

Plastic packaging

Introduction

Sterkur is aiming at having no negative impact on the planet from their products and everything related including packaging. Plastic currently is part of packaging for our products. It has good durability and tolerance to environmental factors. Plastic packaging is used to separate the product from other products, protect the product from environmental factors such as oxidation and humidity and, to be honest, also to give customers a feeling of a new product. However, plastic does not correspond with our goals of zero negative impact because it derives from fossil fuel. This report is done to show alternatives for the plastic packaging to realize we can make a better decision, working towards positive impact.

Plastics

Among our 12 products, we use mainly two types of plastic packaging's, one is polyphenylene ether (PPE) and the other is oriented polypropylene (OPP) (Table 1). PPE is only used in packing foam roller. It can shrink so that the foam roller can be protected in a holistic way. OPP is used in Stretch loops and bands as well as Kinesiology tape and compression tape as an individual packaging.

Product		Packaging
Foam roller		PPE / piece
Stretch loops		OPP / piece
Stretch bands		
Kinesiology tape		
Compression tape	Plastic around the roll	unknown
	Plastic bag	OPP / piece

Polyphenylene ether (PPE)

PPE is a thermoplastic, linear, non-crystalline polyether. It is usually blended with polystyrene to improve its toughness and processability. PPE has outstanding electrical properties, unusual resistance to acids and bases, and is processable on conventional extrusion and injection molding equipment.¹ It also has excellent high temperature properties and good oxidation stability.² However, PPE is blended with polystyrene which is generally not biodegradable and not photo-oxidable,³ and

¹ ('Polyphenylene Ether (PPE) Plastic', n.d.)

² (Klamann, Rost, & Killer, 1984)

³ (Bandyopadhyay & Basak, 2007)

therefore, we would like to replace it for a more sustainable material.

Oriented polypropylene (OPP)

OPP is often referred from biaxially OPP (BOPP) because polypropylene film is extruded and stretched in both direction of along the machine and across the machine. OPP is made from polypropylene (PP).⁴ As it is made biaxially, it possesses better qualities in terms of strength, flatness, clarity, and printability.⁵ BOPP is recyclable but undegradable⁶ and therefore, sustainable alternatives are needed.

The alternatives

For Sterkur, alternatives should have similar functions and qualities as PPE and OPP. It should be able to:

- Separate products individually
- Isolate them against environmental factors
- Provide the feeling of new

Within these boundaries, the packaging needs to have as low environmental impact as possible. In this research we will discuss four alternatives.

- Polyolefin
- Poly- β -hydroxybutyric acid (PHB)
- Stone Paper
- Polylactic acid (PLA).
- Individual paper box

These five packaging materials will be discussed on how they are made and the sustainability. We inspected in 7 categories: biodiversity, air quality, climate, land use change, soil quality, water quality, and water use from the model adopted from De Natuurverduubelaars and measure the environmental impacts on the planet.

1. Polyolefin (POF)

What is polyolefin and how it is made?

Polyolefins are the largest thermoplastic group, and often referred to as commodity thermoplastics or POF. They are polymers of simple olefins such as ethylene, propylene, butene, copolymers etc.⁷ These monomers are mostly obtained through the cracking process in petrochemistry.⁸ The polyolefins are mainly produced in two ways, synthesis from monomers obtained from crude oil and recycling from used polyolefins. For synthesis process, crude oil was processed in thermal or catalyst methods to crack chemically in order to obtain light hydrocarbons such as olefins.⁹

⁴ ('Polypropylene', 2019)

⁵ ('BOPP Film Overview', n.d.)

⁶ (Niaounakis, 2015)

⁷ ('Polyolefin Plastic', n.d.)

⁸ ('Cracking (chemistry)', 2019)

⁹ (Alfke, Irion, & Neuwirth, 2007)

The olefins like ethylene and propylene were then polymerized into PE and PP. Polyolefins can also be obtained from recycled polyolefins.

