From Low Value to Create New Value:

the application of soybean curd residue and bamboo fibre

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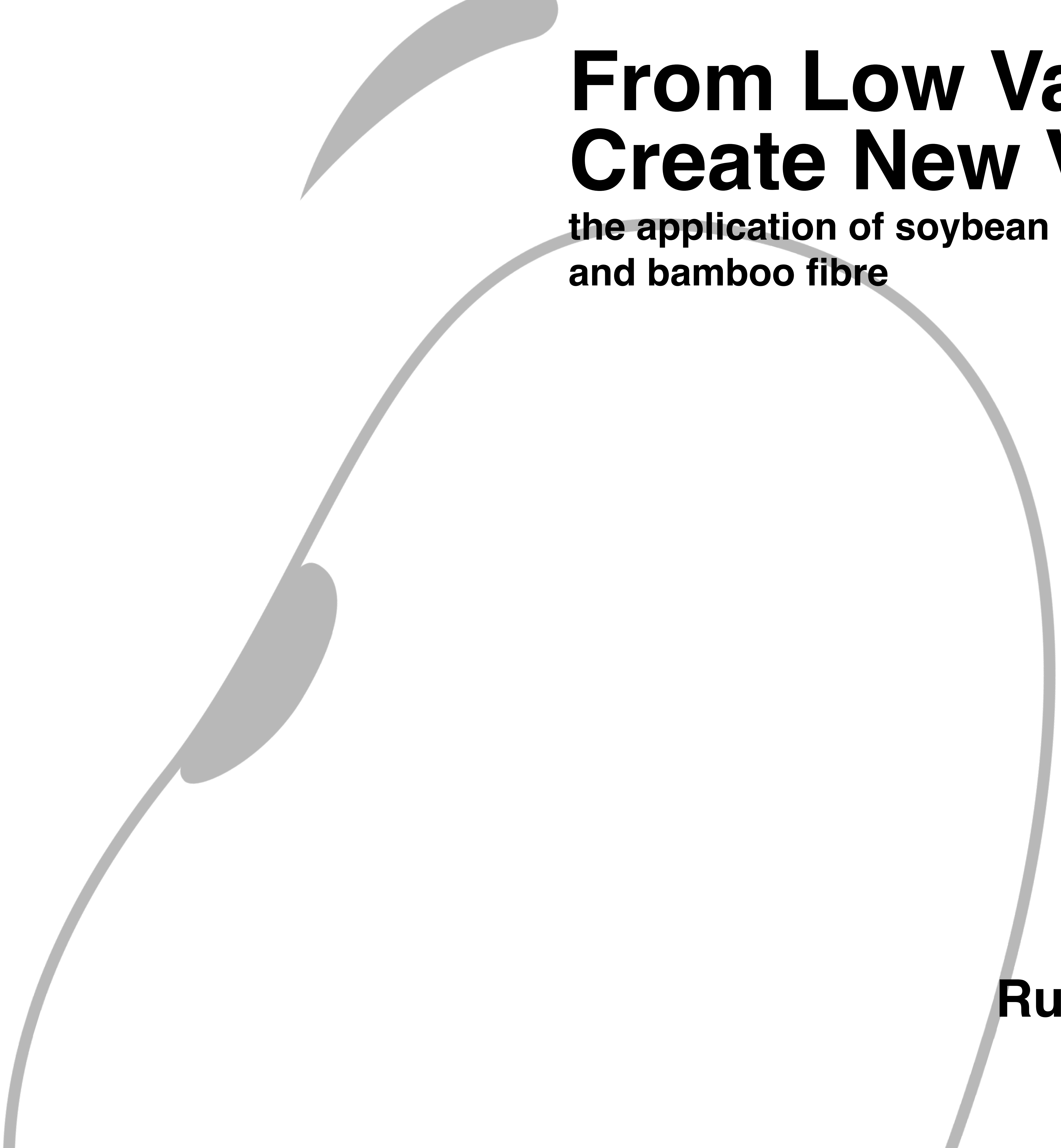

Ruixue Tang
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Abstract

La sostenibilità è stato un argomento di tendenza negli ultimi anni. Individui e governi hanno cercato di affrontare le questioni ambientali con tutti i mezzi possibili. Nel 2018 è stata adottata la prima strategia europea per la plastica in un'economia circolare. Questa strategia promuove anche la transizione verso un'economia circolare. In questo contesto, molti designer si sono dedicati alla transizione dell'economia circolare sviluppando nuovi biomateriali. Questa tesi ha due obiettivi di ricerca. Il primo obiettivo è produrre biomateriali da materiali di basso valore. Il secondo è esplorare le potenziali aree di applicazione dei biomateriali ottenute dal primo obiettivo. Per il primo obiettivo, il residuo della cagliata di soia, un sottoprodotto dell'industria del latte di soia, e la fibra di bambù, una potenziale risorsa dell'industria del bambù, sono stati usati per produrre biomateriali. Questa fase di ricerca ha seguito la metodologia di materiali DIY fornendo diversi campioni molto interessanti. Dopo aver preso in mano i biomateriali, è stata seguita la metodologia del Material Driven Design per esplorare le potenziali aree di applicazione. I risultati mostrano che i biomateriali possono funzionare come alternativa alla plastica nell'industria degli imballaggi e avere un valore estetico elevato nell'industria della moda. Il 21° secolo appartiene all'economia dei materiali e ora siamo al centro di una bio-rivoluzione.

Key words:
Soybean Curd Residue, Bamboo Fibre, Algae, DIY Material, Material Driven Design, Packaging Design

Abstract

Sustainability has been a trending topic in recent years. Individuals and governments made efforts to deal with the environmental issues in all means. In 2018, the first-ever European Strategy for Plastics in a Circular Economy has been adopted. This strategy also promotes the transition towards a circular economy. Under this background, many designers devoted themselves into the transition of the circular economy by developing new biomaterials. This thesis has two researching goals. The first goal is to make biomaterials from low value materials. The second is to explore the potential application areas of biomaterials got from the first goal. For the first goal, the soybean curd residue, the by-product from soymilk industry, and bamboo fibre, a potential resource from bamboo industry, have been used to make biomaterials. This research stage followed the methodology of DIY Materials and got several interesting material samples. After having the biomaterials in hands, the research followed the methodology of Material Driven Design to explore the potential application areas. The results showed that the biomaterials can be a plastic alternative in packaging industry and have some high aesthetic value in fashion industry. The 21st century belongs to a materials economy, and now we are standing in the centre of a bio-revolution.

Key words:
Soybean Curd Residue, Bamboo Fibre, Algae, DIY Material, Material Driven Design, Packaging Design

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Introduction

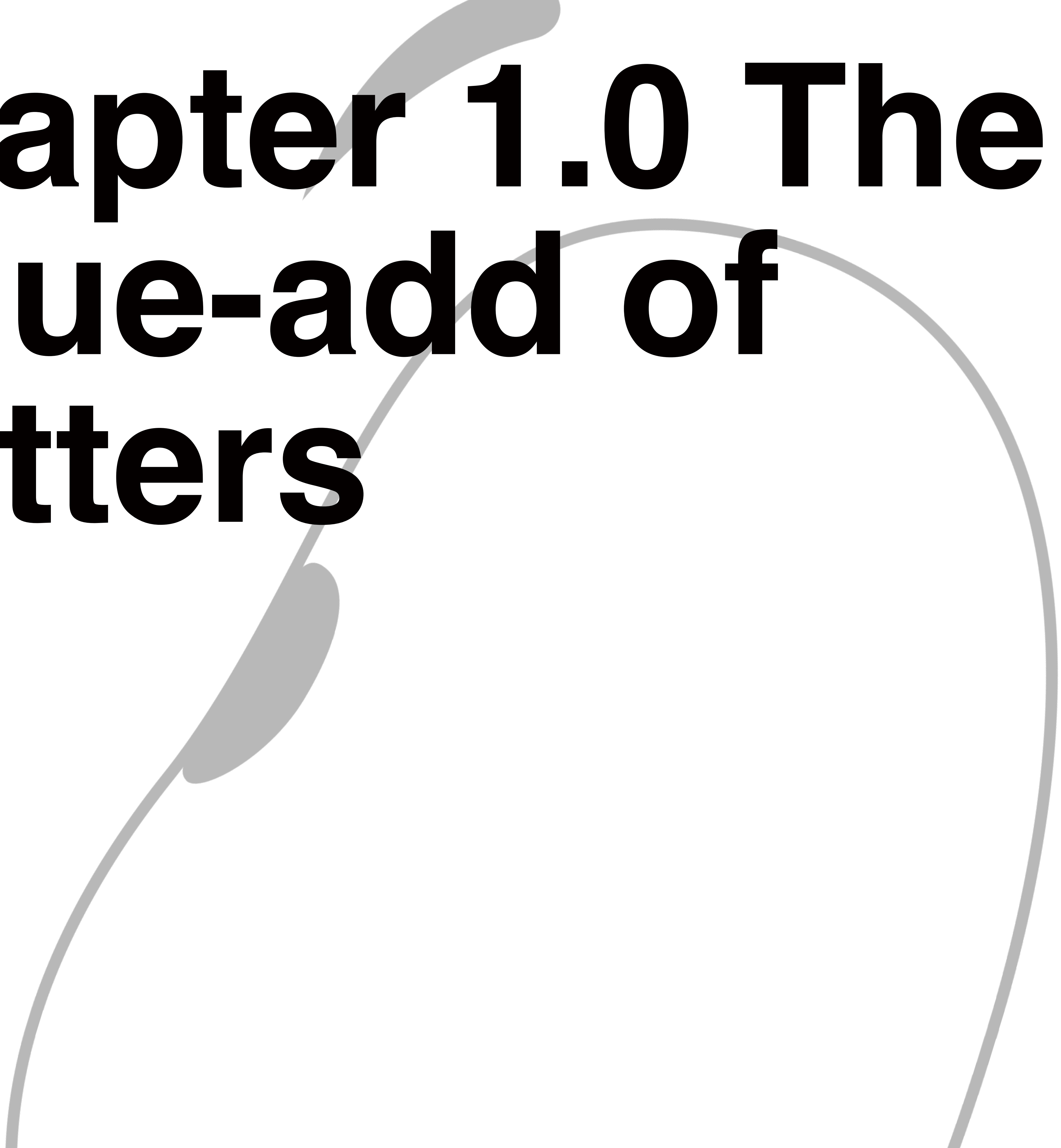
There are two very essential and fundamental courses in the product design education system, material and manufacturing. By knowing knowledge about materials and the manufacturing process, design students could choose a proper material and producing method for the manufacturing process. With the repaid development of modern cities, companies, as well as individuals, have shown an increasing demand for new materials with sustainability, better manufacturing technologies and processes, and fewer impacts. According to Adam Drazin, people are standing in the middle of a materials revolution. Professional people from fields like materials science, engineering, manufacturing and design are feeling the impact of this ongoing revolution, which, as he thought, could even compare with the digital revolution in its implications. (Drazin and Küchler, 2015) Since many materials are limited resources in the world, the conflicts around these materials have never been stopped. It is an urgent time for people to innovate and change the diversity of materials. Many disciplines have responded to the revolution by their own means.

The circular economy is a good example to react the materials revolution. Normally, most manufacturers and production facilities are operating in a linear economy way. They follow the 'take, make, dispose' method of manufacturing. In this linear economy, factories might produce many unwanted and dangerous landfill waste. Meanwhile, countries have to keep searching for new fresh raw materials to feed the market, and this will intensify conflicts between countries. However, circular economy, as a new business method, aims to design out waste and pollution and keep products and materials in using and regenerate natural systems. Once people have changed their mind about waste, they developed new methods and applied new technologies to deal with ‘waste’. Following this design and manufacturing proposal, waste becomes raw materials and keeps creating value.

In recent years, sustainable products become more and more popular in the market. Young people of this generation are more eager to lead a sustainable lifestyle than ever generations. They always feel responsible for the environment and the future of whole human beings. They take care of climate change, Environmental Ethics, the rights of non-humans, the overconsumption issue, the carbon emission, the plastic issue, etc. They show an increasing demand for lower impact consumption goods. Soymilk and bamboo products become the alternative choices for many similar products for their lower impact reasons. However, with the increasing demand for soymilk and bamboo products, there is also an increase in by-products in these two industries. Having circularity in mind, this thesis takes the soybean curd residue, by-product from the soymilk industry, and bamboo fibre, the potential resource from the bamboo industry, to create new biomaterials. Moreover, the thesis also gives a vision of applying these biomaterials in potential fields.

Throughout this thesis, new biomaterials have been innovated. What these biomaterials can do is also explored. There are a wide range of ways that one can think about materials, and the thesis gives some approaches by the vision of the material designer. Hopefully, this thesis could help the reader to rethink the material and their own approaches toward the material.

Chapter 1.0 The Value-add of Matters



1.1 Environmental Ethics

Environmental ethics is a discipline in philosophy that studies the moral and value relationship between human beings and the environment and its non-human contents. This concept, somehow, is challenging the anthropocentrism of traditional western ethical thinking. (Brennan, Andrew, Yeuk-Sze, 2020) In the design subject, there is something called human-centred design or user-centre design, which is a typical application of anthropocentrism. Guiding by human-centre design, designers have made numerous human-convenience, cheap products for different industries. However, apart from that, designers have not used to think about the environment and its non-human contents as part of their design systems. So, about 60 years later now, human has to face the consequence of the waste. Many people start to care about the environmental issue just because a sustainable environment is essential to human well-being in present and in the future. But do the environment and its non-human contents have certain values in their own right which human should be respected and protected? (Brennan, Andrew, Yeuk-Sze, 2020) This question is quite important for humans. If people still did not consider the environment and non-humans have belonged to the part of the design system and the service objects, the same dilemma would keep come out and the situation would get worse.

Just looking around, it is not hard to find that modern society is built upon petroleum and concrete. Even people want to go out of the cities and return to real nature; they can't find pure nature any more. The garbage leaks out from the landfill and finds its way everywhere. From Himalaya to the Amazon rainforest, from the South Pole to the North Pole. Modern civilization goes through every corner of the world through petroleum objects. Nature does not mean natural any more. People are looking for a new coexistence way to reframe the relationship between human and non-humans. An important part of this coexistence relationship is that do not consider the environment as a huge landfill for waste. Waste is a problem for both human and non-humans, but only human have the obligation to solve it. To solve the problem, the first thing is changing people’s notion about waste. Instead of thinking waste is garbage, people should consider it as valuable raw materials.

1.2 Circular Economy

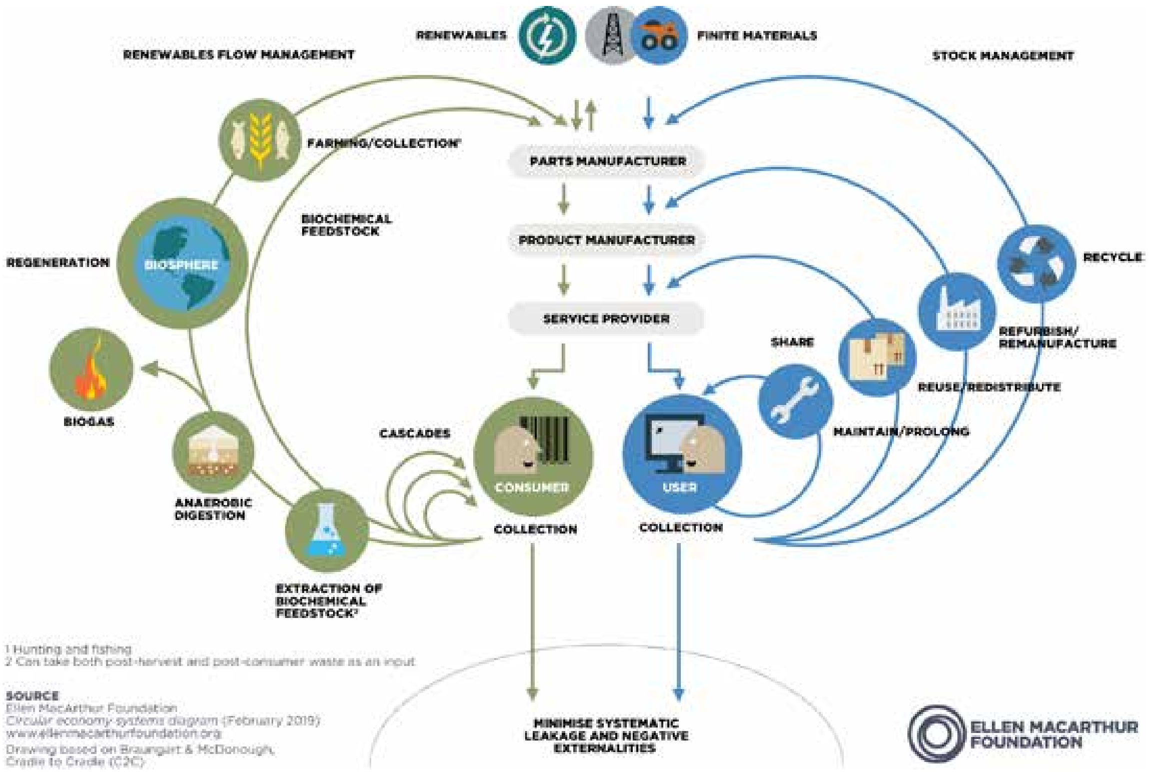


Figure 1: Ellen MacArthur Foundation, 2021. The Circular Economy System Diagram.

