materials. High density polyethylenes are used for hard and inflexible materials such as ice cream boxes. Low density polyethylenes are used for soft materials like meat wrapping films.

Polypropylene (PP): is a type of thermoplastic polymer and its used in numerous things, including as structural and fiber-type plastic. It is also used in rigid form and flexible packages. It is also possible to use PE in the microwaves.

Polystyrene (PS): is a hard cheap plastic, which is commonly used in everyday. There are different kind of polystyrene materials, which has different properties and they are clear and brittle polystyrene. They are used to make both hard and soft drinking cups, trays and etc.

Polyvinyl chloride (PVC): is a hard packaging material, used for food oils and it has a low oxygen permeability. They are classified into two parties, which are thermosetting and thermoplastic resins.

Polyethylene terepthalate (PET): is a plastic, which is commonly used many beverages for food items and other products. It is also used normal food trays. Crystalline polyester could be used in a conventional oven to heat up the food.

Packaging is the knowledge of encircling or protecting products, while they are delivered, stored or used. There are several different forms of packaging such as film packaging, plastic boxes, food, textile and etc. Mostly the products that are being used in our everyday life activity involve packaging. Inappropriate packaging and faulty material mishandling are the main reasons, which causes damage of goods. The quality of a packaging material improves the safety of distributing, delivering and transporting of products. (Soundararajan et al., 2013)

A year after a year, packaging transforms and manufactures come up new designing systems to solve its demand in a modern society. Producers and other industrialized markets are dealing with the growing need for innovation. The developing world is facing serious challenges concerning on packaging to keep food and medication and to avoid contamination and waste. Plastics and their miscellaneous properties are the basic materials, which these growing demands of innovation and performance in a prolonged approach. (APME, 2015)

In the plastic industry, diversity and their natural properties make them invaluable packaging materials for all kinds of commercial users around the world. Usually they are designed and engineered for a specific need by utilizing their adaptability. Plastic packaging is essential to processing, storing, transporting, preserving and protecting products. (APME, 2015)

In Europe, packing operations are the largest operational sector for the plastic industry and it is 40 % of the total plastic demand. Building and construction are the second largest operation sector and it is 20% of the total European demand. Mobile is the third largest sector, 8% and the electronic and agricultural sectors are 6% and 4% respectively. Other operations such as household, pharmaceutical products, and furniture are in total 22%. Figure 1 below shows the European plastic demand by segment in 2013 and the total plastic production was 46.4 Mtone. (APME, 2015)

