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Abstract
New material combinations can offer new opportunities by providing unique material characteristics (e.g. strength, stiffness, look & feel). This pictorial shows the first results of research with regard to combining textile waste and biobased plastics. New materials are created and tested and application possibilities are explored. Aim of the research is to explore and demonstrate lasting and recyclable products from these new materials for the companies who provided textile waste. Next to the unique material characteristics, the developed materials and products should also have economic and ecological value, as well as contribute to the transition towards a circular economy.

Introduction
While the amount of waste continues to grow, raw materials become scarcer and more expensive. The circular economy offers solutions to these growing problems. Within the developing circular economy, bio-based materials are on the rise and close attention is paid to reuse and recycling. New business models are being developed around waste reuse and value creation (EMF, 2013).

Lots of research has been done on biocomposites, biobased plastics and processing textile waste streams, but not on combining these. As most research focusses on mechanical properties and costs, while aesthetic, tactile and emotional aspects, crucial for commercial value, are only very limited researched.

Biocomposites
For the production of biocomposite products so-called virgin natural fibers are combined with biobased plastics. Research done in the past shows that market opportunities for biocomposites are good, in spite of many optimisations which are still possible and useful (Faruka ea, 2012). Important issues that support these market opportunities are lower environmental impact, low specific weight and aesthetic properties (Böttger, Lepelaar, & Bouvy, 2009; van Beurden & Goselink, 2013; van Rooijen, 2012). Not many appealing examples of inspiring and successful products are available. Most examples are not yet in large scale production and knowledge concerning experiential qualities are limited and not widely explored.

Biobased plastics

Many biobased plastic blends and grades are commercially available (Iles & Martin, 2013; Bolck, Ravenstijn, Molenveld, & Harmsen, 2012). Some of these are biodegradable. Often, these biobased plastics are not 100% sustainable due to blending with non-natural additives (for improving properties or process ability) or fibers (Alvarez-Chavez, Edwards, Moure-Easo, & Geiser, 2012; Bolck et al., 2012). Knowledge of processing biobased plastic is limited to only a few plastic processors who have gained experience.

Textile waste streams

In the Netherlands several knowledge institutes, organisations and companies are involved in collecting and recycling textile waste. Value is created in the so-called clothing-clothing recycling (selling second hand clothes), resource recollection and recycling to products with a relatively low added value (like cleaning cloth or isolation materials (Bottenberg, Goselink, & Bouwhuis, 2013)).

Circular Biocomposite of biobased plastics and textile waste streams, RECURF

The aim of the research is to explore and develop new materials suitable for the design and production of circular products with economic and ecological value. This is done through cooperation between different disciplines such as functional material research, product design, engineering and business modelling, also combining research and practice.

In the first stage of the research several tests are performed to find the most favourable material combinations, with regard to production technology, mechanical characteristics and aesthetics, tactiles and emotional qualities (experiential qualities (Karana, 2015)). Theoretically, a vast range of combinations is possible, given the different sorts of received textiles and available biobased plastics, as well as the choice of fibre length and processing methods.

In this pictorial we focus on the assessment of processing techniques, mechanical properties and experiential qualities and the exploration of applications through some first product ideas and prototypes.

The research focuses on the following areas:
- the mechanical and experiential qualities of the material combinations;
- the appropriate processing techniques and design strategies for application of these materials;
- the circular nature of the designs, including environmental impact and end-of-life scenarios;
- circular business models with an interesting value proposition and revenue model.