Willian McDonough, the author of “Cradle to Cradle: Remaking the Way We Make Things’, believed that if industries changed their linear production way into a close-loop, polluted-waste could 100% turn to raw materials and put into the manufacturing process again. Nature and human would be free from the impact of overconsumption. No one gets harms and no one will sacrifice any more. (Cradle to Cradle | William McDonough, 2020) Although the 100% close loop is just an ideal model, many designers have devoted themselves to promote the development of the circular economy. Traditionally, most manufacturers and production facilities are operating in a linear economy way, which follows the 'take, make, dispose' method of manufacturing. In this linear economy way, factories might produce many unwanted and dangerous landfill waste. Moreover, countries with huge eagerness for new fresh raw materials might cause conflicts with each other. (Instarmac, 2018) Compared with the linear economy, the circular economy is a new business method that aims to design out waste and pollution and keep products and materials in using and regenerate natural systems. (What is the circular economy, 2017) Through this circular business method, the impact of production and consumption will decrease, and the value of the waste will increase. Under this new business method, waste is much more than garbage, it becomes raw materials and creates value by processing. Especially with the development of technologies, people have much more methods to deal with materials that might be considered as impossible before.

The application of 3D printing technology could be a good example. This technology brings opportunities to turn plastic garbage into raw materials again. Before, plastic bottles in most cases are single-use products. After using for one time, it goes directly into trash bins and is sent to a landfill. But now, many businesses are built upon recycling PET plastic. For instance, Coco-Cola together with musician Will.i.am have developed a 3D printer that using filament made from recycled plastic bottles. (Howarth, 2014) Everyday human has created tons of plastic waste, especially cheap PET plastic bottles. How to recycle and reuse PET plastic becomes a challenge for everyone. But these PET plastic bottles, on the other hand, are a large quantity and free resource for everyone. Since the 3D printing technology has become easier and easier to access to everybody, there would be one day that everybody could have a 3D printer. Then the PET plastic will no longer waste and pollution. It might become the new symbol of democracy of design.

Figure 2: Howarth, D., 2014. Coca-Cola and Will.i.am's 3D printer.

Another example is ocean plastic. Before finding its value, people just leave it on the beach or burn it. Each year, the ocean brings tons of human-made garbage to remoted Islands. And these small pieces of plastic are fused during the bonfires and creating dense plastic-sand conglomerates. Kelly Jazvac together with Patricia Corcoran and Charles Moore went to Hawaii in 2013 and found these plastic-sand conglomerates on the Kamilo Beach and named them Plastiglomerates. (Antonelli and Tannir, 2019)

Figure 3: Yalcinkaya, G., 2019. plastiglomerate.

Figure 4: Griffiths, A., 2020. Adidas Terrex Free Hiker shoe.

However, with the thriving of the ocean plastic recycling industry, people have a better way to reuse this resource. Adidas collaborated with Parley for the Oceans again to release the updated version of the Terrex hiking boot. The yarn of the Terrex Free Hiker shoe is made from recycled ocean plastic. The plastic is gathered from remote islands, shorelines and coastal areas. Then the plastic is shredded and reworked in the factory to become a high-performance polyester yarn for sportswear. (Griffiths, 2020)

In recent years, many durable products are designed and manufactured with recycled ocean plastic or recycled PET. As companies keeping making profits from the recycling industry, they pay more attention to design the recycling service for their products and reframe their manufacturing systems.

1.3 Value-add of Matters

Not just plastic, the value of other matters from supply chains has also developed by the circular economy. According to Bio-bean, the world population drinks over 2.25 billion cups of coffee every day. The UK alone has 95 million. With an average of 11 grams of fresh coffee powder going into each cup, around 500,000 tons of wet coffee ground waste a year. Generally, the waste coffee grounds are sent to landfill. However, the waste coffee grounds will produce methane which is a greenhouse gas 34 times more potent than carbon dioxide. Coffee grounds become one of the main causes of global warming. (Bio-bean, 2019) Therefore, many designers take a closer look at the waste coffee grounds and find out its significant value. In 2020, Objects and Ideograms have proposed a design project called Caffeinated Architecture. Caffeinated Architecture is an exploration of coffee grounds for design. This project demonstrates an application of using coffee grounds for 3D powder printing, CNC routing and biomass growth through mycelium. (Dezeen, 2020)

Figure 5: OBJECTS AND IDEOGRAMS, 2020. Caffeinated Architecture.

Vietnamese designer Uyen Tran has used waste seafood shells and coffee grounds to develop a new flexible bio-material called Tômtex. The name tôm means shrimp, it refers to the discarded seafood shells mixed with coffee grounds to create the textile. Every year, there are up to 8 million tons of seafood shells and 18 million tons of coffee grounds producing by the global food industry. Since people are running out of raw materials, it would be a good idea to repurpose the large quantity of food waste. Tran claims that after the Tômtex product has reached the end of its life, it can be recycled or just left to biodegrade. (Hahn, 2020)

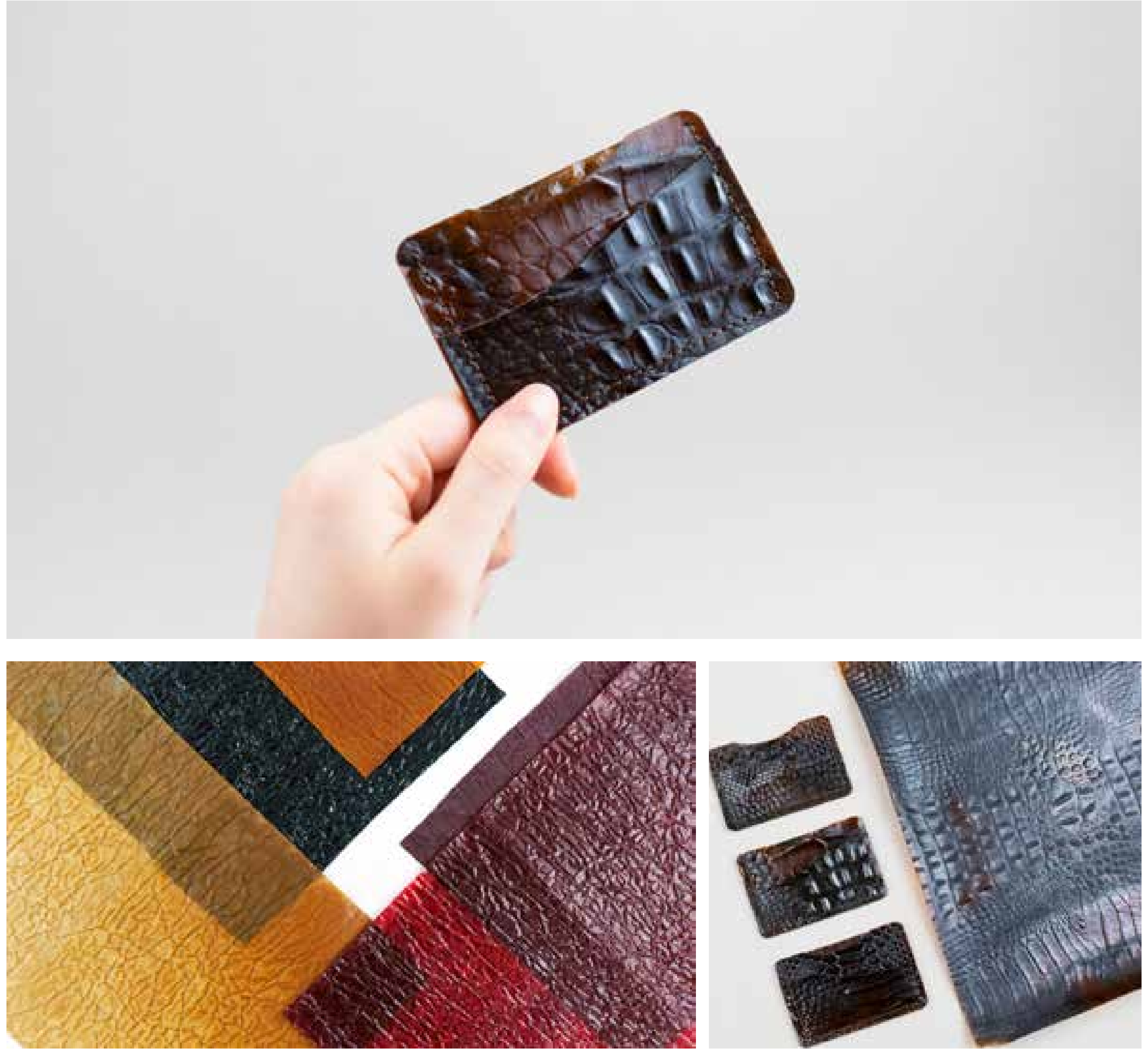


Figure 6, Figure 7, Figure 8: Hahn, J., 2020. Tômtex.

Morning Ritual is a project which use coffee grounds and newspaper waste to make a series of biodegradable containers. The designer got inspiration from her childhood memories. She remembered the scene of her father drinks coffee while reading the newspaper. She collected coffee grounds from local cafes and mixed them with newspaper pulp and a natural binding agent. Then she moulded the mixture by hand and coloured. (Morning Ritual - MaterialDistrict, 2018)

Figure 9, Figure 10: Paola Sakr Design Studio, 2018. MORNING RITUAL.

Another example comes from the meat and dairy industry. Eindhoven-based designer Billie van Katwijk used cow stomachs to make handbags. The meat and dairy industries have produced numbers of by-products and waste. Normally, animals' stomachs are used to make dog food. However, the number of available cow stomach has over outweighed the requirement of the dog food industry. Van Katwijk noticed this problem and decided to transform stomachs into something valuable. Van Katwijk proposed a new idea to design with cow stomachs for its leather-like textures. She set up a collaboration with a slaughterhouse and also worked alongside a tannery to figure out the hygienic of the stomachs and safe to be used for handbags. After all this hygienic process, stomachs turn into some leather materials. This kind of material will be more durable and less sensitive to decomposition. (Solanki, 2018)

Figure 11, Figure 12, Figure 13, Figure 14: studio Billie van Katwijk, 2018. Ventri.

Designer Thomas Vailly turns sunflowers into bio-based materials. Thomas Vailly together with Scientists to develop a series of materials only with sunflower bio-matter. Sunflowers are mainly growing for producing oil, seeds or bio-fuel. Apart from these valuable part of sunflower, the rest are considered as agricultural waste by farmers. Vailly uses the left sunflower crop to create sustainable materials, a non-synthetic binder and a non-toxic varnish. (Hitti, 2019)

Figure 15, Figure 16: Hitti, N., 2019. Thomas Vailly's Sunflower biomaterials.

Apart from waste, the value of some existed commercial goods has been underrated, for example, fungi. Traditionally, people only consider fungi as food. However, with depth research about fungi, people exploited its value in other applications. Reishi is a fungi based 'fine mycelium' material and has many sensory similarities with genuine leather. It grows in the lab under proprietary circumstances. (Graver, 2020) In normal cases, mushroom leather is very weak. But Reishi is more strength and durable compared to other fungi-based materials. The reason is that the company coerce the mycelium cells into a woven structure while the material is growing. MycoWorks would like to use its materials to tell its consumers about the plastic issue and animal rights.

Figure 17: Graver, D., 2020. Reishi.

Algae is another underrated material by humans. But now, many people use it to make sustainable as well as fashionable products. BioGoods, the nominee concepts 2021 of Green Product Award, has used red algae and other plant sources to create 100% biodegradable biomaterial. Biogoods is a series of environmentally responsible products made by this kind of biomaterials. This project also shows a fabrication process without toxic, unsustainable materials and adhesives, and in a small-scale. What is more, this material can be recycled by simply melting it into a new sheet. From this feature, it can be pressed by heating surfaces to achieve self-glue. (BioGoods, 2021)

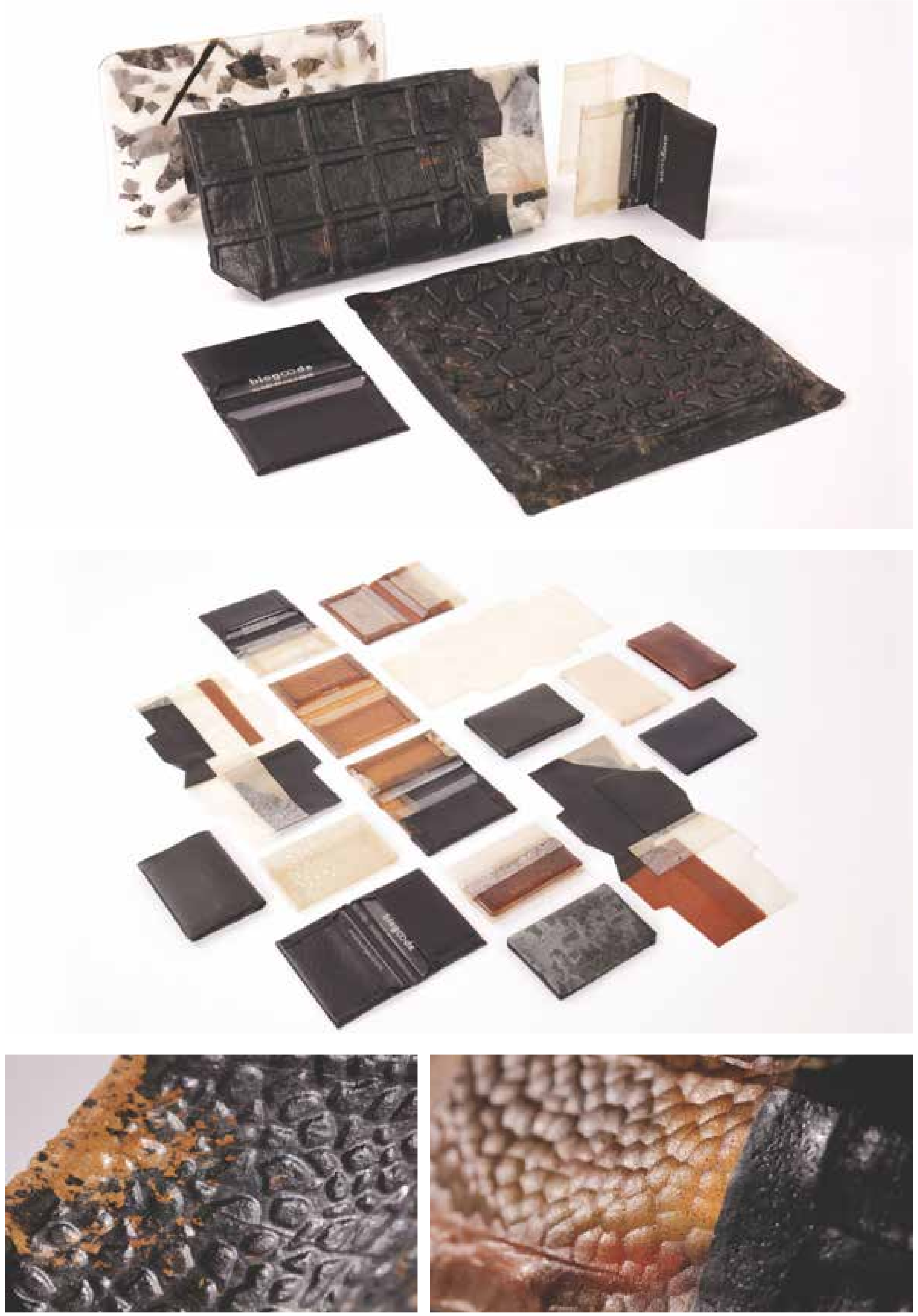
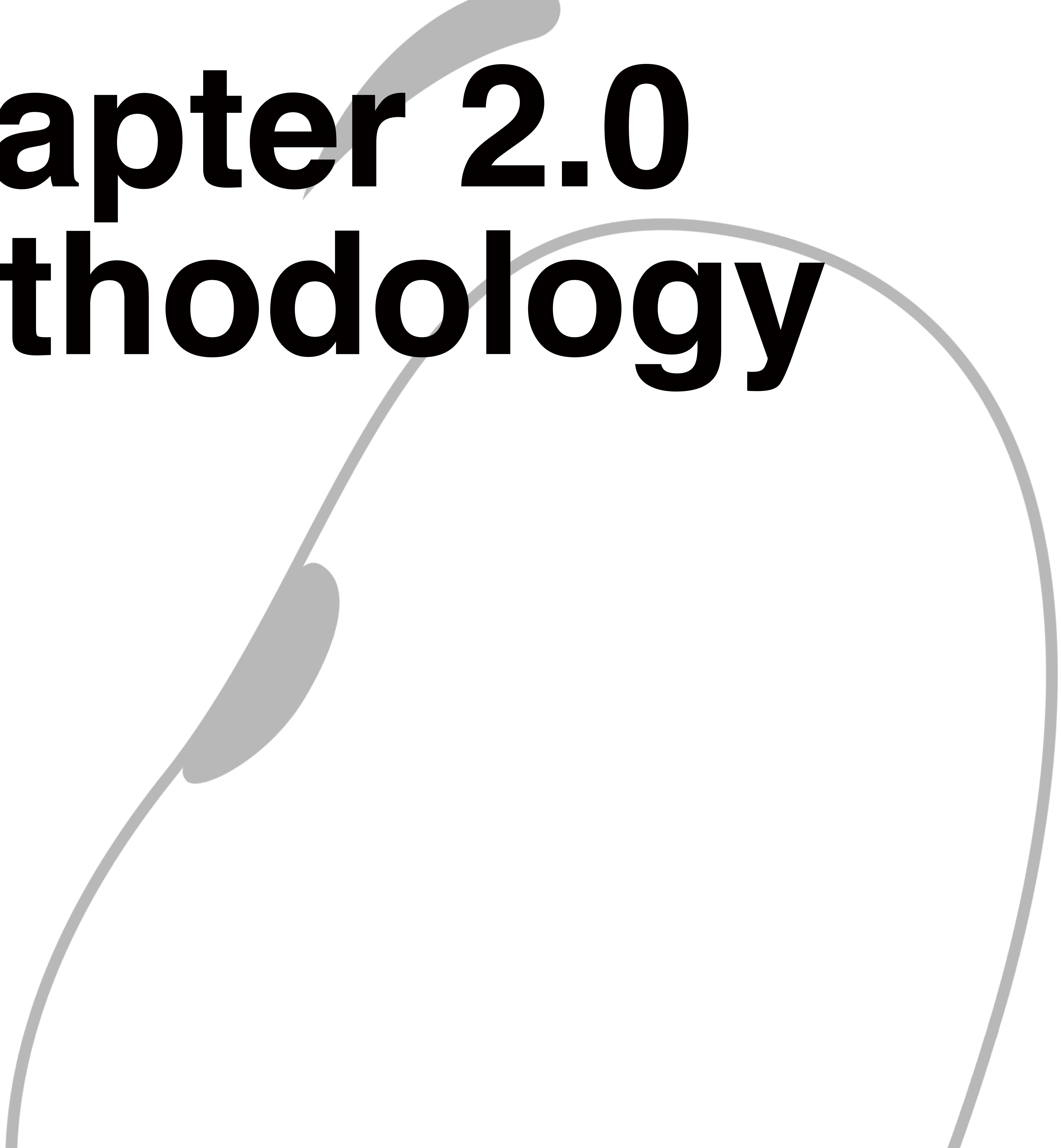


Figure 18, Figure 19, Figure 20, Figure 21: Green Product Award, 2021. BioGoods.