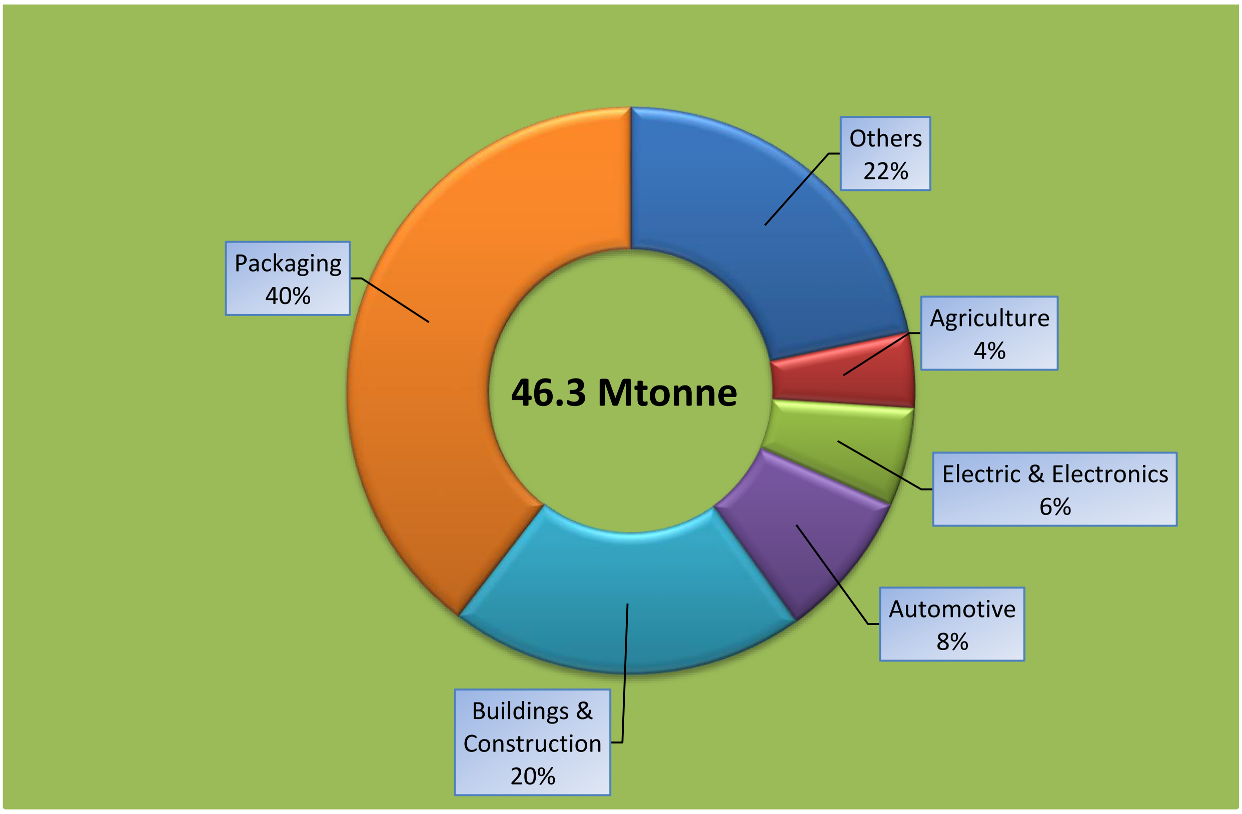

Figure 1: European Plastic demand by segment 2013: (Jama, 2017)

2 LITERATURE REVIEW

2.1 Biodegradation

Biodegradation is the breakdown or mineralization of organic material for the sake of microbial activity. The accessibility of oxygen decides to which molecule the organic carbon is transformed. Under aerobic conditions the material biodegrades completely and it is converted to carbon dioxide and water (1). In the anaerobic conditions biogas, which combines a mixture of carbon dioxide and methane will be made (2). In both cases the organic carbon, is partially converted to biomass and other parts stay as a form of metabolites. (De Wilde, 2013)

$$C_{sample} + O_2 \rightarrow CO_2 + H_2O + C_{biomass} + C_{residual} \quad (1)$$

$$C_{sample} \rightarrow CO_2 + CH_4 + C_{biomass} + C_{residual} \quad (2)$$

The rate of biodegradation is affected by the surrounding environment in which the biodegradation take place. An environment is decided by moisture content, the temperature, the form of micro-organisms, the inorganic nutrient accessibility and etc. The test methods, which decided the biodegradability of a material refers to a particular environment. (De Wilde, 2013)

Biodegradability of a polymer is affected by the general structure of the polymer and main environmental conditions. There are environmental situations affecting degradation like temperature, moisture, total oxygen consumption, acidity and the number of microbes. Microorganisms, which degrade biodegradable polymers are bacteria, fungi and algae. Environmental polymer degradation is the combination of chemical and biological hydrolysis. The final products of biodegradable plastic degradation are water, CO_2, CH_4, humic materials, biomass and other natural materials. (Kapanen, 2012)

2.2 Biodegradability and compostability

Biodegradability is the ability of a material and organic substance to be degraded into simpler units for the sake of enzyme activity and microorganisms. The complete biological process changes the organic substance into tiny inorganic molecules, carbon dioxide, methane and water. The rate of degradation is affected by the chemical nature of the substance and the surrounding environment. Compostability is the ability, which an organic material changes into compost through the composting process.

Composting is a method controlled by a biological decomposition of organic material in the presence of air, which forms humus. There are some techniques of composting such as mechanical mixing and aerating, placing the aerated chambers in a vertical series or putting open place, mixing and rotating it periodically.

Composting needs four important elements. Mixing these things will make the composting organisms such as microbes and insects with nitrogen, carbon, moisture and oxygen to break down the building blocks of the material in a proper way. The table 1 below shows these elements and their contents and functions.

Table1: Compost ingredient (Jama, 2017)

Ingredients	Contents	Function
Greens	Grass, green leaves, fruits, vegetable	
Browns	Woody materials, sawdust, paper	
Water		Keeping moist as a squeezed sponge
Air		Turning compost pile weekly to faster composting

2.2.1 Carbon to nitrogen ratio

Carbon to nitrogen ratio of a material is an important factor in composting. Composting happens successfully when the carbon to nitrogen of all materials in the pile is around 30:1. Some materials have low C: N ratio such as grass and they need to mix with other metals, which has high carbon to nitrogen ratio for good composting. Table 2 shows a list of common carbon, nitrogen ratios of several composting ingredients. (Composting procedure, 2012)

Other important composting factors are also sufficient aeration and pile structure. Bulking agents are materials, which are added to the pile to give structural support and keep air spaces. Wood chips are well known used bulking agents. Aeration could be increased by adding fine sawdust and chopped papers to absorb excess water. (Composting procedure, 2012)

Table 2: List of composting carbon, nitrogen ratios (Jama, 2017)

Ingredient	**C: N Ratio**
Poultry mature (no litter)	10:1
Cattle Manure	20:1
Horse Manure	25:1
Pig Manure	6:1
Paper Sludge	105:1
Peat	70:1
Mushroom Compost	40:1
Garden Waste	40:1