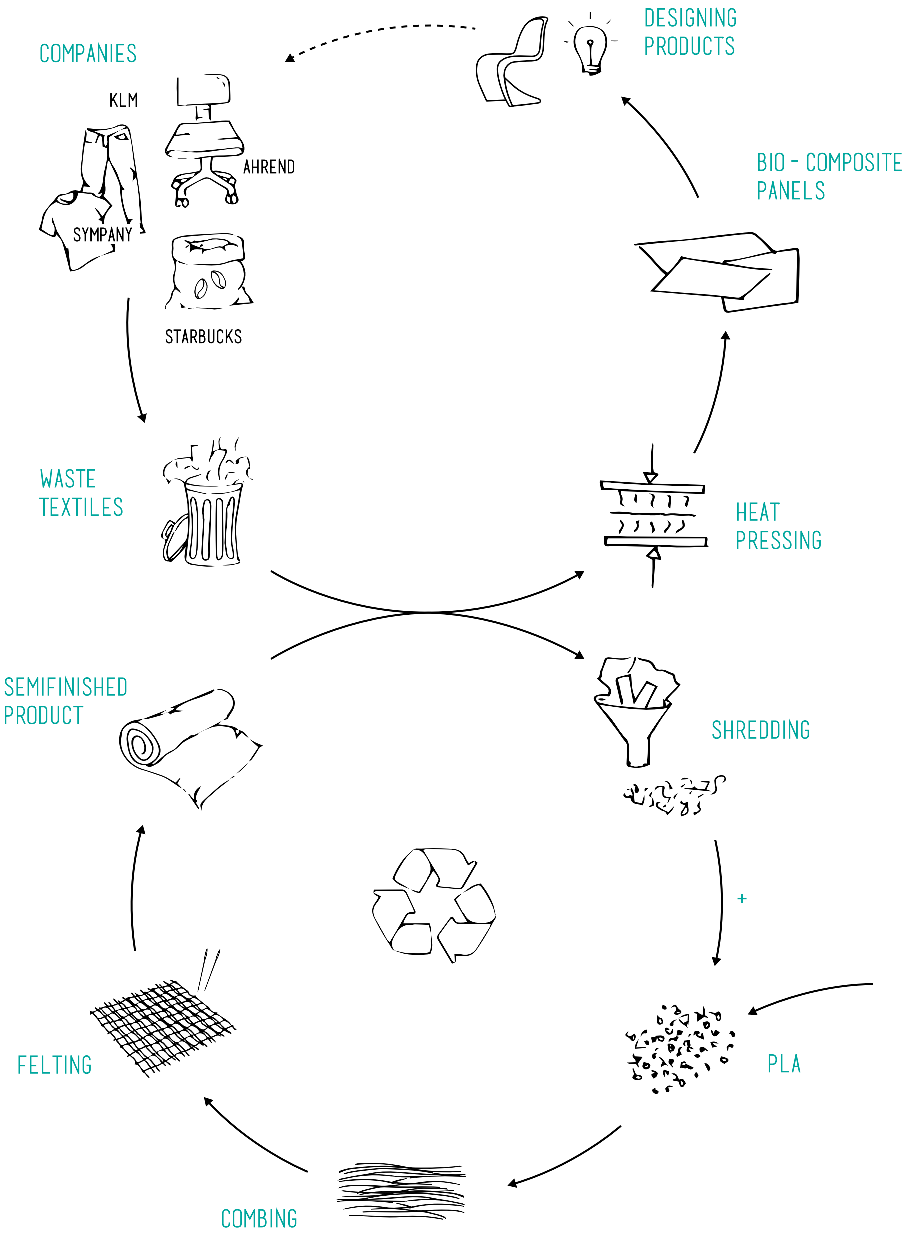
The research combines two sectors and two materials (biobased plastics and textiles) to create new, unique material combinations with favourable mechanical and aesthetic characteristics. The mechanical strength of the new materials is often better than that of alternative materials. Also they are light and have favourable aesthetical characteristics (Böttger et al., 2009; van Beurden et al., 2013; van Rooijen, 2012). As shown by Karana (2012) and Van der Wal (2015) the aesthetical and tactile characteristics are an added value to the perception and appreciation of the natural origin and quality of biobased products.

The figure on the right gives an overview of the circular development process of the new materials and products.

Also the Amsterdam metropolitan area is committed to the circular economy, reuse and recycling and strives to a circular city and waste chain (Gemeente Amsterdam, 2014).

The residents of Amsterdam produce an average of 17kg of textile waste per person per year. Only 16% of this waste is collected separately (Gemeente Amsterdam, 2015). The rest ends up as residual waste and will be incinerated. Only a part of the separately gathered textile is suitable for reuse or high quality recycling. Research question is whether it is possible to combine (non-reusable) textile waste fibres with bio-based plastics to create new materials with unique properties.

Companies such as Starbucks, Ahrend and clothing collection organisation Sympany, are providing some of their discarded textiles to investigate whether the combination of this extra recycling route can help to produce innovative circular products for their own use.



Preprocessing textiel fibres

The raw textile material is processed in three different ways: woven, fiberised and pulverised. The material samples have varying fibre lengths, suitable for the different types of production techniques, such as hot pressing, vacuum infusion, 3D-printing and injection moulding. For demonstration purposes jute is chosen as an example. Other fabrics used are denim (cotton), uniforms (cotton/polyester) and furniture upholstery (wool).