With the thriving of the circular economy, people first have changed their mindset from thinking of low-value materials as trash to an undeveloped valuable resource. Then they get inspirations from this ‘waste’ and make valuable things. With the continued development of technologies and the circular economy, the value of ‘waste’ has also been found and developed. This new circular business model shows a more sustainable future for the planet.

Chapter 2.0
Methodology



2.1 Literature Review

2.1.1 DIY Material Approach

In 2015, Valentina Rognoli together with Massimo Bianchini, Stefano Maffei and Elvin Karana published an article called DIY materials.In this article, they proposed the concept of Do-It-Yourself (DIY) Materials at the first time. DIY materials 'are created through individual or collective self-production practices, often by techniques and processes of the designer's own invention.' (Rognoli, Bianchini, Maffei and Karana, 2015) These Do-It-Yourself materials can be new materials or modified materials or improved versions of existing materials. Furthermore, in this article, they classified the DIY materials into two categories. The first one is DIY new materials, which focus on creating material ingredients. For instance, many kinds of research on bioplastic are focusing on developing new ingredients and recipes. The second one is DIY new identities for conventional materials, which focus on new manufacturing techniques. For example, the 3D printing technique is developed to print clay and metal. People can easy to see that DIY materials is also a new approach of the combinations of making, crafting and personal fabricating.

For example, Maria Idicula Kurian (Solanki, 2018) has a project called 'Calibrated Water Super-Synthetics'. Kurian from MA in Material Futures at Central Saint Martins, London, is concerned about the plastic issue, and try to create drinking vessels from natural materials. The cups she made from gelatine or rice starch could dissolve after minutes or seconds of use. From her studies, she aims to reduce the consumption of single-use plastic items.

Figure 22, Figure 23: Kurian, M., 2017. Super-Synthetics.

2.1.2 Five Kingdoms of DIY material

In 2017, at the 'International Conference on Experiential Knowledge and Emerging Materials', Camilo, Valentina and Elvin together proposed the Five Kingdoms classification of DIY-materials. They took inspiration from the first biological classifications Linnaean Taxonomy: the first three kingdoms of nature (created by the Swedish botanist, zoologist and physician Carolus Linnaeus) to DIY-M Taxonomy: the first five kingdoms of DIY-Materials. (Garcia, Rognoli and Karana, 2017)

According to Linnaean taxonomy, the natural world is divided into three kingdoms: plant, animal and mineral. Camilo, Valentina and Elvin collected and analyzed over 150 cases of DIY-Materials and finally came out the five DIY-Materials Kingdoms as follows: Kingdom Vegetabile, Kingdom Animale, Kingdom Lapideum, Kingdom Recuperavit, and Kingdom Mutantis.

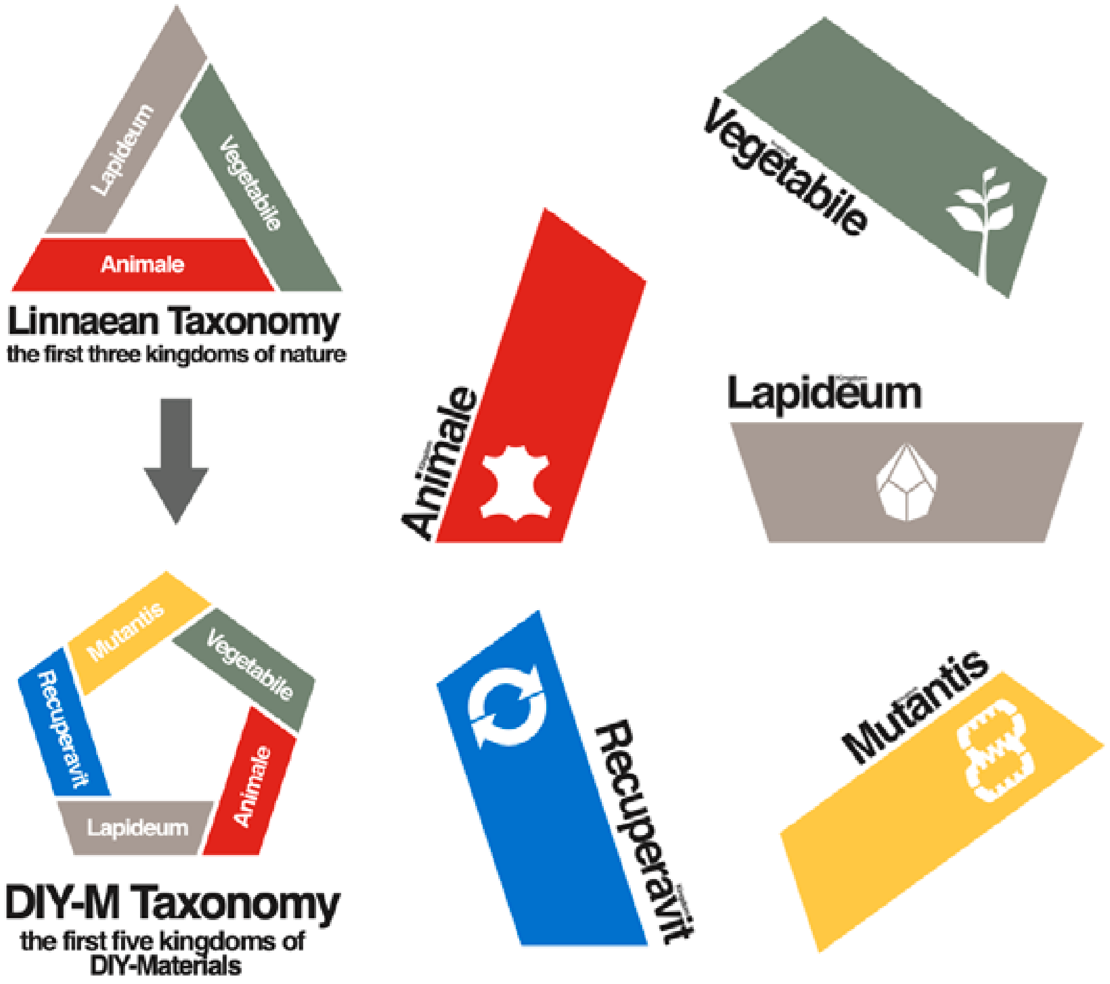


Figure 24: Rognoli, V., Garcia, C., Karana, E., 2017. Five Kingdoms of DIY-Materials.

1. Kingdom Vegetabile

In section Kingdom Vegetabile, the primary source of a DIY-Materials should derive from plants and fungi. Different from other DIY-Materials, DIY-Materials from this section can derive from growing or farming techniques. Designers who work in this direction also collaborate with farmers, biologists, etc. For example, Sebastian Cox and Ninela Ivanova used mushroom mycelium to create suede-like furniture. (Frearson, 2017) This project called Mycelium + Timber. Sebastian and Ninela used discarded goat willow to create thin strips which might weave together to become individual moulds. Then they added a particular fungus called fomes fomentarius into the mould. The fomes fomentarius took wooden strips as food and cultivated them in the mould. Sebastian and Ninela tried to use this fungal material to create more everyday products which suit any domestic interior.

Figure 25: Frearson, A., 2017. Mycelium + Timber.

2. Kingdom Animale

Kingdom Animale is a section of animals and bacteria sourced materials. These materials can either be developed by collaborating with living organisms or by using parts of the animals. In recent years, designers and scientist made some progress on bacterial pigment. Material designer and systems thinker Natsai Audrey Chieza took bacteria to dye silk which has no chemical fixatives. (Solanki, 2018) This achievement of bacterial colours is also a successful collaboration between design and science. The Streptomyces are only cultivated under strict laboratory conditions, for example, the acidity of the environment and the temperature. Since the pigments were derived through the natural excretion process, it could reduce about 500 times water than the traditional dyeing method, and cut off the use of harmful chemicals.

Figure 26, Figure 27: CNN Staff, 2018. Textiles dyed with bacteria.

3. Kingdom Lapideum

Kingdom Lapideum contains all DIY-Materials from minerals, like stones, sand, ceramics, clay. Also, materials in this section have a strong relationship with craftsmanship. Some cases might combine source from Kingdom Lapideum with other Kingdoms, like wool or cotton fabrics. However, compared to the main constituent, the materials from other Kingdoms only take a small portion. In the Lexus Design Award 2019, there is a project Arenophile, by Tezzan Hasoglu, which aims to seek a new purpose for desert sand. (Ghadiok, 2019) Tezzan used the sand from the desert to create a new kind of composite material used in making products in the future. According to Tezzan, the most successful trial was the fusion with glass and ceramic. Thus, she decided to build products by fusing the sand with glass tiles.

Figure 28, Figure 29: Courtesy of Lexus Design Award, 2019. Arenophile.

4. Kingdom Recuperavit

Materials from this section come from all sources that considered as waste by society. Through some proper transformation, the waste turns into a valuable resource. The waste can be plastic, metal or organic waste. It also includes the by-product from the manufacturing process. In the pulp and paper industry, there is a rich lignin resource from the wastewater. Lignin is considered raw material for green and cost-efficient carbon fibres. It proves its value to manufacture light but strong materials. (Nannoni, 2019) In recent years, much research about lignin is focusing on the automotive industry. According to Mainka et al, lightweight design is an important direction of the Volkswagen to reduce the emission of carbon dioxide. (Mainka et al., 2015) Although lignin is pretty attractive, many designers pay attention to the most available open-source, plastic, in people's life. Designer Micaella Pedros excavated the functional value of plastic bottles. Micaella used the heat gun to make the plastic bottles heat-shrinking into malleable rings. And this becomes the assemble tool of the join furniture. (Tucker, 2016) These cases also prove the huge potential in the Kingdom Recuperavit.

Figure 30, Figure 31: Tucker, E., 2016. Joining Bottles.

5. Kingdom Mutantis

Kingdom Mutantis contains the DIY-Materials created from various technologies and hybridization of the industrial, interactive or smart source. The application of new technology in material innovation has significant meanings in the material's nature and behaviours in comparison to other kingdoms. Therefore, cases with technology transformation are included in this section. Since 3D print has invented and gotten into the production process, people have never stopped the exploration with this technology. According to the MIT Self-Assembly Lab, the next generation belongs to self-assembly and programmable material technologies. (Self-Assembly Lab, 2020) BioMolecular Self-Assembly is a project completed for the TED Global Conference in 2012. This project collaborated with molecular biologist Arthur Olson and aimed to demonstrate molecular self-assembly through tangible and physical models. Every beaker has a single molecular structure with different colours. If people shacked the beaker hard enough, the structure would be broken into parts, or consistently, or randomly, which allowed the object to self-assemble.

Figure 32: Self-Assembly Lab, 2012. BioMolecular Self-Assembly project.

These five Kingdoms classification aims to help designers to understand what kind of sources they could choose as a starting point for further development. Apart from the traditional sources from plants and vegetables, animals, or minerals, designers also shifted their definition of waste to raw materials, such as the scraps from industrial processes, food waste, dung and so on. However, many DIY-Materials are not from a single kingdom, they might combine with two or more different kingdoms. In the anther word, the bounders of these five kingdoms are not strict, they just refer some directions for designers. (Garcia, Rognoli and Karana, 2017)

2.1.3 Material Driven Design

Material Driven Design is a method to design for material experience. The commercial success of launching a new material in the market is not only because of the functional aptness of the material but also the meaningful user experiences elicited by the material. Although it is really important to design for experiences with and for a material, there are rare to find some methods. (Karana, Barati, Rognoli and Laan, 2015) Therefore, Karana, Barati, Rognoli and Laan proposed a method, Material Driven Design, in 2015. According to Maine, Probert and Ashby, the adoption of a new material requires a long period, typically of 20 years and more. The application period contains the technology improvements, first commercial application and widespread uptake of the material. (Maine, Probert and Ashby, cited in Karana, Barati, Rognoli and Laan 2015) The PLA was discovered around 1890 but applied in the packaging industry in the 1960s. (Stevens, cited in Karana, Barati, Rognoli and Laan 2015) However, if the material is not socially and culturally accepted, it won't widespread uptake. (Manzini, cited in Karana, Barati, Rognoli and Laan 2015)

The following figure illustrates how the MDD Method works. There are four main action steps in this method, Understanding The Material: Technical and Experiential Characterization, Creating Materials Experience Vision, Manifesting Materials Experience Patterns and Designing Material/Product Concepts. First of all, designers should understand the material in hand. Designers need to characterize the materials both technically and experientially. Second, designers are suggested to create a materials experience vision that shows how a designer envisions a material's role in contributing to performance and user experience. The third step is manifesting materials experience patterns. The designers are guided to analyze and cluster the results from the second step. In this stage, designers are expected to understand how others would interact or experience material by his or her understanding. Stage four creating material/product concepts does not have to be in the fourth step. For instance, a designer might already have an idea for a potential product after step 1. In this case, material considerations and product concept creation come together. (Karana, Barati, Rognoli and Laan, 2015)

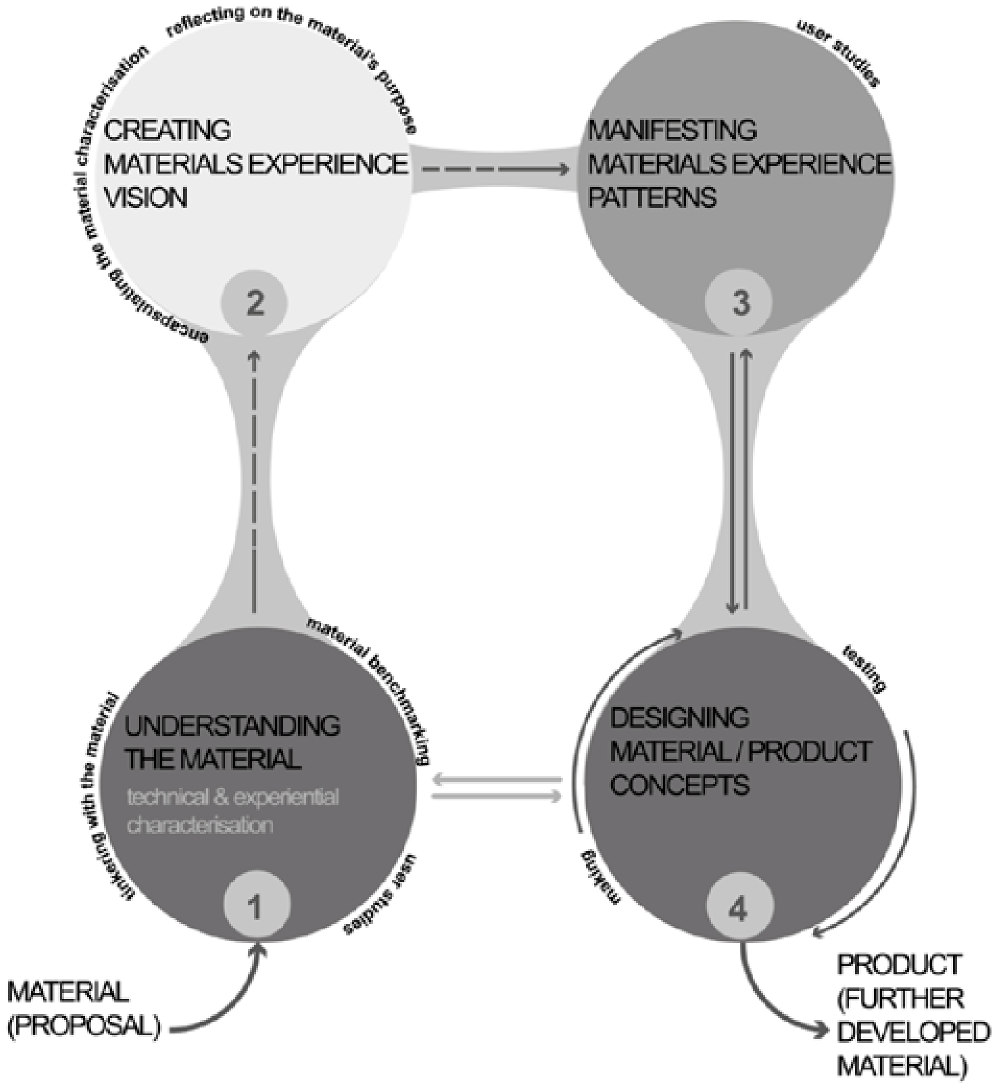


Figure 33: Karana, E., Barati, B., Rognoli, V. and Laan, A., 2015. Material Driven Design (MDD).

2.2 Material Experimentation

During the researching progress, I have made many different experiments to promote my researching results. In the beginning, I was trying out different ingredients and recipes. After getting some progress, I get into the next step, tinkering with materials. Through this ‘learning by doing' process, I have a better understanding of my materials. Therefore, I could have a better vision for its further application.