2.2.2 PLA production

A single monomer of PLA is produced through fermentation or a chemical synthesis. The industrial lactic acid production uses the lactic fermentation process instead of synthesis because synthesis routes have many major limitations, including limited capacity due to dependency on a byproduct of another process. There are two active configurations, the L (+) and D (−) stereoisomers are produced by bacteria. (Datta& Henry 2006)

One of the most important positive sides of PLA production in comparison of other hydrocarbon base polymers is the reduction of CO_2 emissions. Carbon dioxide is the most common factor of global warming and climate change. It is absorbed from the air when corn is grown. Consumption of PLA has a potential to emit fewer greenhouse gases compared to competitive hydrocarbon based polymers. (Bogaert & Coszach 2000)

2.3 Different bioplastics

Currently, there are a number of different compostable plastics found in the market and the most generally used raw material for making these plastics is corn starch, which is converted into a polymer and they have the same properties with similar characteristics like customary Polyethylene plastic products. There are also other materials, which can be made from compostable plastics such as potato starch, soya bean protein and petroleum by-products. Compostable plastics could be derived from both plant based and petroleum, polymers. (Gilbert et al., 2015)

2.4 Biodegradable materials

There are three main categories of biodegradable materials such as agricultural polymer, microbial polymer and oligomers. Polymerized oligomers, which is conventional is a chemical process and acquires from the fermentation of raw materials like PLA. Figure 2 gives the classification of these polymers.

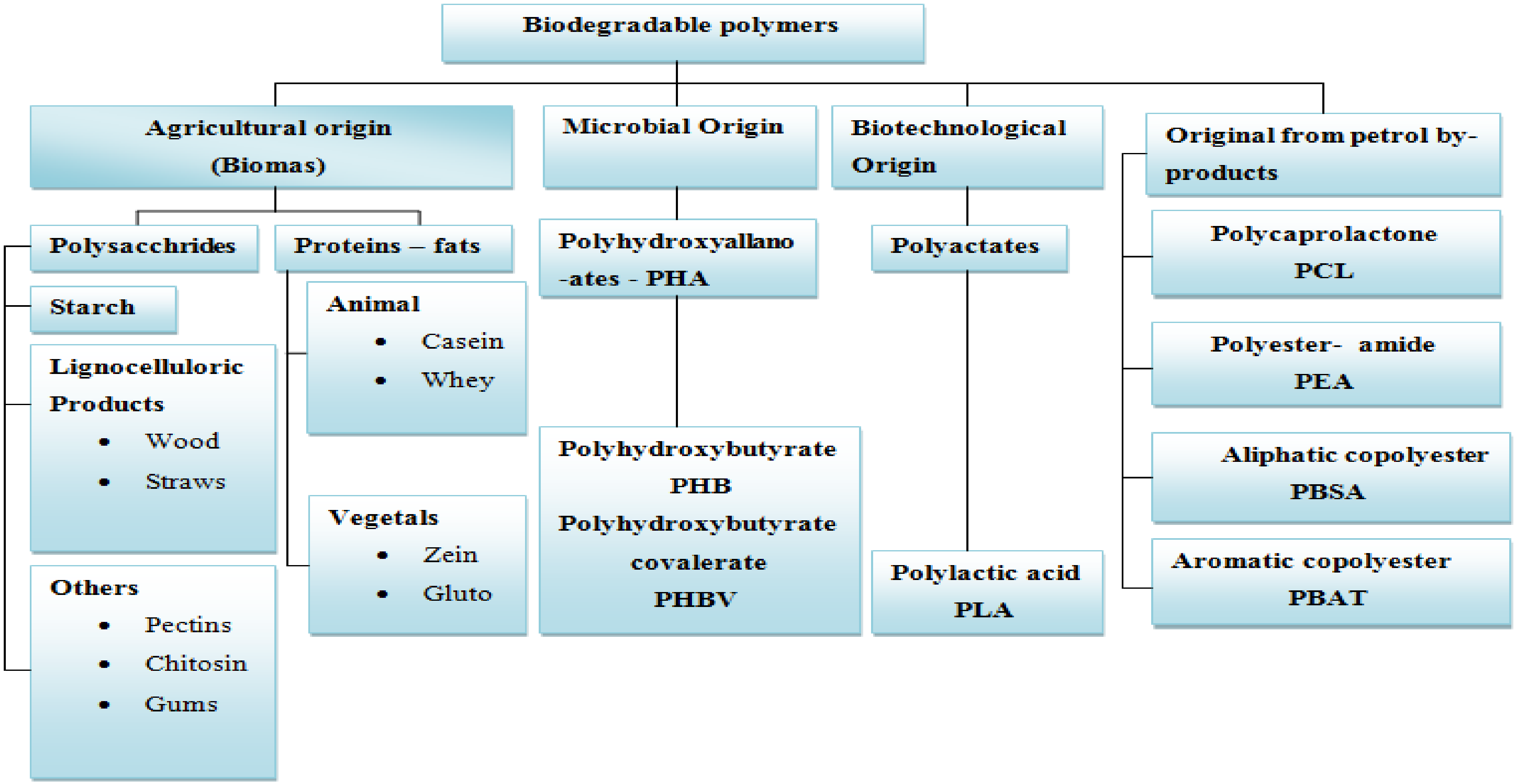

Figure 2: Different biodegradable materials (Kapanen, modified).