Polyolefins are used in many purposes from electric insulation to food packaging, including plastic films. The most common two polyolefins are polyethylene (PE) and polypropylene(PP).¹⁰ As most of the polyolefins are made from petroleum, technology for recycling polyolefins are developing as well as the research on their biodegradability.

Sustainability

POF derives from crude oil. Using crude oil not only causes the exploitation of the land but also increase the emission of greenhouse gases (GHG).¹¹ Therefore, the impacts of POF are mainly from the use of crude oil. The exploitation for crude oil changes the use of the land, and natural habitats may disappear because of these petroleum reservoirs. Local biodiversity is therefore influenced by humans' activities of the oil extraction. Furthermore, the energy used for extraction in these oil fields leads to emission of GHG and other toxic gases. This climate impact also relates to the impact of air quality. If the crude oil is extracted from offshore platforms, the water quality of the ocean could be polluted. The water from oil extraction contains oil fractions, heavy metals, radioactive substances, production chemicals and more, which can harm marine lives.¹² The drilling oil fields on land can also pollute their surrounding air and water, and these fields may originally be natural habitats or parts of the routes for animal migration.¹³ If the water is polluted, it is less possible that the soil can remain good quality. Therefore, we believe that there will also be impacts indirectly on the soil.

POF is oxo-biodegradable and recyclable. It can be processed properly and become degradable and biodegradable.¹⁴ Polyolefins are difficult to be degraded in natural environment, so pre-(bio)degradation processes are needed.¹⁵ The two phases of polyolefin degradation process are called oxo-biodegradation. Recycled polyolefins will be oxidized to react with air forming smaller molecular fragments using ultraviolet light, heating, or some metal pre-degradants as catalysts. After the polymer breaks down, microorganisms could consume the oxidized carbon backbone fragments and produce CO₂, H₂O, and biomass¹⁶. Through preprocess and the reaction with microorganisms POF can be degraded.

¹⁰ ('Polyolefin Plastic', n.d.)

¹¹ (Boden, Marland, & Andres, 2009)

¹² (Jære & Agency, n.d.)

¹³ ('7 ways oil and gas drilling is bad for the environment', n.d.)

¹⁴ (Achilias, Antonakou, Roupakias, Megalokononimos, & Lappas, 2008)

¹⁵ (Ammala et al., 2011)

¹⁶ (Ammala et al., 2011)

2. Poly-β-hydroxybutyric acid, PHB

What is PHB and how it is made?

PHB is a polymer that derived from biological reaction. One of the PHB syntheses is through microbial production. PHB can be produced at 4.94kg PHB/m³/h.¹⁷ The bacteria were treated with sucrose after the reactor is sterilized by steam. After PHB's growth and accumulation, the following processes is performed in batch. Cells are disrupted in a high-pressure homogenizer. Centrifugation is conducted to remove the PHB solid for further purification.

Compared to the plastic derived from crude oil PE and PP, PHB is synthesized by organisms, so it does not require the energy and chemicals that used in refining crude oil for PE and PP monomers. That is, fossil fuels will not be used in the production of PHB. After disposal, likewise some bacteria can be added to facilitate the biodegradation process, which does not need extra chemical or engineering process.

Sustainability

PHB is biodegradable. It is generally regarded as a more environmentally friendly option for plastic since it does not come from crude oil. The main impacts of environment are climate and water related issues. The production of PHB requires a large amount of water and electricity. To be able to cultivate microorganisms, the reactors and all the labware should be sterilized by steam before use. Not only the steps of sterilization but also the steps for purification and its follow-up steps. And electricity is required to heat up water and produce steam. However, the carbon emission equivalent of PHB is lower than those of PE and PP. Producing 1000 kg of PHB will give 1960 kg CO₂ emission to atmosphere, while for PP is 3530 kg CO₂ emission and for PE is 2510-3040 kg CO₂ depending on the density.¹⁸

PHB can be naturally decomposed in the environment. However, it is still suggested to recycle PHB plastic product or dispose of it in the category of general waste, instead of in the environment. This way, the products of natural biological decomposition of PHB will not have much impact on water, soil, and air quality.