2.3 Case Study

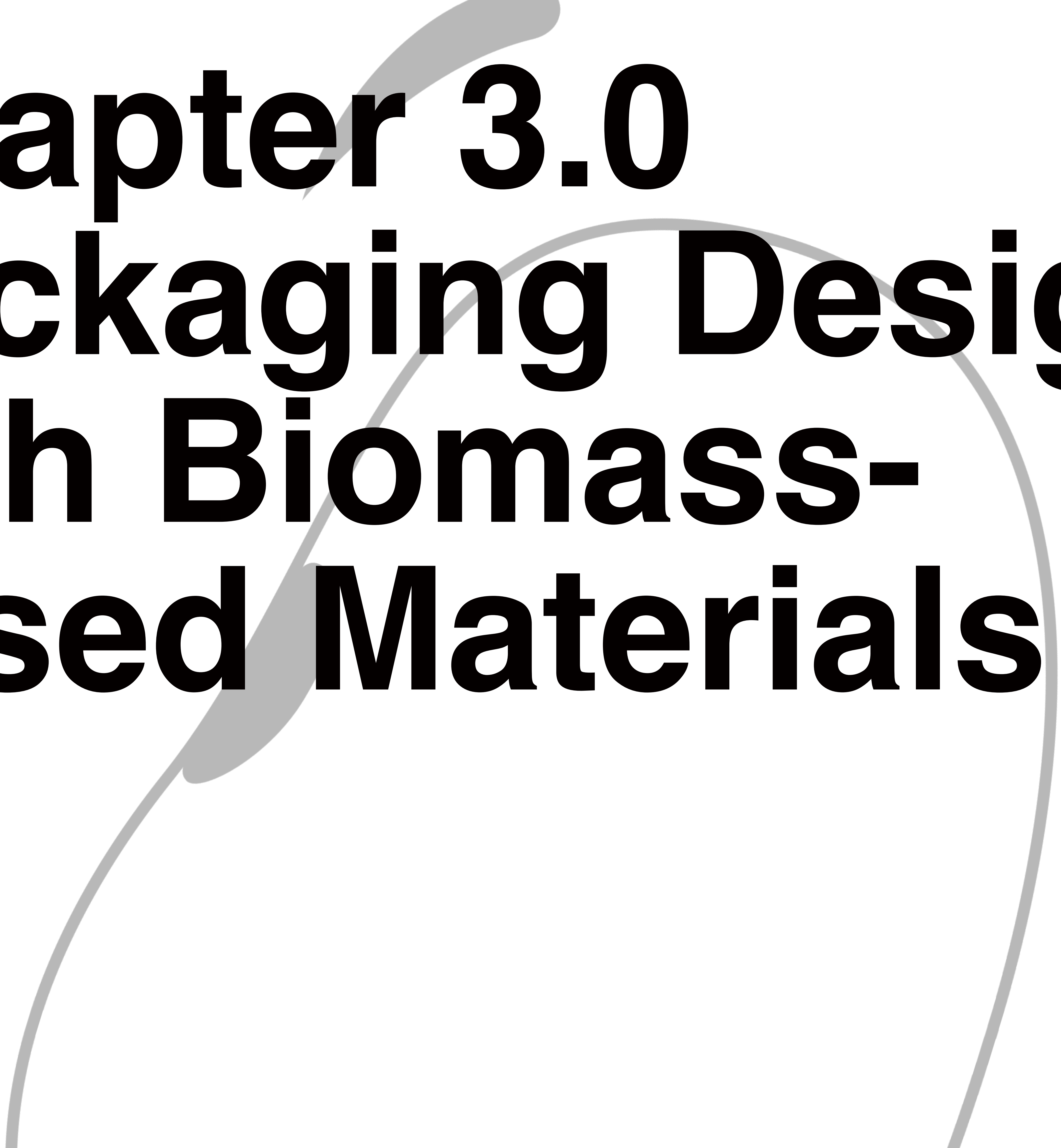
This thesis has collected many case studies from using low-value materials to create new values. They can be materials with creative use of waste, by-products from the supply chain, or even some raw materials with brand-new applications. With all the cases, I focus on the value-add of original matters. Following this preliminary definition, I have collected cases from the internet, published books and scientific papers.

2.4 Industry Researching

Since the EU has announced a commitment to ban certain single-use plastic items from 2021, the requirement of plastic alternative has boomed. Therefore, I have done researches about the packaging market as well as other industries as potential raw material supply chain. For instance, I have researched the constant increase in the soybean milk market. What could be valuable by-products from the soybean milk industry? And I also have brief research about the bamboo industry. The bamboo industry has been overlooked in the past decades. Although people recently admitted bamboo’s value as a wood replacement, it has other values to be developed.

Chapter 3.0

Packaging Design with Biomass-based Materials



In the 21st century, plastic is still the most popular material in the world. The packaging is the largest end-user segment for plastic products. About 40% of the total plastic usage is from the packaging industry. British Plastic Federation states that over 70% of the soft drinks in the global market are packing with PET plastic bottles, and only 30% of them is packed with other materials like glass, metal cans and paper-based cartons. (Plastic Packaging Market | Growth, Trends, Forecasts 2020-2025, 2020) With the Covid-19 pandemic, there shows an increasing demand for a safe and clean package in the food industry. However, the Earth is buried by the single-use plastic trash, humans need to look for ways out.

In 2018, the first-ever European Strategy for Plastics in a Circular Economy has been adopted. This strategy also promotes the transition towards a circular economy. (Plastic waste - Environment - European Commission, 2021) In all kinds of meanings, it is time for people to move away from plastic. Europe comes to a leader in supporting this transition. The EU announced a commitment to ban certain single-use plastic items from 2021. And by 2029, the collection of plastic bottles has to achieve 90% of the total. From 2006 to 2015, paper and cardboard were the main packaging waste material in the EU, then followed by plastic and glass. (Hitti, 2018) Many designers have noticed the urgent transition from the traditional packaging systems. They make efforts on studying the application of bio-materials in the packaging industry.

Seaweed-based Materials

Company Notpla proposed their solution 'NOTPLA', a seaweed-based material for this challenge. NOTPLA is made from seaweed and plant, it can biodegradable, edible and highly functional. Based on the features of NOTPLA, the company designed Ooho as a plastic alternative packaging for beverage and sauces. This packaging will biodegrade in 4-6 weeks, or people can simply eat the packaging. (We make packaging disappear - Notpla, 2021)

Margarita Talep has created sustainable, biodegradable single-use packaging by algae extraction. Talep boils the agar mixture to around 80 degrees Celsius and then transferring the molten liquid onto a mould. When the liquid drops to a temperature below 20 degrees Celsius, it takes on a gel-like consistency. Then leaving the material to dry in a well-ventilated environment with a constant temperature. In the end, it would turn to something similar to paper or thin plastic. According to Margarita, this material takes around two months to decompose in summer temperatures and four months in winter. But the decomposing period will be affected by the material thickness. (Hitti, 2019)

Figure 34: Pasliier, P., Gonzalez, R., 2014. Notpla.

Figure 35, Figure 36: Hitti, N., 2019. Margarita Talep Algae Bioplastic Packaging Design.

Scoby-based Materials

Except for the algae, SCOBY is another popular growing material for packaging application. Elena Amato creates sustainable cosmetics packaging from bacterial cellulose with paper-like qualities. The bacterial cellulose sheets are grown by a mixture of water and a bacteria and yeast culture. Amato leftover Scoby from local Kombucha producers. The dried material could be glued together with water, eliminate the use of glue or other adhesives. (Hitti, 2019)

Figure 37, Figure 38, Figure 39: Hitti, N., 2019. Elena Amato Bacteria Packaging Design.

MakGrowLab (2020) is based in Poland and designs and produces biomaterials for mission-driven companies. They take local food waste and turn it into an alternative to plastic packaging, leather and beyond. They especially focus on developing SCOBY-based materials. SCOBY refers to a ‘symbiotic culture of bacteria and yeast’. It is a key ingredient used in the fermentation and production of Kombucha. (Link, 2018) To make Kombucha, you only need tea, sugar, water and a SCOBY. In another word, Kombucha is the by-product while growing the SCOBY.

Figure 40, Figure 41, Figure 42: Rugile, 2020. MakeGrowLab Biodegradable Packaging.

Italian Designer Emma Sicher also proposed a project called ‘From Peel to Peel’, which combined food waste with bacteria and yeasts to create packaging material. Scoby together with fruit and vegetable scraps soak into water and acetic compound. During this process, the microorganisms will turn the fructose and vitamins into pure cellulose and form a gelatin-like material. Then, let the gelatin-like material dry for two to four weeks. When it gets ready, it becomes translucent and similar to paper, plastic and leather. (Hitti, 2018)

Figure 43, Figure 44, Figure 45: Hitti, N, 2018. From Peel to Peel.

Chitin-based Materials

Also, Chitin is another ingredient for a plastic alternative. A group of UK based designers have developed a series of machines that could turn seafood waste into biodegradable and recyclable bio-materials. Project Shellworks is developed by four designers from Royal College of Art and Imperial College. Their bioplastic material is made up of vinegar and a Chitin. Chitin is a biopolymer which they extracted from seafood shell. For this project, the group have invented five manufacturing machines to extract the Chitin from seafood waste. Through this way, the group hope that the bioplastic will be easier to access and could be widely adopted by other designers and promote the transition towards a circular economy. (Hitti, 2019)

Figure 46, Figure 47: Hitti, N, 2019. Shellworks.

Animal-based Materials

Icelandic design studio At10 created a bioplastic meat packaging made from the skin of the animal itself which is also the byproduct of the meat industry. This project is called Bioplastic Skin. It is the packaging used for hot dogs and ham slices. (Yalcinkaya, 2019)

Figure 48: Yalcinkaya, G., 2019. At10 Bioplastic Packaging.

Another Icelandic designer Valdís Steinarsdóttir also turned meat industry by-products into something sustainable. Valdís proposed a project called Just Bones, which use animal bones to make vessels and animal skin for packaging. Both materials could dissolve in hot water and biodegrade within weeks. (Carlson, 2021)

Lucy Hughes won the UK 2019 James Dyson Award with her fish scale bioplastic. MarinaTex is a compostable alternative material to single-use plastic, which made from wasted fish scales and skin. MarinTex is translucent and flexible, which made it a candidate for single-use packaging like bags, sandwich wrappers. Meanwhile, it takes only about four to six weeks to biodegrade. (Aouf, 2019)

Figure 49, Figure 50, Figure 51: Carlson, C., 2021. Steinarsdóttir's Bioplastic Skin and Just Bones Vases.

Figure 52, Figure 53: Aouf, R., 2019. Fish Scale Bioplastic.

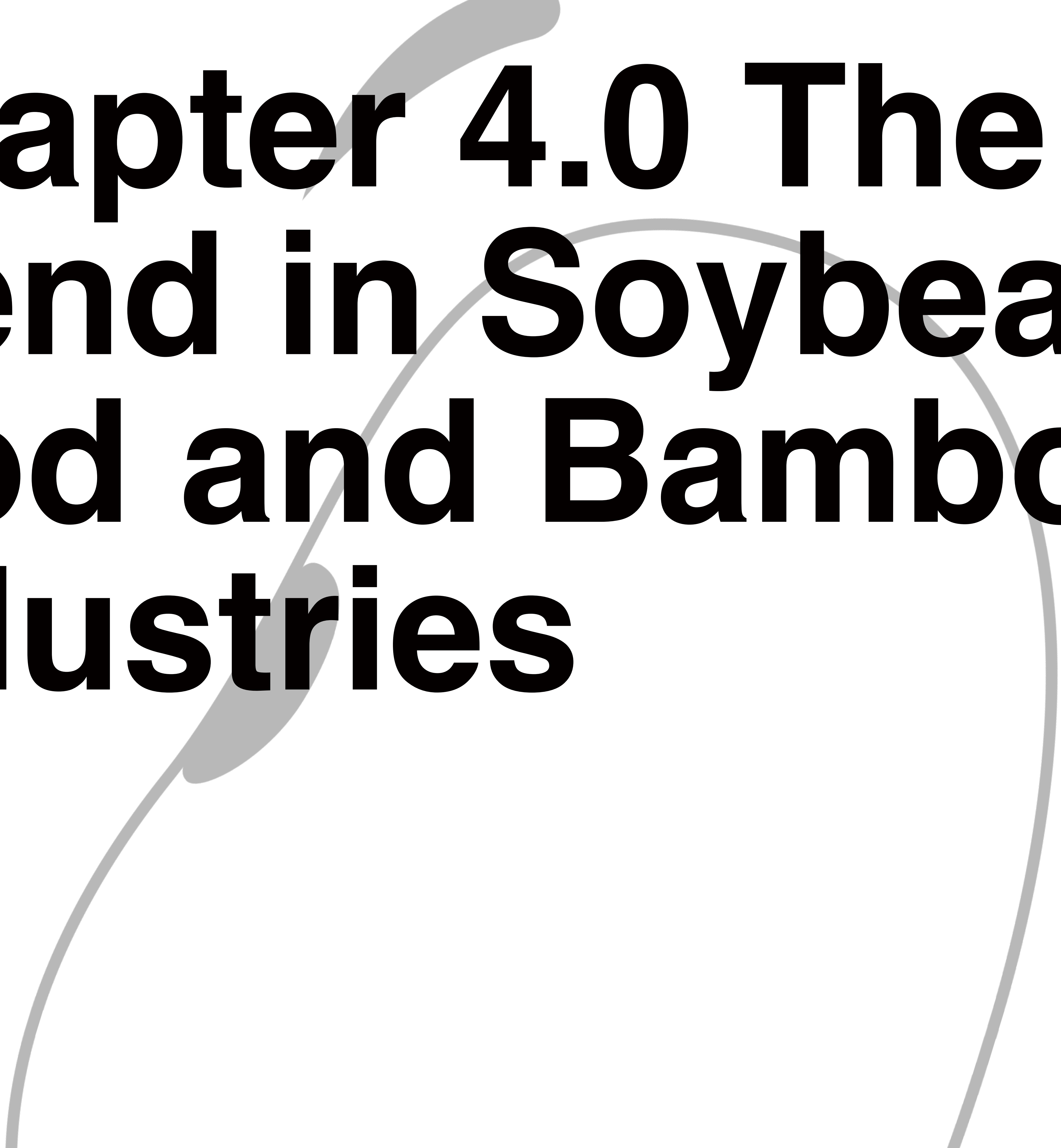
Plant-based Materials

Felix Pöttinger, a student from the Royal College of Art, used washed-up seagrass to create an alternative to plastic goof packaging. This seagrass packaging is not only biodegradable but also has antibacterial properties which could help to keep dry food fresh. The designer also claimed that he only used the dead seagrass fibres that appear on the beaches around the Mediterranean coast. (Tucker, 2017)

Figure 54, Figure 55: Tucker, E., 2017. Felix Pöttinger Biodegradable Seagrass Packaging.

Bio-materials become the new fashion in the consumption industries. Compared to plastic, bio-material is easier to access raw materials and biodegrade into harmless elements. It is such a clean and environmentally friendly choice for humans. But this industry is just started up. People should spend more time applying them in mass production systems.

Chapter 4.0 The Trend in Soybean food and Bamboo Industries



The most popular application of biomass is a biomass power plant in recent years. A biomass power plant is a power system based on burning biomass to generate heat and electricity and decline the environmental impacts. (Vallios, Tsoutsos and Papadakis, 2008) There are four main sections of biomass sources for energy, ‘Wood and wood processing wastes’, ‘Agricultural crops and waste materials’, ‘Biogenic materials in municipal solid waste’ and ‘Animal manure and human sewage’. Wood and wood processing wastes include firewood, wood pellets, sawdust and liquor from pulp, etc. Agricultural crops and waste materials contain corn, soybeans, sugar cane, switchgrass, algae, crop and food processing residues. Paper, cotton, wool products, food and yard and wood wastes are belonging to biogenic materials in municipal solid waste. According to EIA, biomass provided about 5% of total primary energy use in the United States in 2019. However, only 9% was from biomass waste. (Biomass explained - U.S. Energy Information Administration, 2020) As the article has mentioned before, the development of technologies gives people new possibilities to deal with low-value matters and process for value-add.

In recent years, the soy milk and bamboo industry are the two fast-growing markets on a global scale. Therefore, this thesis focuses on exploiting the value from the supply chain of the soy milk industry and bamboo industry.

4.1 The trend in soybean food industry

Soybean products have existed in the history of Chinese food for more than 2000 years. The tradition of drinking soymilk and soybean related products has been always popular in Asian area. However, thanks to the key point leaders in western social media, soybean products spread out band become popular all over the world. Soybean products represent the increasing popularity of non-dairy foods. It is a perfect plant protein supply for vegetarians and a new symbol for a healthier lifestyle. According to the ‘Global Soy Milk Market _ Industry Trends and Forecast to 2027’ (2020), the soy milk market is expected to achieve USD 13.44 billion by 2027.

With the increasing demand for the soybean products market, there is also a corresponding increase in the quantity of soybean by-product, soybean curd residue. Among all the soybean products, the most popular two are soy milk and tofu. Both of these two wide popular products have created large quantities of by-products during the manufacturing process. This by-product is soybean curd residue, namely, Okara in Japanese and Dòuzhā in Chinese. However, soybean curd residue is normally regarded as biomass waste. About 1 kilogram of soybeans could produce 1.1 kg soybean curd residue. (Li et al., 2013) According to Li et al, the soybean curd residue is rich in fibre, fat, protein, vitamins and trace elements. Currently, the soybean curd residue is used as a stock feed or fertilizer or just landfilled. But it has potential for value-added processing and utilization. (Li et al., 2013)

Figure 56: Data Bridge, 2020. Golbal Soy Milk Market – Industry Trends and Forecast to 2027.

Although the soybean curd residue has huge potential for value-added, it is hard to storage and transportation. The fresh soybean curd residue is very easy to spoil, especially in the warm season. It is important to expand the industrial chain of soybean curd residue, particularly on the local scale. Recently, there are more and more studies about the application of soybean curd residue.