2.5 Different standards

ASTM standards describe composting as a managed process, which controls the biological decomposition and conversion of biodegradable materials into humus material known as compost. Aerobic mesophilic and thermophilic degradation of organic matter make compost in bio-oxidated controlled procedure. British standard (PAS 100) describes composting as a process of controlled biological decomposition of biological materials under managed situations, which mainly aerobic and allows the growth of thermophilic temperatures for the sake of biologically produces heat to gain compost in a stable way. (Rudnik, 2008)

In Germany, the German Deutches Institute für Normung (DIN) and Japan's Biodegradable Plastic Society (BPS) gives to the development and concerning of standards on compostable polymers. The main goal of them is to provide producer and consumers, as also the authorities with test systems and quality levels for biodegradable materials. (Bastioli, 2000)

European Committee for Standardization (CEN) EN13432: is a European standard used to develop and ensure the conditions on biodegradability set by the European Package Directives known as EN 13432. The table 2 below shows the requirements needed to obey biodegradable packaging in this standard.

The definition and composting and biodegradation and organic recycling of EN 13432 standard is identical when applied to packaging. It does not allow for a clear difference between biodegradability and compostability.

European standard (SFS EN 14045): provides a method for assessing disintegration of packaging materials using a composting aerobic method. The scope of the standard states that other standards should be used to determine the biodegradability of packaging materials.

SFS EN 14046 is also another European standard, which offers a method of evaluating an aerobic biodegradability of packaging materials under controlled composting conditions and it is based on the amount of carbon dioxide produced (SFS, EN 14045:2003). The main objective used this standard is to ensure if biodegradation takes place on not by monitoring microorganism activity in the compost.

Materials can be identified as biodegradable if they fulfil the principles of biodegradability set in standardization organizations such as ISO, ASTM, DIN. Summary of standard tests for biodegradable assessment of biodegradable plastics in aquatic, soil and compost are shown in table 3 and 4. Biodegradability principles require that the organic carbon material, should decay to nontoxic end product during a particular time. (Itävaara & Vikman 1996)

Table 3: List of important standards used by various organizations for biodegradable food packaging (Chiellini, 2008).

Standards		Environment
ASTM D6400		Standard specification for compostable plastics
ASTM D338-98 (2003	ISO 14852	Controlled composts
ASTM D5988	ISO 17556:2003	Aerobic biodegradation in soil compost
ASTN D5209-91		Aerobic, sewer sludge
ASTN D5210-92		Anaerobic, sewer sludge
ISO 14852		Aerobic biodegradation in aqueous enviroments
ISO 145985		Aerobic biodegradation in high-solid sewerage environment
CEN 13432		European standard for biodegradability

Table 4: Standards related to composting of biodegradable plastics (Kapanen, 2012).

Standard	Biodegradation	Disintegration	Safety
EN 13432:2000 Packaging requirements for packaging recoverable through composting and biodegradation. The test method is the evaluation criteria for the final acceptance of packaging.	Biodegradation could be 90% of the degradation of positive control in six months.	10% residues larger that 2 mm allowed.	Limits for heavy metals. Physical/Chemical analysis. Ecotoxicity assessment includes plant growth.
EN 14995:2006 Plastics. Evaluation of compostability. Tes scheme and cosmpostability.	Biodegradation could be 90% of the degradation of positive control in six months.	10% residues larger that 2 mm allowed.	Limits for heavy metals. Physical/Chemical analysis. Ecotoxicity assessment includes plant growth.
ISO 17088:2008 Specifications for compostable plastics	Homopolymer's mineralization 60% in 180 days. Other polymers minerals 90% during 180 days.	10% of the original dry mass allowed in a size larger than 2 mm after 84 days in a controlled composting.	Heavy metals volatile solid ecotoxity assessment includes growth.
ASTM 6400-04 Standard specification for compostable plastics	Homopolymer's mineralization 60% in 180 days. Other polymers mineralize 90% during 180 days.	10% of the original dry mass allowed in a size larger than 2 mm after 84 days in a controlled composting.	No adverse effect on compost as a growth medium.

2.6 Environmental fate of biodegradable materials

The environmental fate of the polymer and the materials released during the life cycle, such as the degradation products and the bioaccumulatoin potential will affect humans and their surrounding environment. There are physical and chemical properties caused by these substances for example, boiling point, vapor pressure, water solubility and actonal-water partition coefficient, which could be used to forecast the environmental fate and bioaccumulation potential of these substances. Plastic materials contain many different chemicals and their main parts broken down in the environment.