Textile wastestream: jute coffee bags, in which the raw coffeebeans are transported from a worldwide scatter of suppliers to the Starbucks coffee processing factory in the Amsterdam harbour. Approx. 240 tons/yr.

Woven jute

Fiberised jute

Pulverised jute

Woven jute with Solanyl (TPS-based bioplastic) hot pressed

Fiberised and needle punched jute and PLA hot pressed

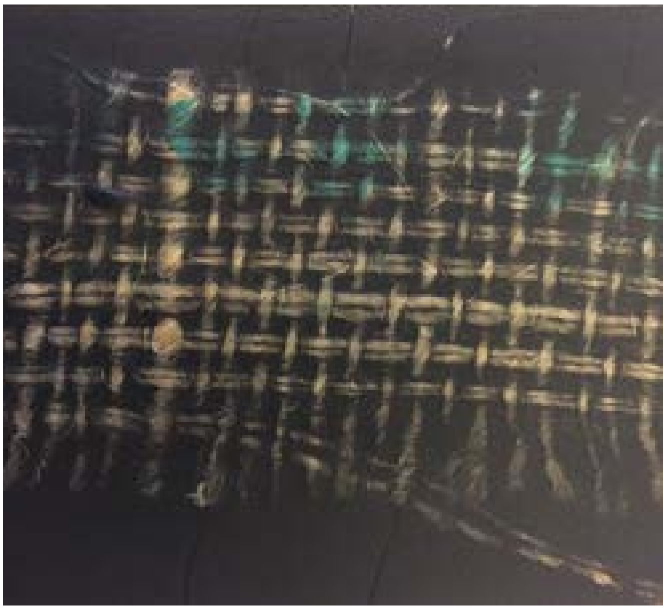
Pulverised jute with PLA tension bar plus granulate

Woven textiles combined with biobased plastics - material samples

If the textile is directly, without hardly any preprocessing, used in circular biocomposites the full strength of the original textiel adds to the mechanical properties in the material combination. Also is the visual feedback most direct; in this case the jute bag or in other cases the jeans pants are still recognisable. So it is clear to users what the origin of the used textile waste stream is. It has a very strong recylce or “eco” appearance. However, upscaling production is hard to realise in an industrial and continuous manner because of handling and maxmum size of the textile cloth.

Jute mat with PLA granulate

Jute mat with Solanyl sheet



Recycled PLA

Fiberised textiles combined with biobased plastics - material samples

In most cases the first step in recycling non rewearable textiel waste is fiberising the collected cloths. This leads to randomly ordened fibres with a typical length of about 30mm's. If we combine these fibres with biobased plastics a more amorphous look is created, allthough it is still very clear that the material consists of a fibre like material. The tactiles have a soft touch smooth surface, but not as smooth as pure plastic. The fiberised fibres can be processed by needle punching into continues rolls of non wovens with a defined weight per m2 and are therefore very suitable for industrial processing.

Jute with Solanyl (PLA/TPS)

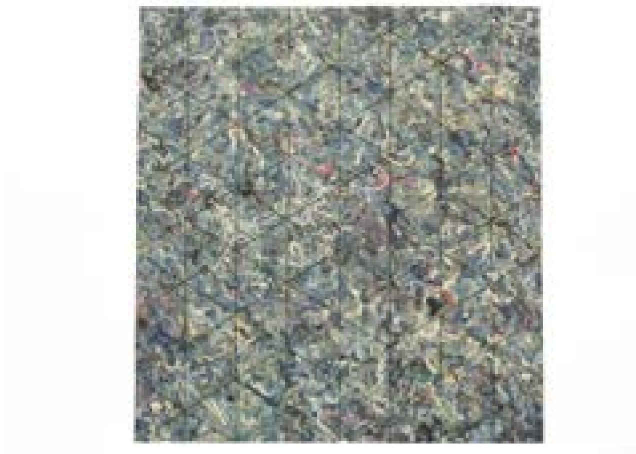
Denim with PLA fibres

Uniform with Solanyl (PLA/TPS)

Fiberised textiles combined with biobased plastics - examples of (digital) processing

When needlepunching the fiberised textiles in non wovens a biobased plastic PLA fibre can be integrated. This non woven can be heated and pressed into sheets or directly in sheet based shapes/products. The sheet based products can be post processed by digital production techniques like lasercutting. It is also possible to create sheets and products that can be rigid as well as soft.