For example, 2018/2019 Green Product Award winner Youyang Song invented biodegradable materials with soybean residues. (Cooking New Materials, 2019) Cooking New Materials is a project based on self-developed process to recycle, reuse and turn organic wastes into biodegradable textile materials. Through this project, she gives banana skin, orange peels and soya milk pomace a second life. These 100% natural products also open up new design possibilities both in product design and fashion design.

Figure 57, Figure 58, Figure 59: Youyang Song, 2019. Youyang Song's Bioplastic.

As people have an in-depth study of soybean curd residue, they open up for more ideas for utilizing the soybean curd residue, instead of just treating it as waste from the supply chain. Meanwhile, the development of technology also provides people with new possibilities to understand, utilize, to combine materials. In the nearly future, people might have better ways to store, transport, process the soybean curd residue and make it more valuable.

4.2 The trend in bamboo industry

Bamboo is a traditional material in Asian area. It serves as food for humans and animals, construction materials and raw materials for furniture. But in recent years, people admire its value as renewable and clean energy, an element against erosion, and excellent performance in strength and stiffness. The application of bamboo is ancient and widely used in eastern countries. But in the western regions, it is still seen as lower quality material. (Barbosa, Morales, Lahr et al, 2015) But in the last decades, the international trade of bamboo and rattan have increased constantly. According to the International Bamboo and Rattan Organization (2021), bamboo is considered an untapped extremely strategic resource for countries to tackle the negative effects of climate change. People recognize the value of bamboo, from a low-value material to create its new values from different applications.

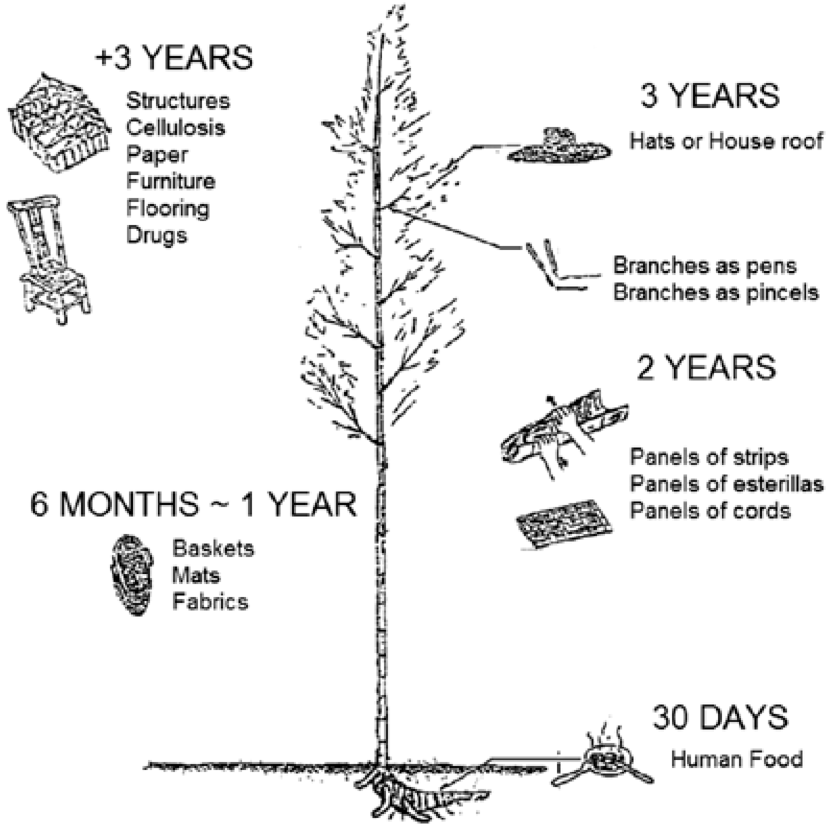


Figure 60: Nascimento, M., Morales, E., Barbosa, J. and Lahr, F., 2015. Bamboo.

With the increasing demand for wood and wood-based products, it is necessary to find alternative materials with similar properties. Bamboo can produce new bamboo shoots in the spring. These bamboo shoots will grow in height and diameter for around 60 days and then use three years to get established. (Lewis Bamboo, 2016) As bamboo is one of the fastest-growing plants, it becomes the best alternative options to wood. Europe is not a natural home of bamboo, but Italy has successfully made a bamboo forest in Parma, near Milan. (Friederich, 2019)

In the bamboo supply chain, there exist some waste, such as tops, bases, small-diameter logs, chips, branches and saw-mill waste. Barbosa, Morales, Lahr, Nascimento, De Araujo and Zaia (2015) use these waste parts to make particleboard, which shows a more valuable and sustainable use of the waste from the bamboo supply chain.

According to Nayak and Mishra (2016), the major constituents of bamboo are cellulose, hemicellulose and lignin, which take up to 90% of the total mass. For its rich cellulose contents, bamboo becomes a suitable raw material for the pulp and paper industry. Traditional uses of bamboo include pulp, paper industry, building and handicraft. (Kaur, Pant, Satya and Naik, 2016) In recent years, it is popular to use bamboo fibre to make fabric. Apart from using bamboo fibre to make fabric, people also found its value as food. People in the Asian area, especially in China, take bamboo shoots as food. In recent years, there are more and more researches about taking bamboo as food for the future. Felisberto, Miyake, Beraldo and Clerici (2017) published their study titled 'Young bamboo culm: Potential food as a source of fibre and starch'. In this research, they have pointed out the potential of using bamboo clumps to produce bamboo flour and using young bamboo culm for starch extraction, which may have good properties for good applications. What is more, fibre could be the by-product of starch extraction from the young bamboo culm. (Felisberto, Miyake, Beraldo and Clerici, 2017) Since bamboo starch is rich in fibre and barely calories, it helps to set up a healthier diet.

This material also shows its potential to face the UN global goals for sustainable development, such as No Poverty, Clean Energy, Good Jobs and Economic Growth, Sustainable Cities and Communities, Responsible Consumption, Protect the Planet, Life on Land and Partnerships for the Goals. (Friederich, 2020) With the in-depth study of bamboo, people have opened up the doors for the application of bamboo in different industries.

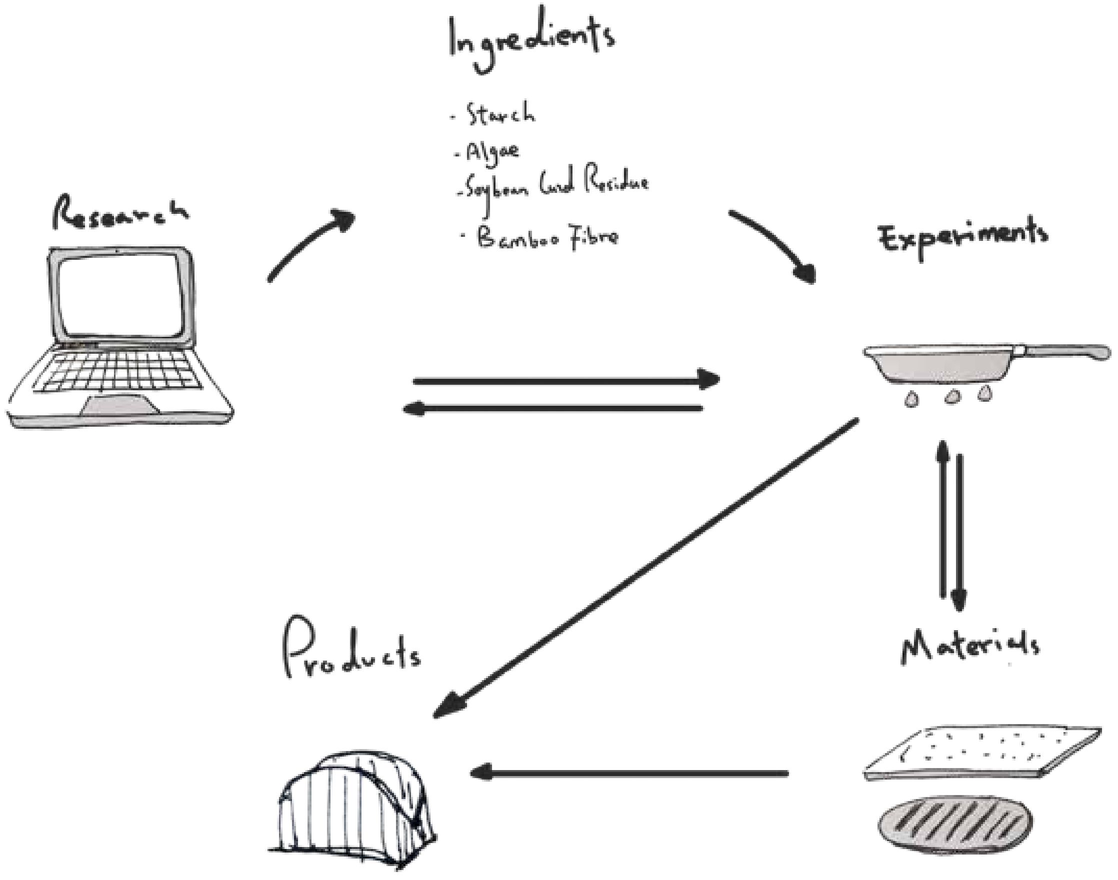
Figure 61: Felisberto, M., Miyake, P., Beraldo, A. and Clerici, M., 2017. Bamboo Culm Starch.

Chapter 5.0 Project Development

5.1 Experiment Description

This thesis aims to transmit low-value matters into valuable materials and explore This thesis aims to transmit low-value matters into valuable materials and explore the potential application fields. At the beginning of this project, I did not have any knowledge about where should I start, what kind of tools do I need and how do I make them. As a result, I researched the cases, ingredients, tools, processes and recipes in the first stage. Through this studying process, I have a better understanding of what is the bioplastic, how do I make them, what is the value of it and how could I start with my own research.

Meanwhile, I tried out some open recipes. And based on these original recipes, I gradually built up my own experimental systems, including ingredients, tools, methods, and even recipes. In the following part, I would like to share some recipes invented by myself.



Design Flow

Corn Starch Based Plastic 1.0

Ingredian:

Glycerol	10 grams
Water	80 ml
Vinegar	15 ml
Corn Starch	1.6 grams

Performance:

Sticky | Soft | Flexible | Super easy to break | No smell | Transparent beige | Thick

Recipe:

1. Add corn starch, water, glycerin and vinegar into a pot.
2. Heat over medium fire and stir for a while until the solution becomes viscous to evaporate the excess liquid.
3. Pour the mixture on a **plastic surface** and spread out a thin layer. (It will crack as it dries if the layer is too thick).
4. Leave it to dry.

Corn Starch Based Plastic 2.0

Ingredian:

Glycerol	23 ml
Water	625 ml
Vinegar	15 ml
Corn Starch	14 grams
Ink	2 drops

Performance:

Sticky | Soft | Flexible | Super easy to break | No smell | Black | Thin

Recipe:

1. Add corn starch, water, glycerin and vinegar into a pot.
2. Heat over medium fire and stir for a while until the solution becomes viscous to evaporate the excess liquid.
3. Pour the mixture on a **plastic surface** and spread out a thin layer. (It will crack as it dries if the layer is too thick).
4. Carefully mix the ink with mixture.
5. Leave it to dry.

Corn Starch Based Plastic: meet avocado skin

Ingredian:

Glycerol	10 grams
Water	80 ml
Vinegar	15 ml
Corn Starch	1.6 grams
Fresh Avocado Skin	1/2

Performance:

Sticky | Soft | Flexible | Super easy to break No smell | Transparent | Colours from avocado skin | Thick

Recipe:

1. Add corn starch, water with avocado skin (using a blender to blend it), glycerin and vinegar into a pot.
2. Heat over medium fire and stir for a while until the solution becomes viscous to evaporate the excess liquid.
3. Pour the mixture on a **plastic surface** and spread out a thin layer. (It will crack as it dries if the layer is too thick).
4. Leave it to dry.

Sodium Alginate Based Plastic

Ingredian:

Glycerol	5 grams
Water	200 ml
Vinegar	10 ml
Sodium Alginate	4 grams

Performance:

Smooth | Brittle | Flexible | No smell | Transparent | Thin

Recipe:

1. Add Sodium Alginate into water and leave it overnight to get a mixture.
2. Add the glycerol into the mixture.
3. Pour the mixture on a **plastic surface** and spread out a thin layer. Wait for few hours.
4. Pour vinegar on the surface and leave to react for 1 hour.
5. Carefully wash off the vinegar.
6. Leave it to dry.

Sodium Alginate Based Plastic: meet banana skin

Ingredian:

Glycerol	10 grams
Water	80 ml
Vinegar	15 ml
Corn Starch	1.6 grams
Fresh banana skin	1/2
Sodium Alginate	2 grams

Performance:

Smooth | Brittle | Flexible | Easy to break | No smell | Transparent | Colours from banana skin | Thin

Recipe:

1. Add corn starch, water with banana skin (using a blender to blend it), glycerin, Sodium Alginate and vinegar into a pot.
2. Heat over medium fire and stir for a while until the solution becomes viscous to evaporate the excess liquid.
3. Pour the mixture on a **plastic surface** and spread out a thin layer. (It will crack as it dries if the layer is too thick).
4. Leave it to dry.

Sodium Alginate Based Plastic: meet banana skin

Ingredian:

Glycerol	10 grams
Water	80 ml
Vinegar	15 ml
Corn Starch	1.6 grams
Fresh banana skin	1/2
Sodium Alginate	2 grams

Performance:

Rough | Brittle | Stiff | Easy to break | No smell | Transparent | Colours from banana skin | Thin

Recipe:

1. Add corn starch, water with banana skin (using a blender to blend it), glycerin, Sodium Alginate and vinegar into a pot.
2. Heat over medium fire and stir for a while until the solution becomes viscous to evaporate the excess liquid.
3. Pour the mixture on a **metal surface** and spread out a thin layer.
4. Leave it to dry.

Sodium Alginate + Corn Starch: meet spinach water

Ingredian:

Glycerol	20 ml
Water	750 ml
Vinegar	15 ml
Corn Starch	14 grams
Spinach	10 grams
Sodium Alginate	4 grams

Performance:

Smooth | Soft | Flexible | Not easy to break | No smell | Transparent | Colours from spinach | Thin

Recipe:

1. Add corn starch, water with spinach, glycerin, Sodium Alginate and vinegar into a pot.
2. Heat over medium fire and stir for a while until the solution becomes viscous to evaporate the excess liquid.
3. Pour the mixture on a **plastic surface or metal surface** and spread out a thin layer. (It will crack as it dries if the layer is too thick). Plastic surface gives the mateiral a shinning surface, and metal surface gives the material a matte surface.
4. Leave it to dry.

Sodium Alginate + Corn Starch: meet black tea 1.0

Ingredian:

Glycerol	10 ml
Tea Water	625 ml
Vinegar	20 ml
Corn Starch	14 grams
Sodium Alginate	4 grams

Performance:

Smooth | Soft | Flexible | Stiffer | Not easy to break | No smell | Transparent | Colours from black tea | Thin

Recipe:

1. Add corn starch, tea water, glycerin, Sodium Alginate and 15 ml vinegar into a pot.
2. Heat over medium fire and stir for a while until the solution becomes viscous to evaporate the excess liquid.
3. Pour the mixture on a **plastic surface or metal surface** and spread out a thin layer. (It will crack as it dries if the layer is too thick). Plastic surface gives the mateiral a shinning surface, and metal surface gives the material a matte surface.
4. Leave the mixture for four hours, then pour the other 5 ml vinegar on the mixture and let it to react with the mixture.
5. Wait for three hours and rain off the vinegar.
6. Leave it to dry.

Sodium Alginate + Corn Starch: meet black tea 2.0

Ingredian:

Glycerol	10 ml
Tea Water	625 ml
Vinegar	20 ml
Corn Starch	14 grams
Sodium Alginate	4 grams

Performance:

Smooth | Brittle | Hard | Not so flexible | Easy to break | No smell | Transparent | Colours from black tea | Thin

Recipe:

1. Add corn starch, tea water, glycerin, Sodium Alginate and 15 ml vinegar into a pot.
2. Heat over medium fire and stir for a while until the solution becomes viscous to evaporate the excess liquid.
3. Pour the mixture on a **plastic surface** and spread out a thin layer. (It will crack as it dries if the layer is too thick).
4. Leave the mixture for four hours, then pour the other 5 ml vinegar on the mixture and let it to react with the mixture.
5. Leave it to dry.

5.2 Ingredient Inspiration

Starch

Starting from the starch-based bioplastic recipe, I have kept use starch as my key ingredients for my experiments. I also try natural dye with starch-based bioplastic and get many wonderful pieces.

Algae

Waterproof is an essential element of packaging materials. Thus, I decided to turn my researching direction into water resistance ability. Agar-agar, also known as agar, is a plant-based gelation extract from red algae. (Adams, 2020) It is popular in the Asian area. People know it as China glass, China grass, China isinglass, Japanese Kanten or Japanese gelatin. In the food industry, agar-agar is used in a variety of dishes, such as puddings, mousses, jellies, ice cream and so on. I started to use algae extraction ingredient to explore the water-resistance materials, and the followings are part of the results. Meanwhile, I have made material benchmarking to generate insights on potential application areas.

Soybean Curd Residue

In China, people have a tradition of drinking fresh soy milk for breakfast. Therefore, the soy milk machine is quite popular in China. My roommate has one from China. To make soy milk, you should put the dry soybeans into the cold water and leave it overnight. After soaking enough water, the soybeans become much bigger and soft than before. Then you can just put the soybeans into the soy milk machine, add enough water, and press the button to start cooking. After about 30 minutes, the soy milk is ready for breakfast. You should use a filter to separate the soymilk liquid and the soybean curd residue. In China, people might use the soymilk curd residue to make kinds of pies, to feed livestock, to make fertilizer, but, in most cases of modern time, to throw it away. And this time, I added it into my materials and got some good results. The soybean residue provided the material with a unique matte texture, and the material becomes soft, flexible, stiffness and it is also not easy to break during the drying process. This is a very important improvement of material exploration.