The life cycle assessment (LCA) of the environmental impacts of biodegradable materials should focus on an end-life assessment. The greenhouse gas emissions during the degradation process of biodegradable plastics harms the environment and increases air pollution and the CO_2 emission at the end of life biodegradable materials is balanced. Figure 3 below shows the ideal closed life cycle of biodegradable plastics. (Kapanen, 2012)

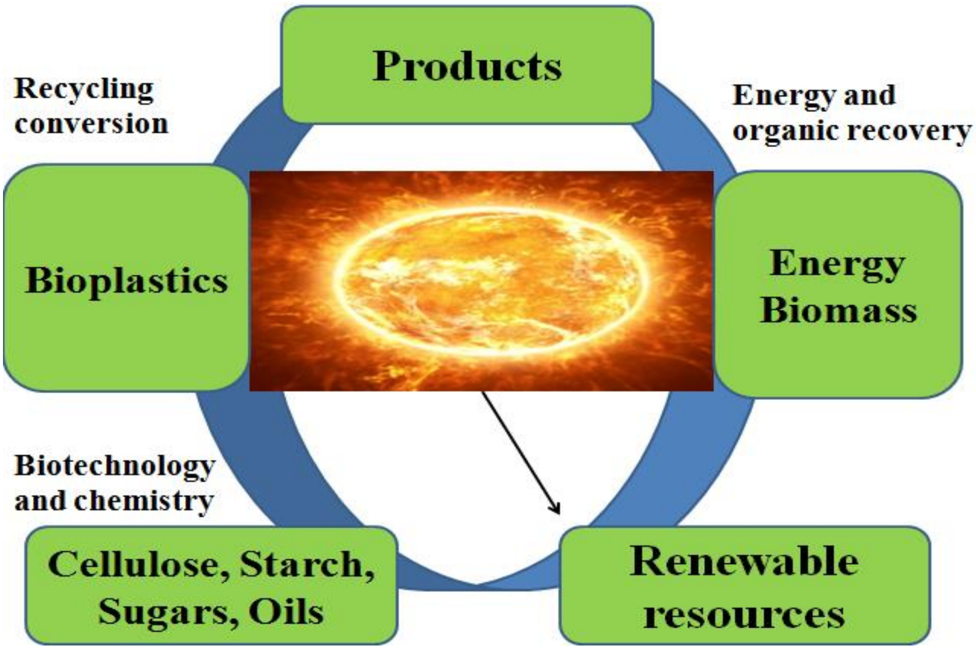

Figure 3: Closed life cycle of biodegradable plastics (Kapanen, modified).

The increasing number of biodegradable polymer production makes pressure for the acquiring knowledge on proper waste disposal methods. European landfill directives such as (1999/31/EC) includes targets concerns for reduction of the amount of biodegradable waste in landfills and encouraging recycling and composting. Thematic Strategy of decreasing and recycling of waste polymers focuses on reducing the environmental impacts. Biodegradable materials should be used instead of conventional plastics to reduce the cost and risk of plastic materials in the environment. (Kapanen, 2012)

2.6.1 Biodegradation in soil

Using compost as a soil improver causes that biodegradable plastics can enter into the soil either deliberately or accidentally. The main influences of biodegradation rate polymers in the soil are soil type, pH, organic matter, etc.Factors affecting biodegradation in soil are irradiation, heat, rainfall, irrigation, microorganisms and activity of microorganisms. Sunlight heats increase temperature and this direct proportionally increase microbial activity or melting the polymer. Water increases hydrolysis and leaching of plasticizers that allows active biodegradability. (Degli-Innocenti, 2005)

3 BIODEGRADABILITY AND COMPOSTABILITY CASE STUDIES

3.1 Materials Technical Datasheets

Before testing the material in practice, it is important to know their properties and process ability. These are found from the materials Technical Datasheets and the producer's description of the material. Several data sheets have been selected and best ones has been taken. Table 5 shows biodegradable plastic materials taken from various manufacturers.

Table 5: List of biodegradable plastic materials gathered from different manufacturers.

Manufacturer	**Material**	**Product name**	**FDA**
Futuramat	Biodegradable polymers (Wheat flour-bases material)	BioCeres	
Biomer	Biodegradable plastic PHB	Biomer	X
Heritage plastics	A mineral containing compound based on a blend of biodegradable resins. (Non Specific Food Applications)	Biotuf	X
Cereplast	Biodegradable materials (Derived form starch (PLA) and other renewable materials)	Cereplast (Compostable)	X
Perstorp	PLA + Calcium Carbonate filler 40%	CAPA	
Cardia Bioplastics	TPS + Copolyester Based on corn starch	Cardia Compostable	X
Eco-Tech Environment	Biodegradable material	Ecopure	X
Natureworks	Biodegradable materials derived from starch	Ingo	X
Novamont	Biodegradable materials	Mater-Bi	X
NaturePLAST	Biodegradable material PBS (succinic acid and butanediol) Blend able to other bioplastics	NaturePLAST	X
Plantic technology	Biodegradable material derived from corn starch	Plantic	X
Transmare	Biodegradable materials PLA	Transmare	X

3.1.1 Selected biodegradable materials

In the Table 6 below shows that three biodegradable materials, which are chosen from the data set because of their best properties and ease to use.These chosen materials are derived from wheat, corn, potato and Starch and they have different properties for the sake of their manufacturing processes.