3. Stone paper

What is stone paper and how it is made?

Stone paper is a paper-like material manufactured from calcium carbonate bonded with small amount of resin, high-density polyethylene (HDPE). It is basically made with inorganic calcium carbonate and plastic. Stone paper is very durable and strong. It is water-proof and resistant to grease. It can also be added with UV-resistant

¹⁷ Harding, Dennis, Vonblottnitz and Harrison (2007)

¹⁸ Harding et al. (2007)

substance to prevent photodegradation. Stone paper packaging can even serve to contain food, and therefore, it has good qualities on separation, isolation and the feeling of new.

Stone paper is made from the waste of marble mining and recycled HDPE. In the case of Stone-Paper.nl, stone paper is made with 80% of calcium carbonate and 20% of HDPE. The stone raw materials are cleaned and ground into powder. The powder is mixed with polyethylene and pelletized. The pellets will then be blown and coated and be treated in rolling process of papermaking.¹⁹ The whole production of it requires no tree and water as well as chemicals.²⁰

Sustainability

Compared to traditional pulp paper, stone paper saves much more resource consumption. Replacing 1 ton of pulp paper can save 18 trees since the production of stone paper does not require trees.²¹ No water is used during the production while it needs 2770 liters of water to produce pulp paper. The carbon emission to produce 1 ton of stone paper is 949 kg less than that for pulp paper, and the energy consumption from stone paper is only 15% of which from pulp paper.

No water consumption means no impact on water quality and use, and no trees required mean no land use change happened in the forest and the biodiversity can be preserved. The impact of climate is lower compared to which of pulp paper. The impacts of air and soil quality are limited because the production of stone paper is constrained in factories and recycle centers where the raw materials are from.

Stone paper is not biodegradable. Yet, it can degrade under the exposure of UV light after a period, and ideally it can be recycled unlimitedly. Currently, the application of stone paper is not common enough, so the recycle mechanism is not well-developed. In the Netherlands, stone paper needs to be recycled ideally by mean of the category 2 recycling stream(only for HDPE).²² However, it is possible that people can recycle the stone paper to paper category because it will still be separated and removed to the category 2 stream and burned to generate energy. No harmful gasses are released by burning stone paper.

4. Polylactic acid, PLA

What is PLA and how it is made?

PLA is a thermoplastic derived from renewable resources such as sugar cane, corn starch, or tapioca. PLA is currently used in packaging industry for cups, bowls, and also disposable bags as well as compostable agricultural films. The fermentation of starch (dextrose) produces two kinds of lactic acid. Polymerization is obtained by

¹⁹ ('Stone Paper Making/ Manufacturing Process/ Line', n.d.)

²⁰ ('Stone paper', 2019)

²¹ Stone-Paper.nl

²² [Stone Paper Recycling](#)

condensation of the lactic acid monomers or by polymerization of the cyclic diesters (lactides). The resulting products can be processed into sheets, films and of course our packaging.²³

Sustainability

PLA is made from renewable resources. The raw materials of PLA are plant-based such as from corn and sugar beets.²⁴ This way, it can replace petroleum-based plastic. However, the concern of using PLA is that it is potentially using the crops as feedstock, but these crops are also the main food for many people in the world.

PLA is biodegradable and compostable, and it can be processed in three ways, traditional landfill, and incineration as waste, and through standard mechanical recycle systems. It is biodegradable under a controlled situation (Temperature >58°C, relative humidity >90%, presence of micro-organism). It can be degraded into CO₂, water, and biomass. It can also be incinerated to generate energy. It can also be recycled mechanically or chemically to recover to raw materials again.²⁵ For example, through hydrolysis process PLA can be converted back to lactic acid, which is very easy to deal with. The time for biodegradation can vary depending on environmental factors and the composition of the PLA.