Bamboo

Bamboo is considered the best replacement for wood. And in recent years, there are more and more bamboo-based tissues, fabric and papers appearing in the market. As a result, I would like to use the waste from the bamboo supply chain to make some paper-like material to replace the paper used in the packaging industry. However, I could not get the resource during this pandemic. I decided to use the bamboo fibre I got from Amazon. But to test my hypothesis, I also collected some wood sawdust from Prototype Lab to mimic the bamboo sawdust from the supply chain.

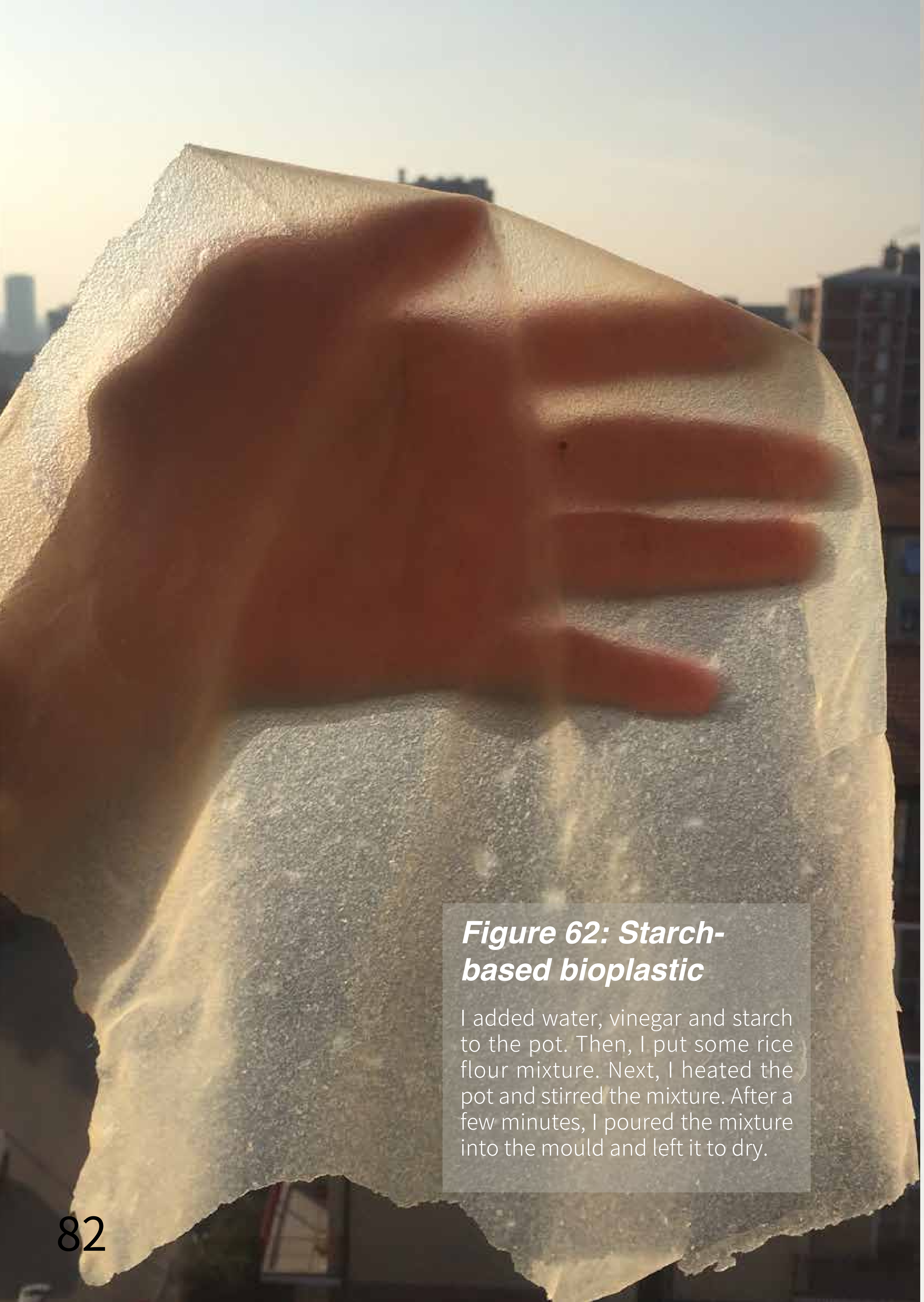


Figure 62: Starch-based bioplastic

I added water, vinegar and starch to the pot. Then, I put some rice flour mixture. Next, I heated the pot and stirred the mixture. After a few minutes, I poured the mixture into the mould and left it to dry.

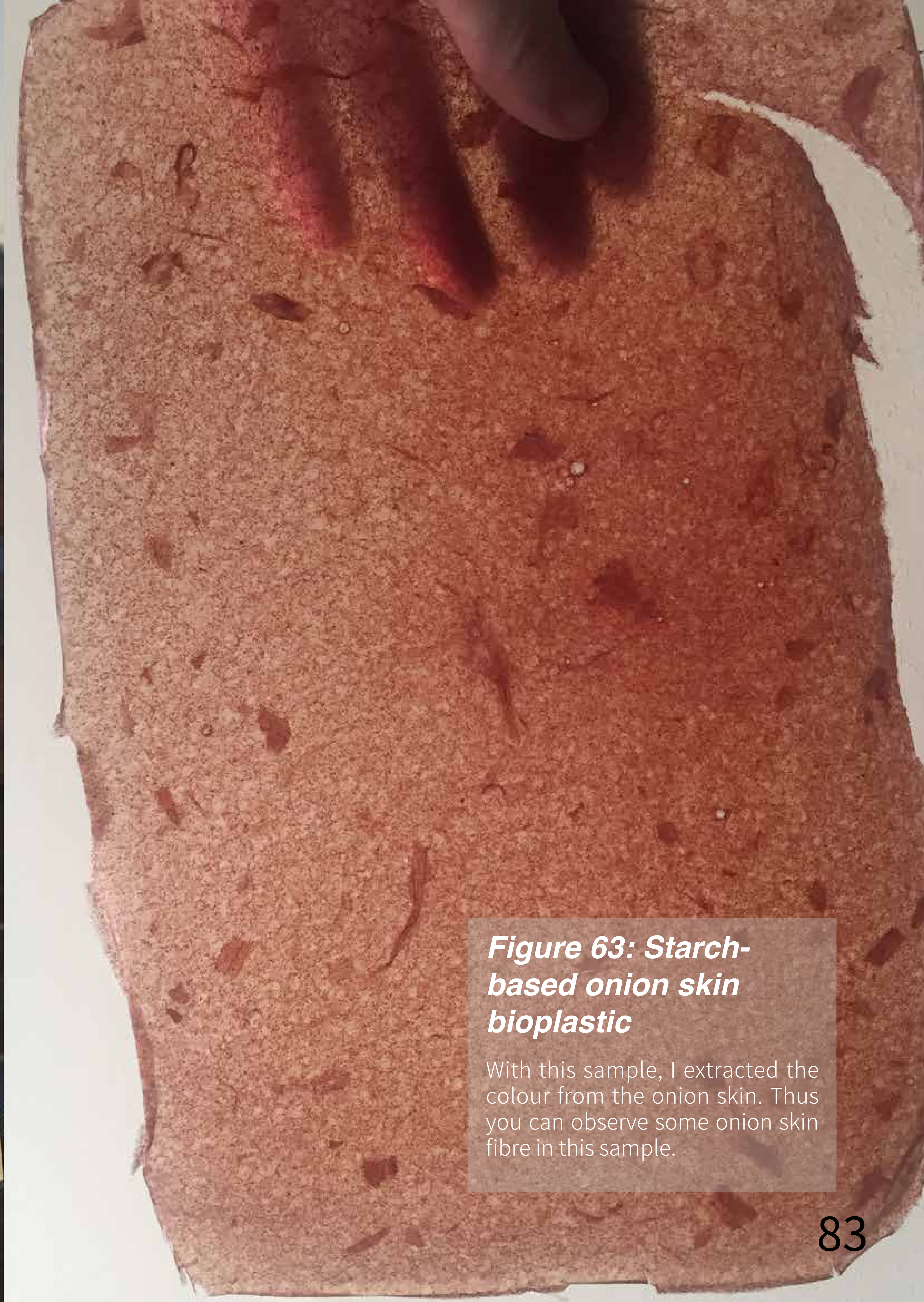


Figure 63: Starch-based onion skin bioplastic

With this sample, I extracted the colour from the onion skin. Thus you can observe some onion skin fibre in this sample.

Figure 64: Starch-based coffee ground bioplastic

This Coffee Sample is the very first starch-based coffee ground bioplastic I have made. First, I prepared about 300ml starch-based bioplastic. Before pouring bioplastic into the mould, I added about 3 spoons of coffee grounds in the bioplastic and blended them together. Then I poured the mixture into the mould and left it to dry.

Figure 65: Starch-based blueberry bioplastic

First, I blended the blueberry into small pieces. Then I used the blueberry liquid to make bioplastic. The vinegar that added in the bioplastic also affected the colour of the material. I made a mould from plastic wrap. And I poured the mixture into the mould that gave this bioplastic this unique surface texture.

Figure 66: Seaweed-based bioplastic 1.0

With this recipe, I used only water and Algae. This sample is thick, elastic and strong.

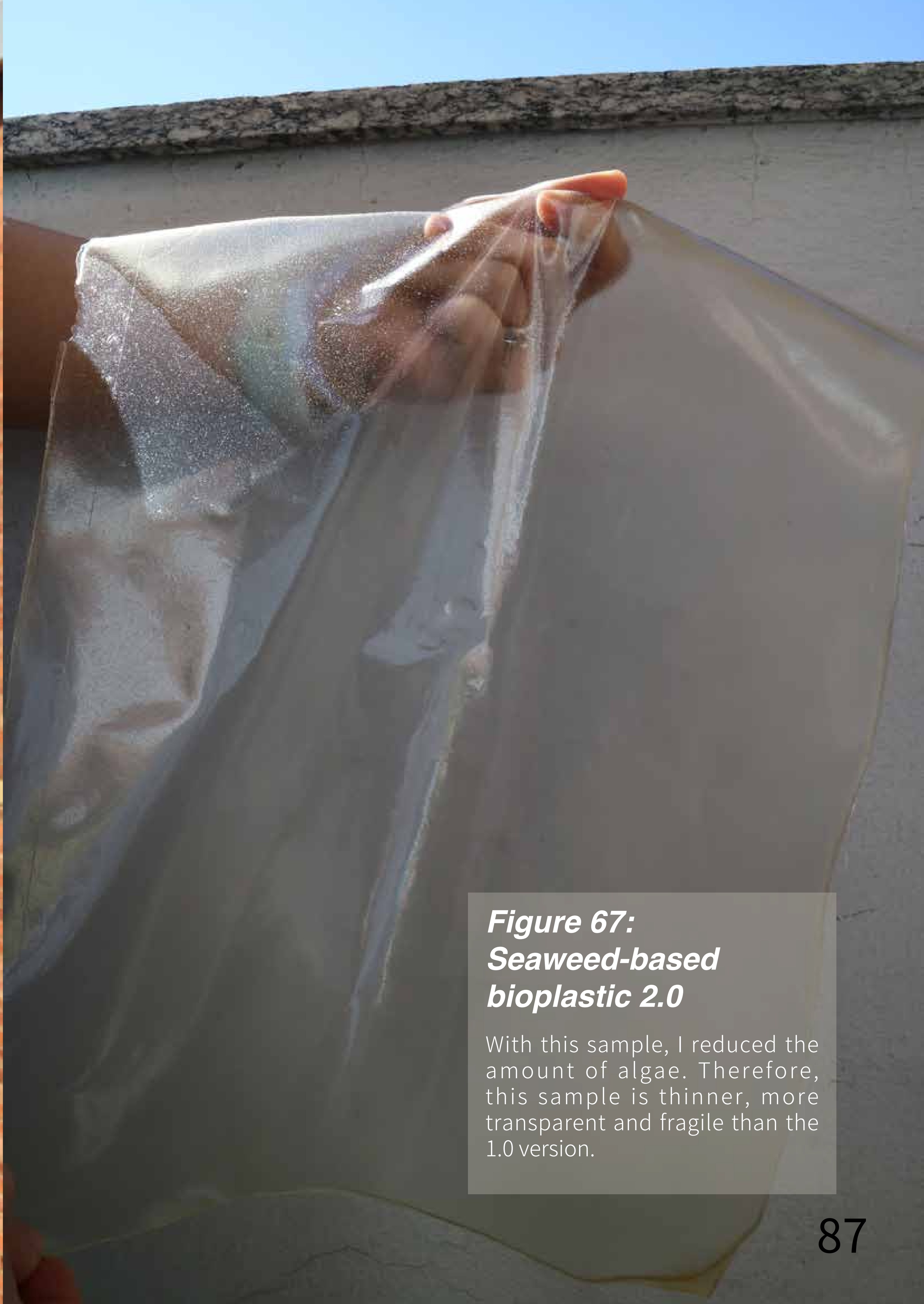


Figure 67: Seaweed-based bioplastic 2.0

With this sample, I reduced the amount of algae. Therefore, this sample is thinner, more transparent and fragile than the 1.0 version.

Figure 68: Seaweed-based bioplastic 3.0

With this recipe, I used different algae to make the sample. Moreover, I added some soybean curd residue to this sample. So you can see the soybean fibre in this sample.

Figure 69: Seaweed-based Banana bioplastic

With this material sample, I added banana skin to the recipe. The banana skin gives the material an amazing colour and texture.

Figure 70: Soybean curd residue bioplastic 1.0

The soybean curd residue gives the sample a unique texture as well as colour.

Figure 71: Soybean curd residue bioplastic 2.0

This pure soybean curd sample was poured into a metal mould.

Figure 72: Red bean and Soybean curd residue bioplastic

This sample is made of red bean and soy bean residue. Thus, the sample has a pinkish colour.

Figure 73: Plastic Net and Soybean curd residue bioplastic

I combined the Plastic Net with the Soybean curd residue to get this sample. Since the bioplastic part could biodegrade, the plastic net could be recycled and reused again.

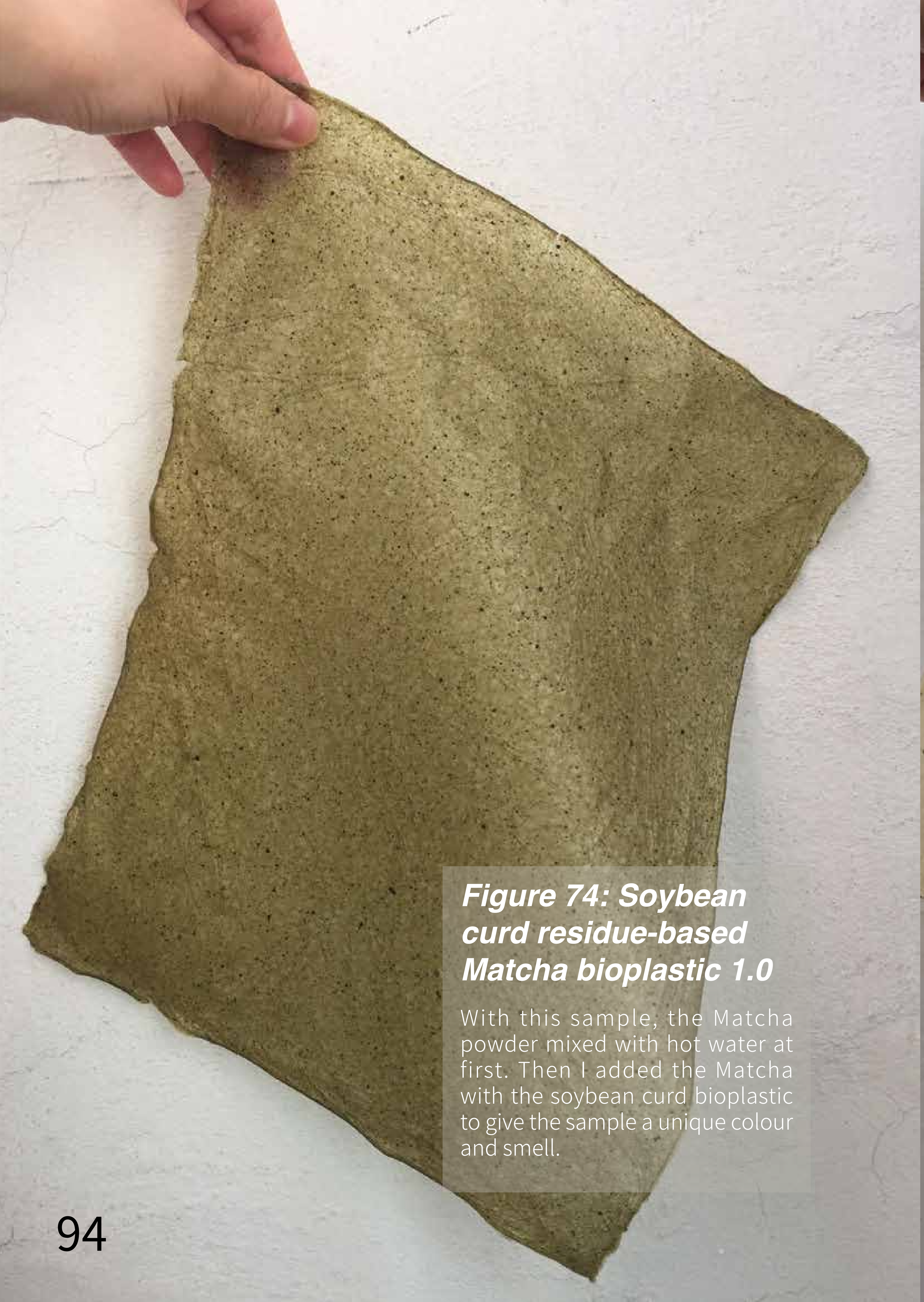


Figure 74: Soybean curd residue-based Matcha bioplastic 1.0

With this sample, the Matcha powder mixed with hot water at first. Then I added the Matcha with the soybean curd bioplastic to give the sample a unique colour and smell.