Table 6: Selected biodegradable materials

Manufacturer	Material	Product name	FDA
Cereplast	PLA (starch-based resins)	Cereplast Compostable	X
Natureworks	PLA (starch based resins)	Ingeo	X
Transmare Compounding	PLA (starch based resins)	Transmare	X

3.2 Biodegradablilty testing

This section unpublished report done by TAMK group of students about testing biodegradability has been used. The temperature monitoring was made to observe the temperature of the compost and the air in the cupboard.

Testing of the material the group used three different substances. The samples were measured in the first phase and the last phase of the testing to check the decrease in weight. These samples were also visually observed each week and their surface activity was checked by using a microscope.

The OxiTop device is used to measure the pressure change in the OxiTop-vessel during the respiration process. Microorganisms consume oxygen and make carbon dioxide CO_2 and the reagent solution sodium hydroxide (NaOH) absorbs. The soil respiration has been determined by calculating the oxygen consumption. (Hartikainen, 2015)

3.3 Material results

In Paroprint the tests the results had no big problems with the machines or the materials. Paroprint thought that the results would be easy due to oil based plastics, but they were not good, because there was a lack of experience to produce them. These results had both negative and positive things, which came up with the processes and materials. The prices were more expensive than PE, and they recommend to do more tests to gain their target. (Ketonen, 2011)

Three different kinds of PLA materials were tested to make biodegradable packing materials and Paroprint requirements were that the materials should be good and easy to process and biodegradable. Table 7 below shows details about these three biodegradable materials. These three materials had both advantages and disadvantages, but they can be used as a biodegradable packaging material, because they fulfill all the requirements needed. Even though these materials are hard to process. In the future more tests will give us the best end product.

According to appendix 1 NatureWorks PLA polymer is designed for injection molding application. It is designed for clear applications with heat temperature lower than 55 degrees. The applicationincludes cups, plates, cutlery and saucers. Appendix 2 shows that Careplast is renewable, ecologically alternatives for petroleum-based plastic products, which replaces approximately 100% of petroleum additives used in traditional plastics.

Table 7: Results from the test (Ketonen, 2011).

	Process capability			Advantage	Disadvantage
CEREPLAST	Material processing temperature (Feed zone 160 and nozzle 250 degrees Celsius.	Screw speed 50-100 RMP. The plastic will lose its strength.	Drying time Temperature of is 40-50 degrees per four hours. Without drying the material will become brittle.	Good adhesive to the cardboard and end product looks good.	End product depends on the machine parameter. Wet material leads to brittle end product.
TRANSMARE COMPOUNDING	Material processing temperature (Feed zone 165 and nozzle 250 degrees Celsius.	Screw speed 70-110 RMP. Worked also quite good when lower or higher.	Drying time Temperature: No need for drying, only in specific occations.	Good adhesive to the cardboard and end product looks good. No mold shrinkage, the material was rigid, but slightly elastic.	If used more strength to bend the plastic materials it broke.
NATUREWORKS	Material processing temperature (Feed zone 150 and nozzle 205 degrees Celsius.	Screw speed 100-175 RMP. If it is over plastic had a too high viscosity.	Drying time and temperature is 50 degrees per three hours.	It has no necessarily be dried before use, but is recommended.	Material had a problem of sticking to the cardboard. If it is not dried the material finally break if used more strength to bend.

4 CONCLUSION

Plastic packaging is one of the main causes of municipal waste, and there is no simple solution to get rid them. Plastics are economically cheap, available and easy to process. Actually, it is difficult to get cheap biodegradable material in the following years and more material testing is needed. These alternatives should also contain plant-based materials, because glue is also highly toxic to the environment. Biodegradable packaging materials are a green future to solve these problems.

In the following years, we need more effort to understand the properties of PLA and their additional properties should be learnt. PLA has a similar characteristics to petroleum derived polymer such as PE and PET. The main objective of this thesis was achieved, because using PLA materials as an alternative of plastics is the only option to conserve environment and manage municipal waste.

Global demand for food and energy will affect the development of biobased packaging materials. There is no doubt that using packaging materials derived from genetically modified crops will result shortage of food supply in the developing world. On the other hand agricultural resources as packaging materials may affect the production of bioethanol. The biggest challenge could be how to persuade consumers the benefits of environmentally sustainable food packaging materials, while they can get more cheaper traditional materials.