Denim and PLA
Laser cutting before pressing

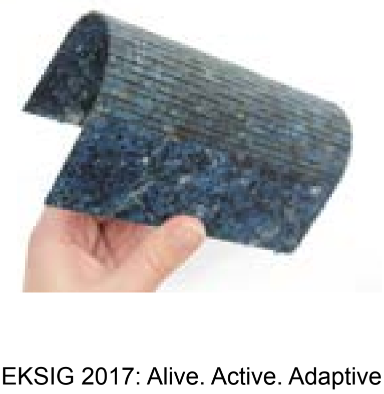


Denim and PLA
Laser engraving

Jute and PLA
Laser cutting combining hard and soft

Uniform and PLA
Local hot pressing hard and soft

Uniform and PLA
Laser cutting



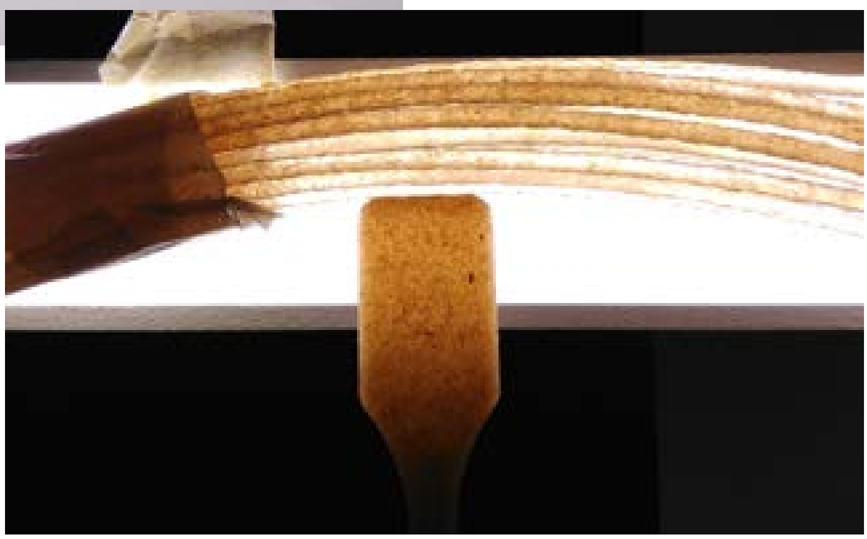
Pulverised textiles with biobased plastics - material samples & processing techniques

When processing plastic in most industries the plastic is process as a granulate of approximately 3x3x3 mm. In order to be able to proces a fibre fileld plastic biocomposite the fibre length should be no longer than 3 mm. To achieve this the fibres are pulverised and compounded into granulate. After doing so the granulate can be processed through fe. injection moulding or 3D printing.

Granulate from Solanyl (PLA/TPS) and denim

Cotton dust from filter and Cradonyl (PLA/TPS) hot pressed

Denim and PLA/TPS
Injection moulded



Jute and PLA
Filament 3D-printing

Exploration of applications - woven textiles combined with biobased plastics

Besides making square and flat samples it is usefull to explore and demonsrate the new material combinations in products as well. The ultimate goal of using material is using material in useable products.

Serving trays made from a.o. jute mats and Solanyl (PLA/TPS) Hot pressing

Tabel Minor New Materials

Material: Jute bag, jute fiberised and PLA non woven
Processing method: Hot pressing, laser cutting.

Exploration of applications - fiberised textiles combined with biobased plastics

Since the fiberised fibres are usable in industrial production techniques most prodcuts that are further elaborated are using these fibre/plastic combinations. Properties of the materials, like aesthetics, mechanical, emotion, biodegradability etc. are used in strengthening the designs.

Surf board Fin

Material: denim/ jute PLA in non woven
Processing methode: Hot pressed into sheet, laser cut, hot pressed

Lounge chair

Material:
Combination of Jute and UP
Processing methode:
Bulk Moulding Compound,
Hot press

Spectacle case

Material:
Combination of Denim and PLA
Processing methode:
Hot press

Results and discussion

Creating new matierals by combining textile waste and biobased plastics offers a great range of different appearances, forms and formats. Applying several processing methods expands this range even more. The new material combinations have varying mechanical characteristics and perceptive forms: from smooth to rough, from glossy to mat/dull, from flexible to rigid. The new material combinations have a new and unique look and feel and perceptive values.