Figure 75: Soybean curd residue-based Matcha bioplastic 2.0

The Matcha 2.0, the Matcha powder directly added into the soybean curd bioplastic without pre-dissolve. Therefore, the Matcha powder was agglomerated and gave the sample a 3D texture.

Figure 76: Soybean curd resdue-based Curcuma bioplastic

I dissolved the Curcuma powder in the hot water and then mixed the Curcuma with 1/3 of soybean curd bioplastic. Then I poured the mixture to the mould. Next, I added more Curcuma powder in another 1/3 of soybean curd bioplastic and poured the mixture to the mould to have the dot pattern. The last 1/3 of soybean curd bioplastic poured to the mould for the dot pattern.

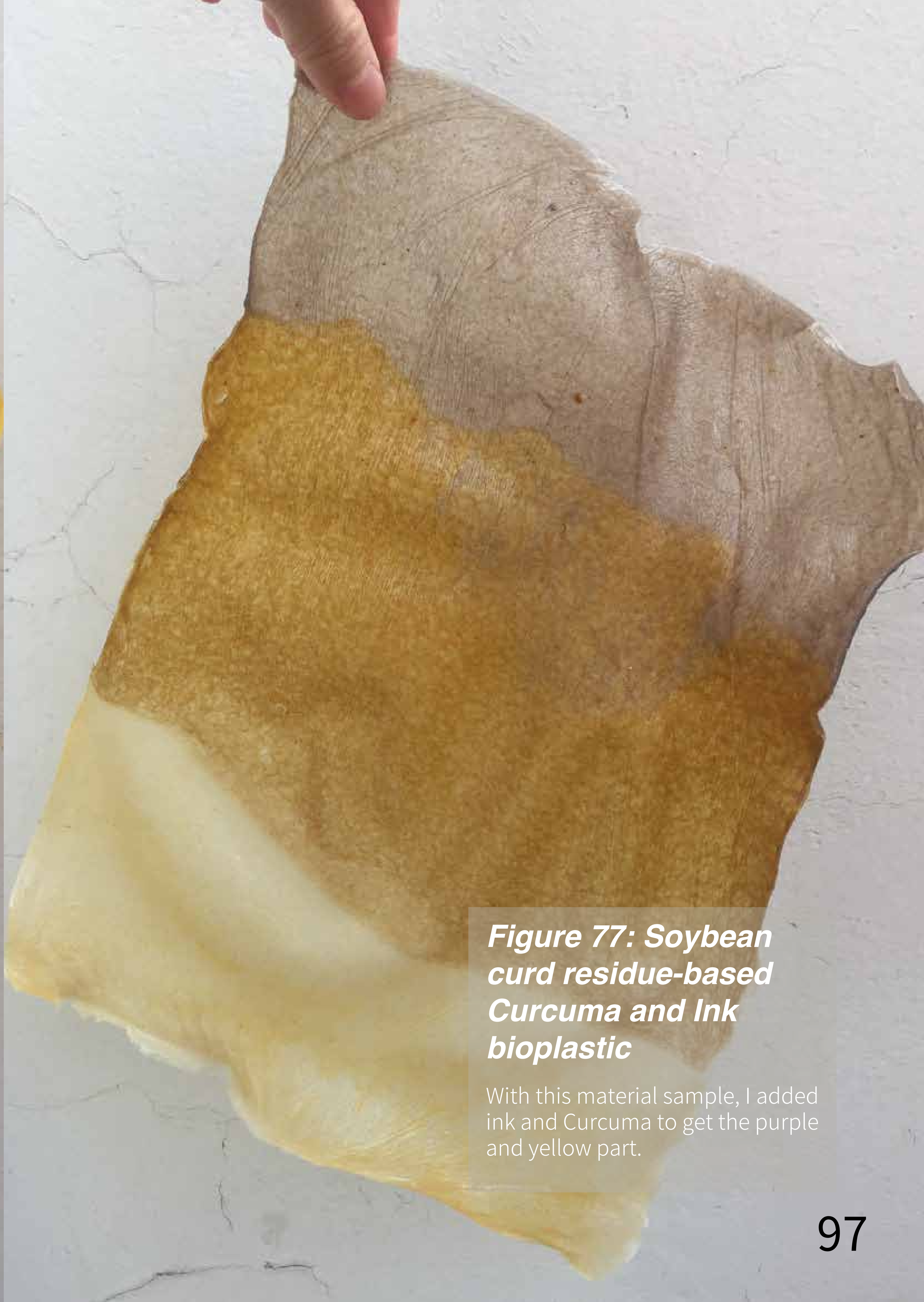


Figure 77: Soybean curd residue-based Curcuma and Ink bioplastic

With this material sample, I added ink and Curcuma to get the purple and yellow part.

Figure 78: Bamboo-based bioplastic

I used the edible bamboo fibre to make this material sample. It has a unique suede-like surface. I also added some thread scraps to make this sample.

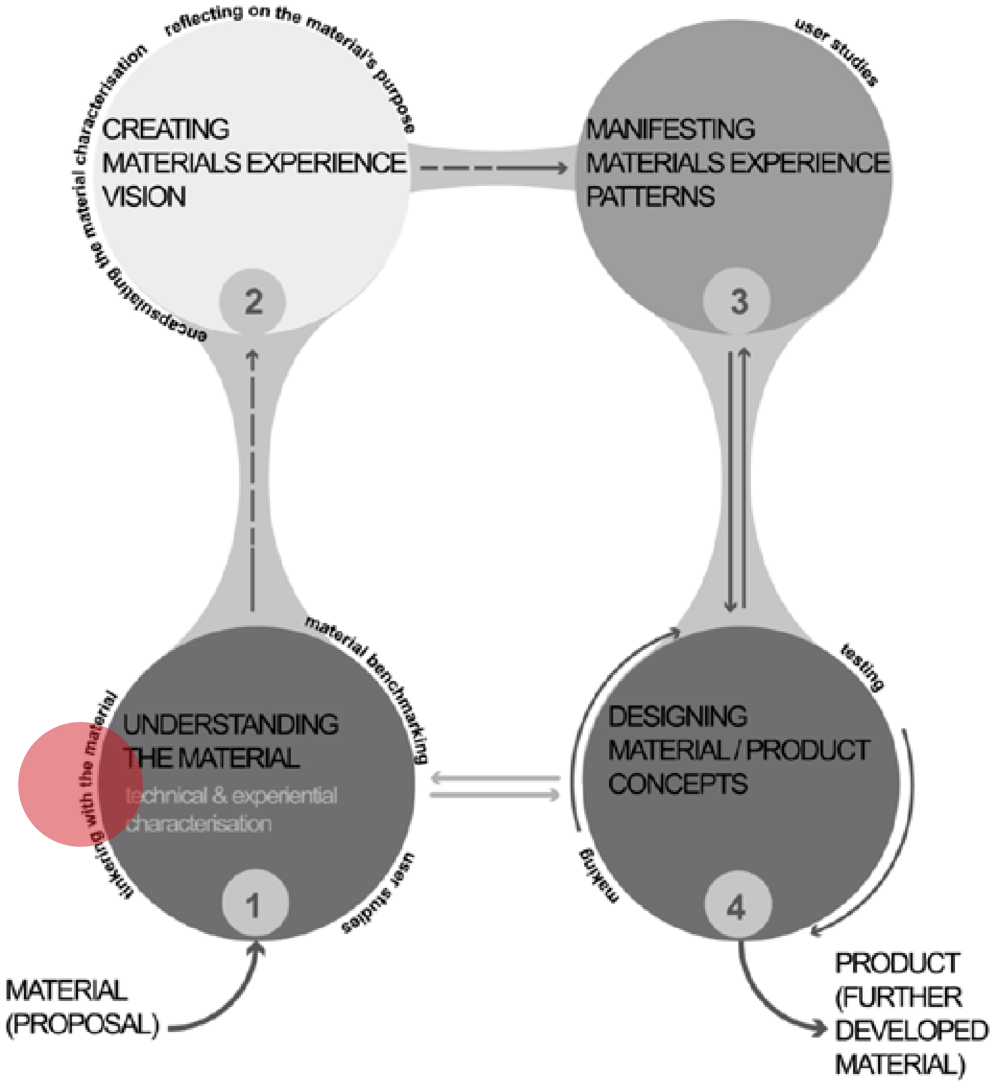
Figure 79: Wood sawdust bioplastic _ a test for bamboo

This sample is a test for further exploration. I went to Prototype Lab to collect some sawdust to make this sample. With this sample, I believe that I could find some similar bamboo sawdust waste from the bamboo supply chain to make the material.

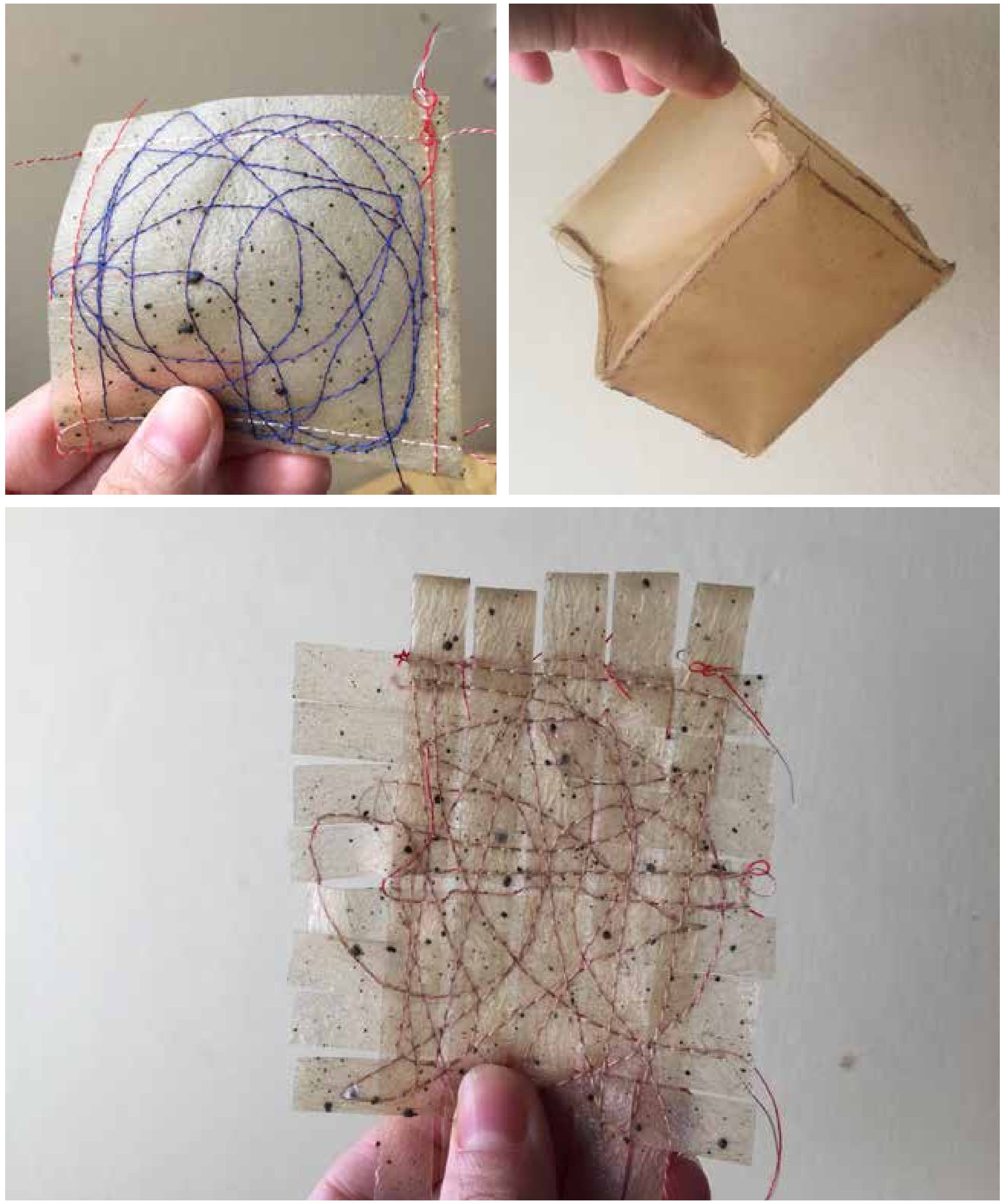
5.3 Application Exploration

5.3.1 Understanding the Material

According to Elvin et al, the qualifying of material is not only for what it is, but also for what it does, what it expresses to people, what it elicits from people, and what it makes people do. (Karana, Barati, Rognoli and Laan, 2015) As a result, I decided to apply Material Driven Design Method to guide my material application explorations. The first step of MDD is 'Understanding the Material: technical & experiential characterisation'. Following this step, I started to **Tinkering with the Material**. According to Rognoli et al (2015), Tinkering with the material is a method to get insights on what the material affords, the technical/mechanical properties of it, and how it can be shaped/embodied in products. Therefore, I have tested the usability of my DIY material, like sewing, folding, water resistance, oil resistance, heating, downcycle, etc.



Sew



The material is suitable for machine sewing as well as hand sewing.

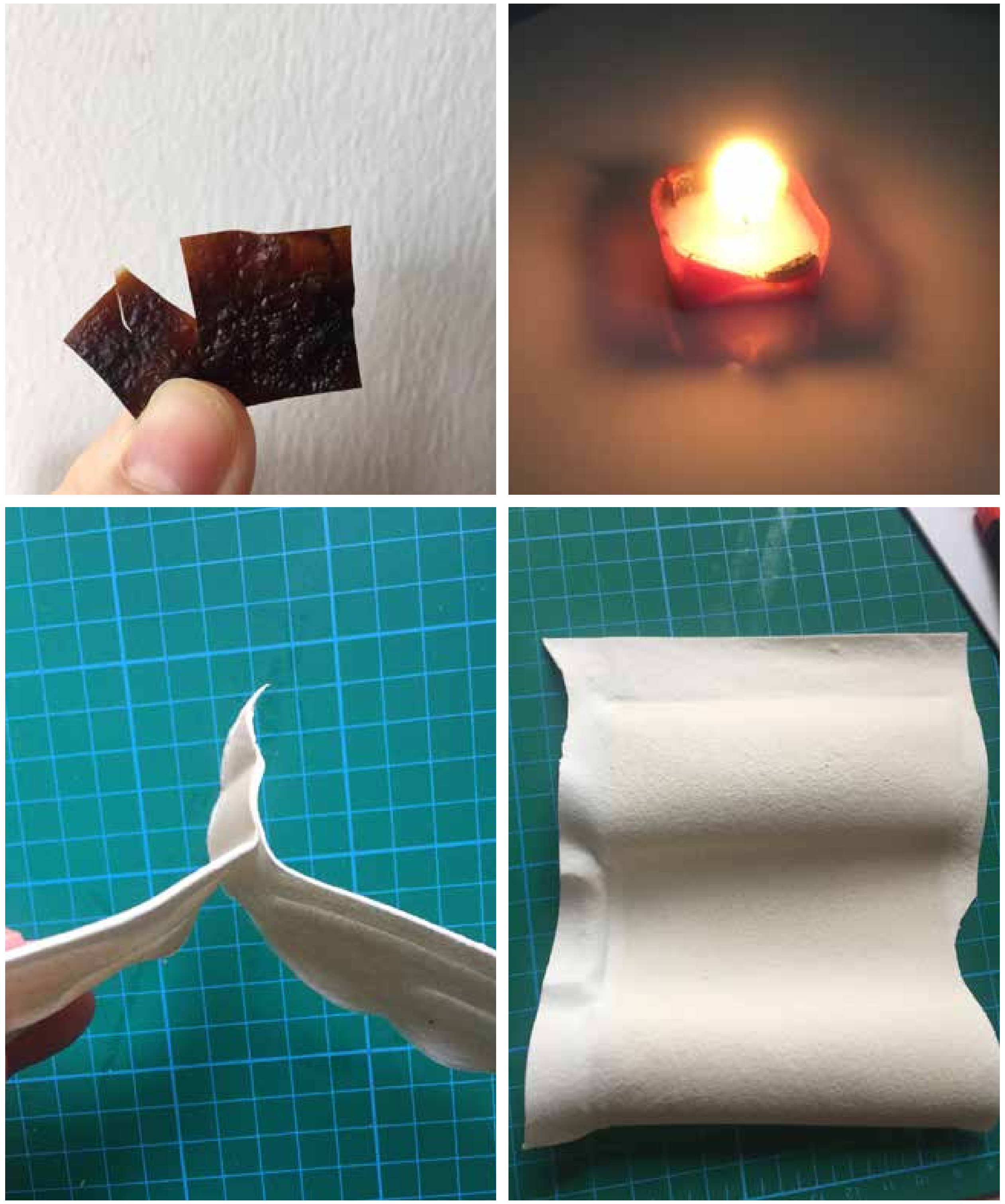
Fold

I have tried to fold the material and also make some origami with them. Although these materials are not good as paper, they have shown the possibility of being fold.

Water Resistance

The BambooMe materials have shown its great waterproof feature.

Heat



The starch-based material shows its ability to be non-flammable. And when it burns, it has a smell like popcorn. And when heat and press the BambooMe material, the material will melt and could be reformed.

Oil Resistance

The material has great oil resistance. I had left the oil on the material for 3 days, and did not observe any oil leaking out to another side.

Downcycle

The BambooMe material could downcycle.