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APPENDIX

Appendix 1. NatureWorks PLA

NatureWorks® Ingeo™ 3001D Injection Grade PLA

Category : Polymer , Renewable/Recycled Polymer , Thermoplastic , Polylactic Acid (PLA) Biopolymer

Material Notes:

NatureWorks® PLA (polylactide) polymer 3001D is designed for injection molding applications. It is designed for clear applications with heat deflection temperatures lower than 130ºF (55ºC). Applications include cutlery, cups, plates and saucers, and outdoor novelties.

Order this product through the following link:

http://www.lookpolymers.com/polymer_NatureWorks-Ingeo-3001D-Injection-Grade-PLA.php

Contact Songhan Plastic Technology Co.,Ltd.

Website : www.lookpolymers.com
Email : sales@lookpolymers.com
Tel : +86 021-51131842
Mobile : +86 13061808058
Skype : lookpolymers
Address : United North Road 215,Fengxian District, Shanghai City,China

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Appendix 2. Cereplast compostable:

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Cereplast Sustainables

Injection Molding Grade Property Guide

Cereplast Sustainable® resins are renewable, ecologically sound substitutes for petroleum-based plastic product, replacing nearly 100% of the petroleum-based additives used in traditional plastics. Cereplast Sustainable® 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 Sustainable® resins, including Sustainable 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).

Sustainable 1001 has been designed to have an excellent balance of toughness, rigidity and processability. Sustainable 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

Cereplast, Inc.

Tel. 310.615.1900 Fax 310.615.9800

300 North Continental Boulevard, Suite 100 El Segundo, CA 90245 Email: info@cereplast.com

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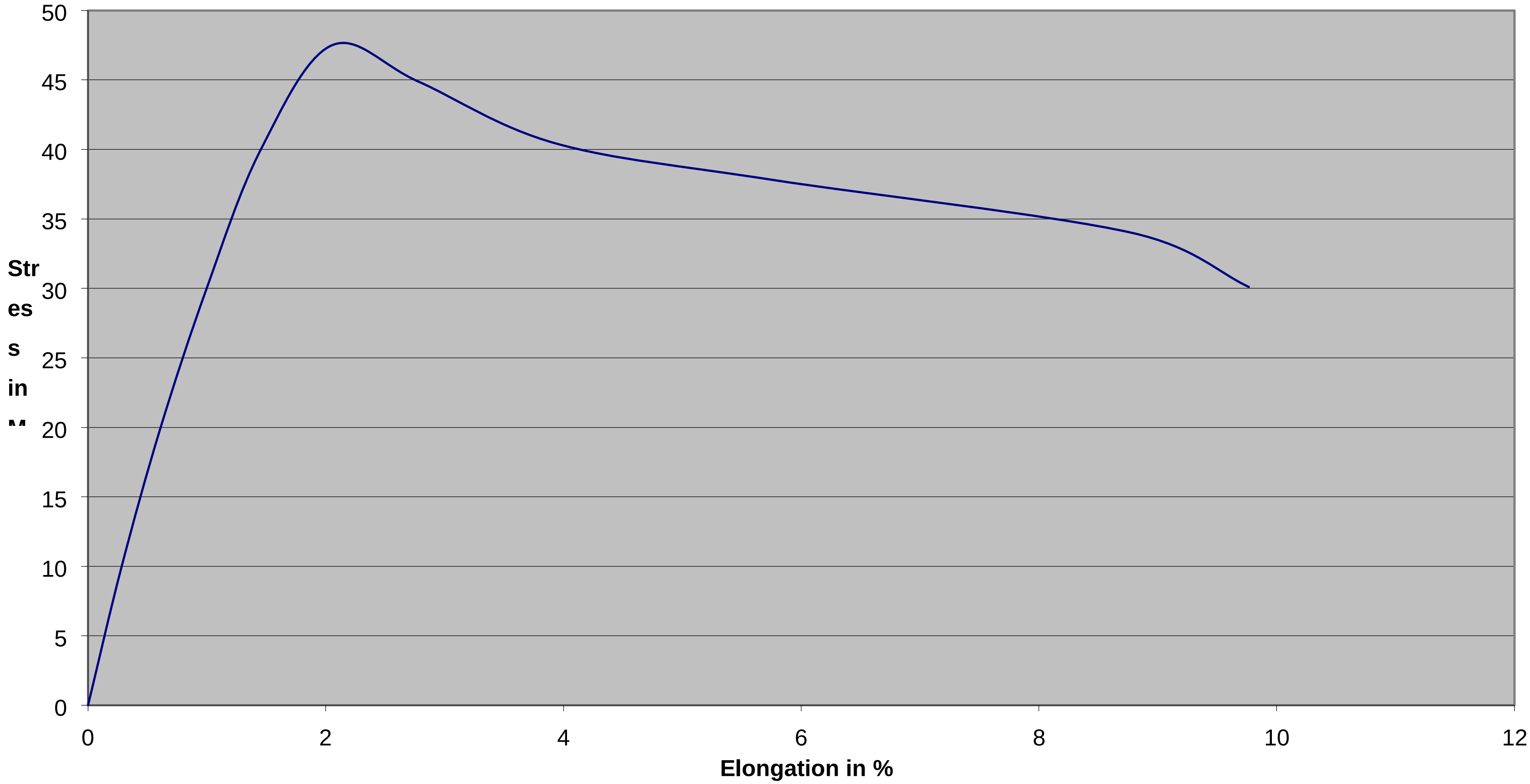
Sustainable 1001