Also the physical and mechanical characteristics are interesting. Mechanical properties in comparison to pure biobased plastic could be increased up to 50% in strength and 66% in stiffness (when combining PLA granulate with 30% pulverised jute)(Callenbach, 2016). At the bottom scale of mechanical properties it was possible to at least keep mechanical properties constant, while saving on costs for biobased plastic. Textiles combined with biobased plastics can be processed into materials with interesting physical properties like sound-damping and vibration-damping qualities, products can be engineered very lightweight or very strong and stiff and they can combine hard and soft in one material.

The search for material combinations and suitable matching product applications has just begun. Together with partners from research and industry, such as the TU Delft and several medium sized companies (SME's) from the biobased plastic chain, the most promising material combinations, processing methods and applications have been identified and will be further developed. Material samples and prototypes are produced to better understand the relationship between material, process and form. Most pictures show the original colours of the textiles and plastics. Experiments with pigments and mould surfaces have not yet been done, and offer additional possibilities with regard to the experiential qualities.

Material samples and prototypes are produced to better understand the relationship between material, process and form. From this understanding the research partners have concluded that further research on sheet based products for interior use is most promising. Further research on the whole value chain is recommendable in order to optimize circularity and commercial feasibility. The promising result on the exploration of using flexible digital production techniques to customize products, shapes and appearances should be elaborated and further explored.

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References

Álvarez-Chávez, C. R., Edwards, S., Moure-Eraso, R., & Geiser, K. (2012). Sustainability of bio-based plastics: general comparative analysis and recommendations for improvement. Journal of Cleaner Production, 23(1), 47-56.

Beurden, K.M.M. van & Goselink E.A. (2013). BioComposiet, Thermoplastische kunststof met natuurvezels [Biocomposite, thermoplastic synthetic material with natural fibres]. Saxion working paper, 2013-05-01

Bolck, C., Ravenstijn, J. T. J., Molenveld, K., & Harmsen, P. (2012). Biobased plastics 2012. Wageningen UR Food & Biobased Research.

Bottenberg, E., Goselink, E., Bouwhuis G. et al. (2013). Recycling in ontwerp, 'State of the art' van de Nederlandse recycling industrie [Recycling in design, 'State of the art' of the Dutch recylcing industry], Saxion Kenniscentrum Design en Technologie, Enschede

Bottger, W. O., Lepelaar, M., & Bouvy, R. (2009). Aesthetic composites based on natural fibres: NaBasCo. International Journal of Materials and Product Technology, 36(1-4), 3-10.

Callenbach, K. (2016). Natuurlijke vezel composiet voor de 3D printer [Natural fibres for 3D printer], Unpublished graduation thesis, Amsterdam University of Applied Science (AUSA)

Ellen MacArthur Foundation (EMF) (2013). Towards the Circular Economy. Vol.1. Isle of Wight

Faruka, O., Bledzkia, A.K., Fink, H-P., Saind, M. (2012). Biocomposites reinforced with natural fibers: 2000–2010, Progress in Polymer Science, Volume 37, Issue 11, Pages 1552–1596.

Gemeente Amsterdam (2014). De Circulaire Metropool Amsterdam 2014-2018 [The circular metropolis Amsterdam 2014-2018] Amsterdam: Gemeente Amsterdam.

Gemeente Amsterdam (2015). Afvalketen in Beeld, Grondstoffen uit Amsterdam [Wastechain on screen, resources from Amsterdam]. Amsterdam: Gemeente Amsterdam.

Iles, A. & Martin, A. N. (2013). Expanding bioplastics production: sustainable business innovation in the chemical industry. Journal of Cleaner Production, 45, 38–49.

Karana, E. (2012). Characterization of 'natural'and 'high-quality'materials to improve perception of bio-plastics. Journal of Cleaner Production, 37, 316-325.

Karana, E., Barati, B., Rognoli, V., & Zeeuw Van Der Laan, A. (2015). Material driven design (MDD): A method to design for material experiences. International Journal of Design, 9(2), 35-54.

Rooijen, D. van (2012). Presentatie BIOPREG project, 2012 Retrieved September 1, 2014 http://www.holland-innovative.nl/agro/pdf/Project BIOPREG.pdf

Wal, M. van der (February, 2015). Ontwerpers kunnen biobased plastics herkenbaar maken [Designers can make biobased plastics recognisable]. Product Magazine. Nr. 1, 10-12.