Regarding environmental impacts, the land use of corn and sugarcane production for plastic may influence the food supply for humans. Transforming a forest or a natural area into a corn field can reduce the local biodiversity. Climate and air quality impacts may result from the low carbon sequestration ability of the crop species and from a lower amount of oxygen release compared to a forest. Water use may increase to grow the crops for PLA's raw materials. Soil and water quality of the land may be disturbed using pesticide and fertilizer.

5. Individual paper box

What is paper box and how it is made?

Please see the document of CARTON with detailed information and analysis of environmental impacts because carton and individual paper box has very similar production process.

Conclusion

Paper box and PLA turned out to be the most sustainable, followed by stone paper and PHB. Paper box derived from trees, which is a renewable resource and PLA can be derived from plant-based materials. Both are biodegradable and recyclable. The impact of them are in different aspects. The impacts from paper box main are from the production in the factories, while PLA has more impacts on the beginning of the

²³ ('PLA Film', n.d.)

²⁴ (Drumright, Gruber, & Henton, 2000)

²⁵ ('Environmentally alternatives for Nativia® end of life - Ti', n.d.)

production where the crops are grown. Between PHB and stone paper, PHB is biodegradable while stone paper is not. Table 1 you can find an overview of this analysis and given points.

Replacing the current use of plastic packaging seems promising, since that the supply can be provided from China as well. As some of the alternatives is biodegradable and possible to decompose in natural environment, it is still recommended to recycle these alternatives or at least to general garbage stream, instead of disposal in the environment. It would be a good step towards sustainability for us to shift the plastic packaging to one of these alternatives.

Table 1. Comparison of 4 alternatives with the extent of their sustainability and summaries of their characteristics.

Alternatives	POF	PHB	Stone Paper	PLA	Individual box
Function	Similar functions and the feeling of new				
Biodiversity	Habitat and species loss ●●●			Loss of species richness ●●○	Habitat species loss ●○○
Air quality	Air pollution ●●○		Air pollution ●○○	Lower carbon sequestration ability ●○○	Air pollution ●●○
Climate change	GHG emission ●●●	GHG emission (energy use) ●●○	GHG emission (energy use) ●●○	Lower carbon sequestration ability ●○○	GHG emission ●●●
Land use change	Crude oil exploitation ●●○			Monoculture plantation ●○○	Monoculture plantation ●○○
Soil quality	Impact from water quality ●○○			Fertilizers, pesticides ●○○	Fertilizer ●○○
Water quality	Water pollution ●○○			Fertilizers, pesticides ●○○	Acidification ●○○
Water use		High water use for cultivation of PHB ●●●		Higher water for crop cultivation ●●○	High water ●●○
Pros	Easily accessible and low price, oxo-biodegradable and recyclable	Via biological production and is biodegradable	Energy and resource-saving, excellent durability	Plant-based feedstock, biodegradable, recyclable, recoverable	Renewable source, biodegradable, recyclable
Cons	Made from crude oil	Highly water- and energy-demanding	Not biodegradable, not yet compatible to current recycle system in NL	The use of food crops for plastic production	Energy- and water-demanding when produced and recycled

Practical extras

POF

POF has lower market prices as it has mature techniques in terms of production and the price of fossil fuel is in lower points in recent 5 years('Crude Oil Prices - 70 Year Historical Chart', n.d.). According to [Alibaba](#), the price of POF shrink film per kg varies from RMB 9.5 to 49. Minimum amount of order is 20 kg or 1000 pieces depending on the suppliers.

PHB

According to search results on [Alibaba](#), the price of PHB per kg varies from RMB 20 to 80. Minimum amount of order can be 1 kg or 1 ton depending on the suppliers.

Stone paper

According to search results on [Alibaba](#), the price of stone paper varies from RMB 1.6 per 100m². Minimum amount of order can be 100m² or 1 ton depending on the suppliers.

PLA

According to search results on [Alibaba](#), the price of stone paper varies from USD 0.1-0.5 per m² or USD 8 per 1000 rolls. Minimum amount of order varies from 1000 m² or 1000 rolls depending on the suppliers.

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