Technical & Safety Data Sheet

Chemical Product Information

Product Name	Sustainable 1001
Common Name	PLA Blend Resin
Manufacturer	Cereplast, Inc. Headquarters 300 North Continental Boulevard, Suite 100 El Segundo, CA 90245 Manufacturing 2213 Killion Avenue Seymour, IN 47274
Emergency Number:	+1.310.615.1900

Composition/Information on Ingredients

Chemical Name	Poly-Lactic-Acid & Biodegradable Polymers
CAS Number: 9051-89-2	Non-Hazardous

Hazard Identification

Eye	Particles may cause mechanical irritation
SkinContact	Low order of toxicity
Inhalation	Low order of toxicity
Ingestion	No hazard in normal industrial use

First-Aid Measures

Eye	Flush eyes with large amounts of water until irritation stops
SkinContact	Wash with soap and water
Inhalation	Remove to fresh air

Ingestion	N/A

Firefighting Measures

Auto ignition	N/A
Flash Point	N/A
Extinguishing Media	Dry chemical; CO_2; Water fog; Foam
SpecialProcedures	None Required
Fire & Explosion Hazards	N/A
Upper Explosion Limit	N/A
Lower Explosion Limit	N/A
NFPA Flammability Hazard Class	0 = Insignificant

Accidental Release Measures

Spill and Leak Procedures	Sweep or scoop up and remove

Handling and Storage

Storage Temperature	Ambient
Handling/Storage	Sweep or vacuum up and place in container for disposal
Ventilation	General

Exposure Controls/ Personal Protection

Ventilation	General
Eye Protection	Safety glasses optional
Gloves	Gloves for hot resin
Clothing	N/A
Wash	Wash with soap and water
Respirator	None

Physical and Chemical Properties

Pure Substance or Mixture	Mixture
Physical Form	Solid

Appearance/Odor	Resin Pellet with cereal odor
OdorThreshold	N/A
Molecular Weight	>10,000
PH as is	N/A
PH in 1% Solution	5.8 +/- 0.6
Boiling Point	N/A
Melting/ Freezing Point	N/A
Solubility in Water	Low
Partition Coefficient	N/A
Specific Gravity	1.18 +/- 0.03 gm/cc
Evaporation Rate	N/A
Vapor Pressure (mm Hg)	N/A
Vapor Density	N/A
Volatiles	None
Volatile Organic Compounds	N/A
Auto ignition	N/A
Flash Point	N/A
Oxidizing Properties	N/A

Stability and Reactivity

Stability	Stable
Materials to Avoid	None
NFPA Reactivity Hazard Class	0 = Insignificant
Hazardous Decomposition Products	This product does not undergo spontaneous decomposition. Typical combustion products are CO, CO_2, C, N, H_20

Toxicological Information

Product Toxicology

Oral Toxicity	Low order of toxicity
Dermal Toxicity	Non-hazardous
Inhalation Toxicity	Non-hazardous
Eye Irritation	Non-hazardous

Chronic (Long-Term) Effects of Exposure

Route of Entry	Eye, skin, inhalation, ingestion
Effects of chronic exposure	None
Target Organs	N/A
Special Health Effects	None known

Ecological Information

Biodegradability	Biodegradable in compost Meet ASTM 6400 -D99
Incineratability	Incineratable
Toxic Volatiles	None present with complete combustion

Disposal Considerations

Waste Disposal Methods: In accordance with existing federal, state, and local environmental regulations

Empty Container Warnings: Empty container may contain product residue; follow MSDS and label warnings even after they have been emptied.

Transportation Information

DOT Information	N/A

Regulatory Information

CAS Registry No.	9051-89-2

U.S. Regulations

SARA 313 title III	Not Listed
TSCA Inventory List	Listed

State Regulations

Proposition 65 listed material	Not Listed

International Inventories

Canada DSL Inventory List	Listed
EU EINECS List	The components of this product listed in Section 3 are listed

China inventory of Existing Chemical Substances list: Listed

Other Information

Temperature: Material will soften above ambient temperatures and melt at temperatures above 160°C.