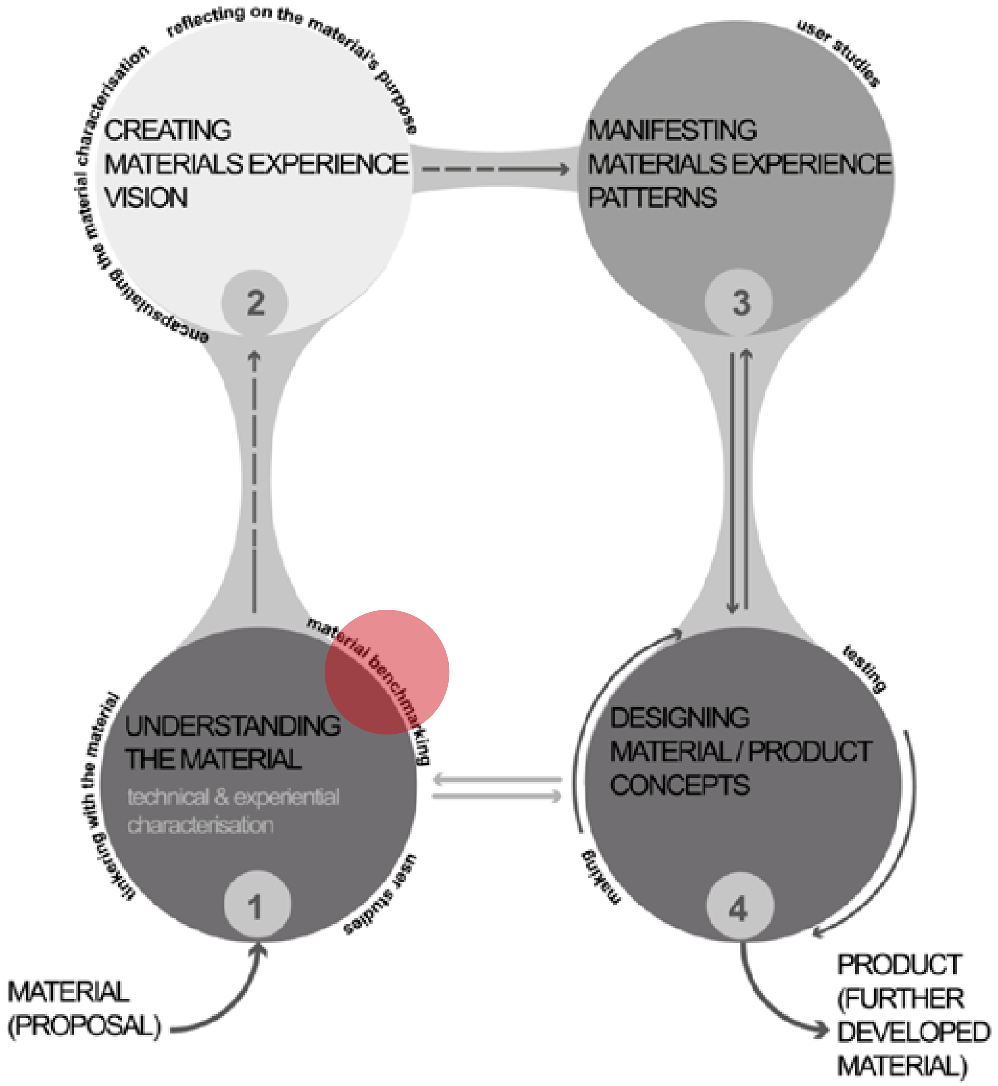
Biodegrade

Both BambooMe material and SoyMe material can biodegrade. The small SoyMe pieces took one week to biodegrade. And the Bamboo piece requires more weeks to totally biodegrades. Water and rotten petals will accelerate the process of degrading.

Superimpose

While making different materials, I also tried to superimpose different materials. I put the AglaeMe material on the first layer, then the SoyMe material on the second layer and the BambooMe material at the end.

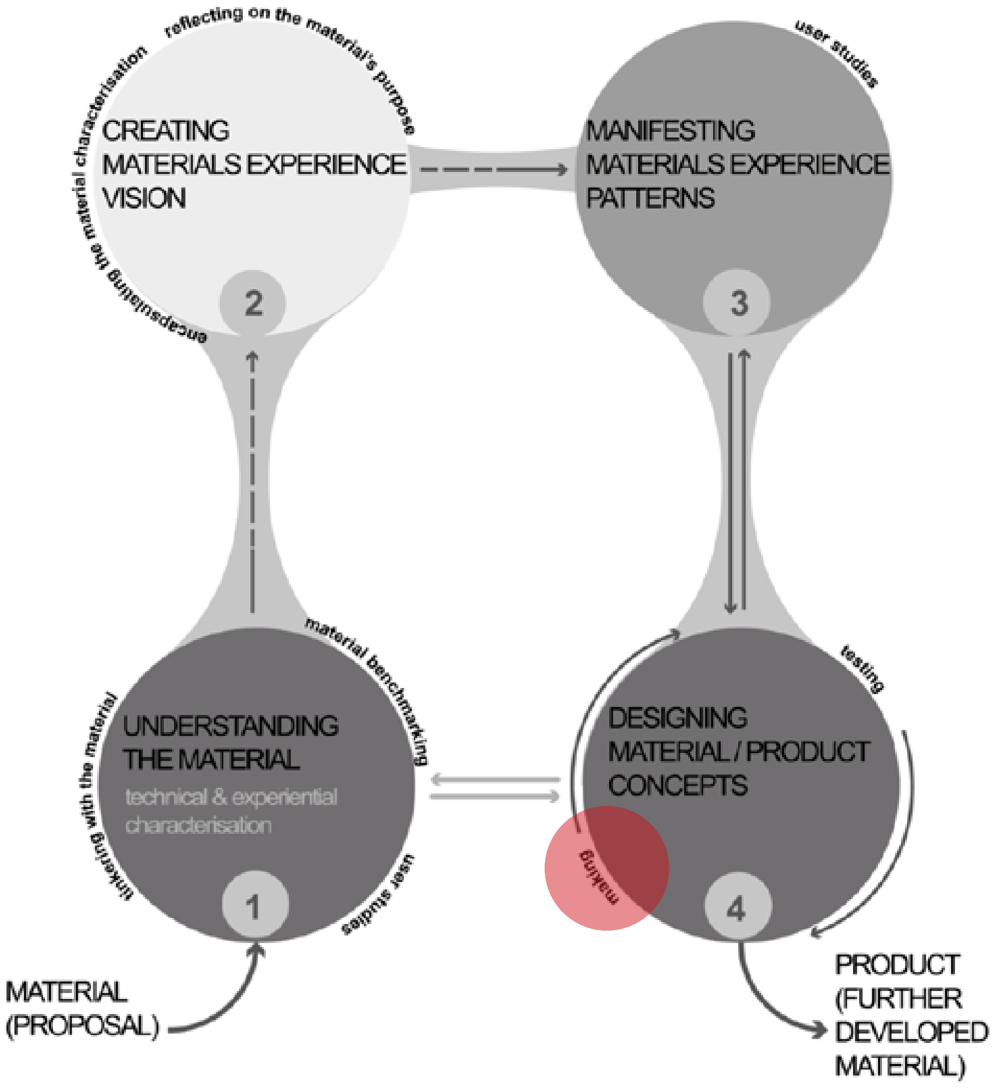
Apart from Tinkering with the Material, **Material Benchmarking** is another powerful tool to position the material amongst similar or alternative materials. It helps designers to generate insights on potential application areas of the material. (Karana, Barati, Rognoli and Laan, 2015) I collected information, images, ideas, and examples to make the Material Benchmarking and figure out the potential application areas of my DIY materials.



Material Benchmarking

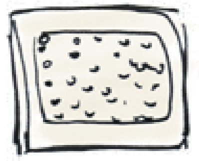
5.3.2 Designing Material/ Product Concepts

Through the first step, I have understood the material from what it can do, what it cannot do. I was inspired by what I have learned from the first step and turned it into the fourth step, **Creating Material/Product Concepts**. I sort these concepts into three categories by their attributes, algae, soybean curd residue and bamboo fibre. The following part has given examples of product concepts and the material datasheets.



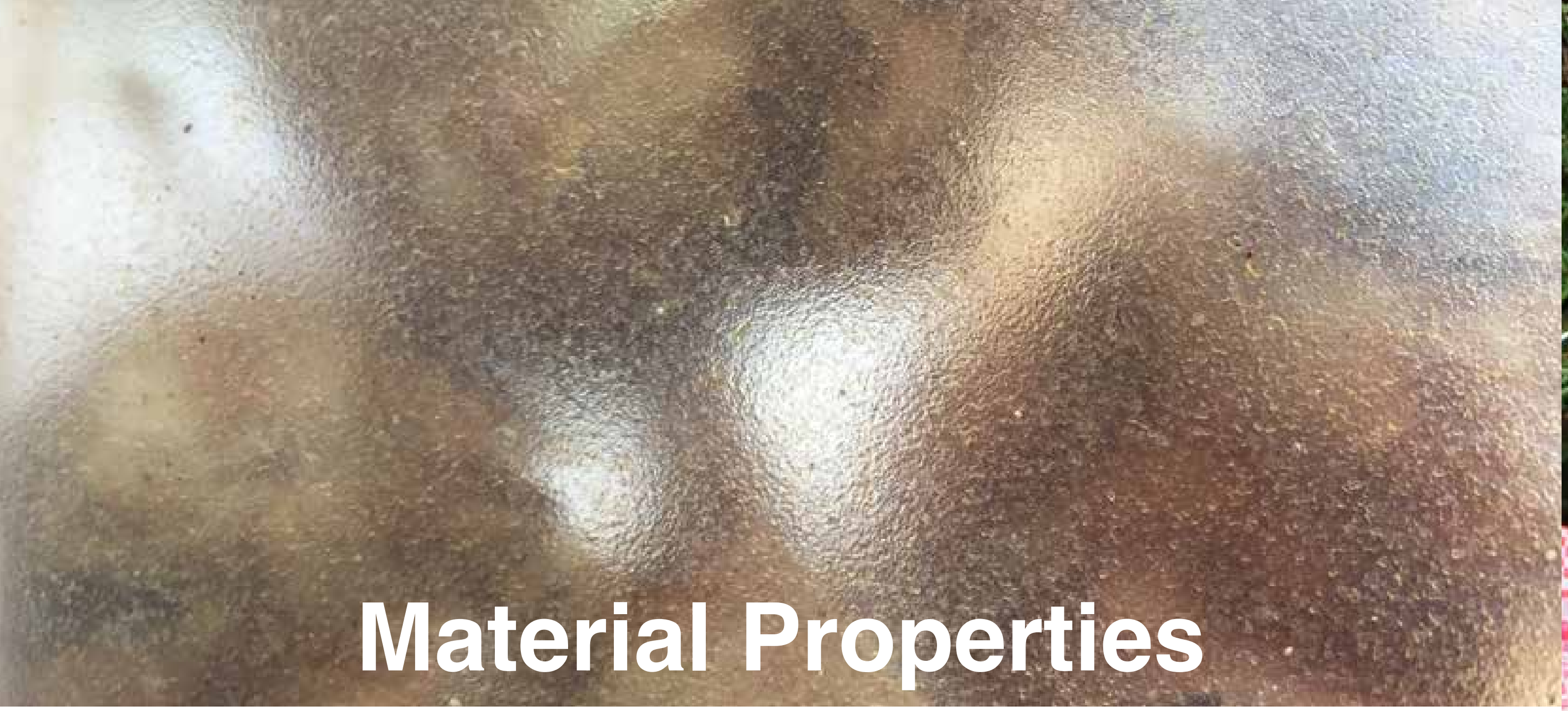
Packaging

Product

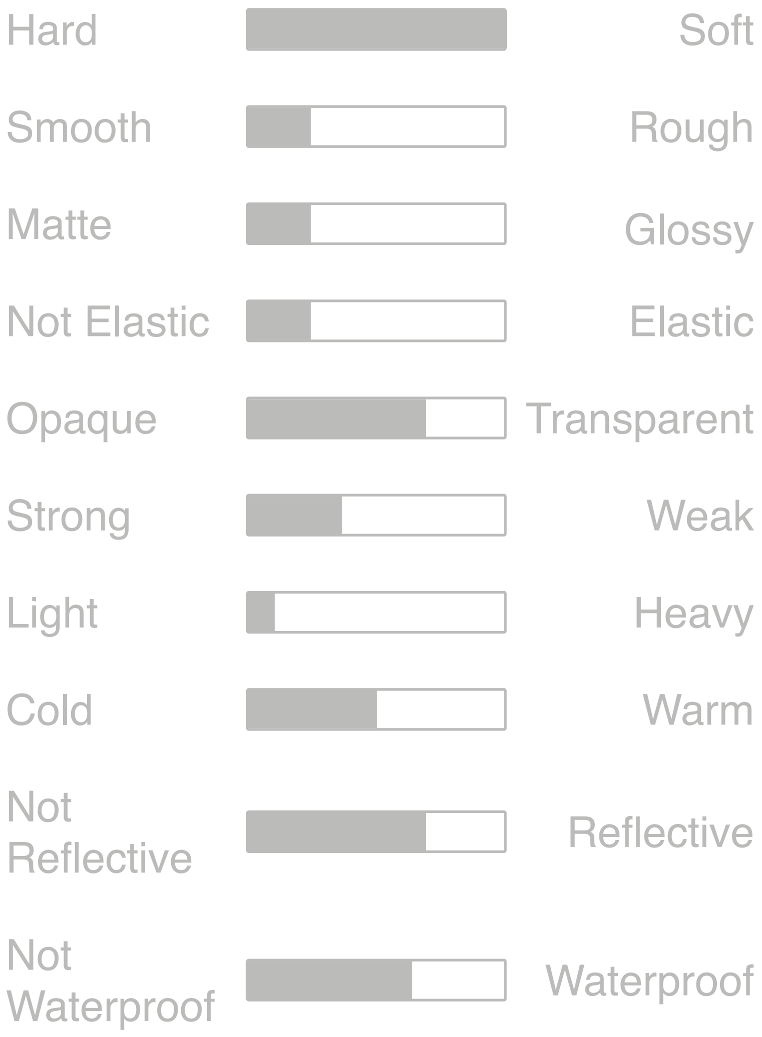


AlgaeMe Products Line

Algae Material Economy (AlgaeMe) : Materials made from algae, especially red algae.



Material Properties

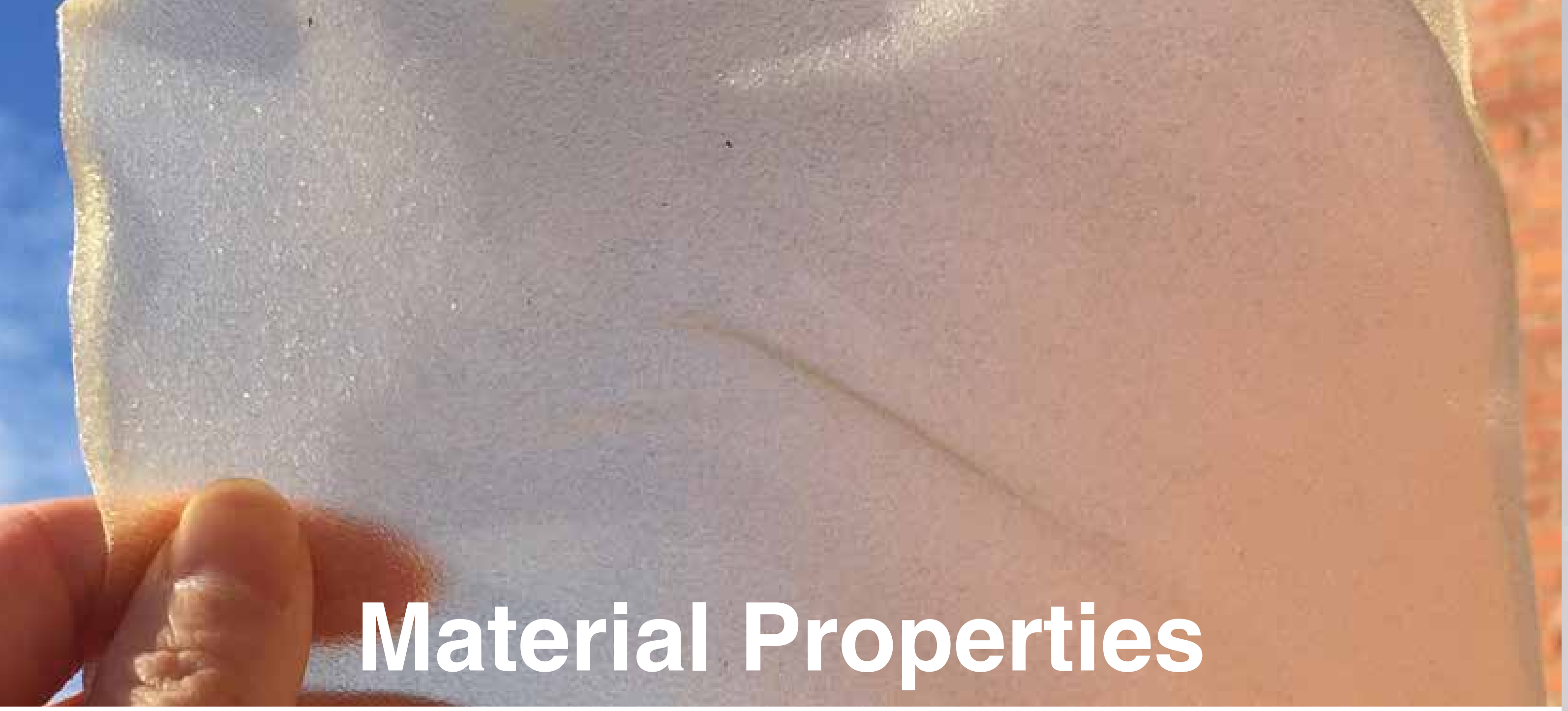


Seaweed-based Bioplastic:

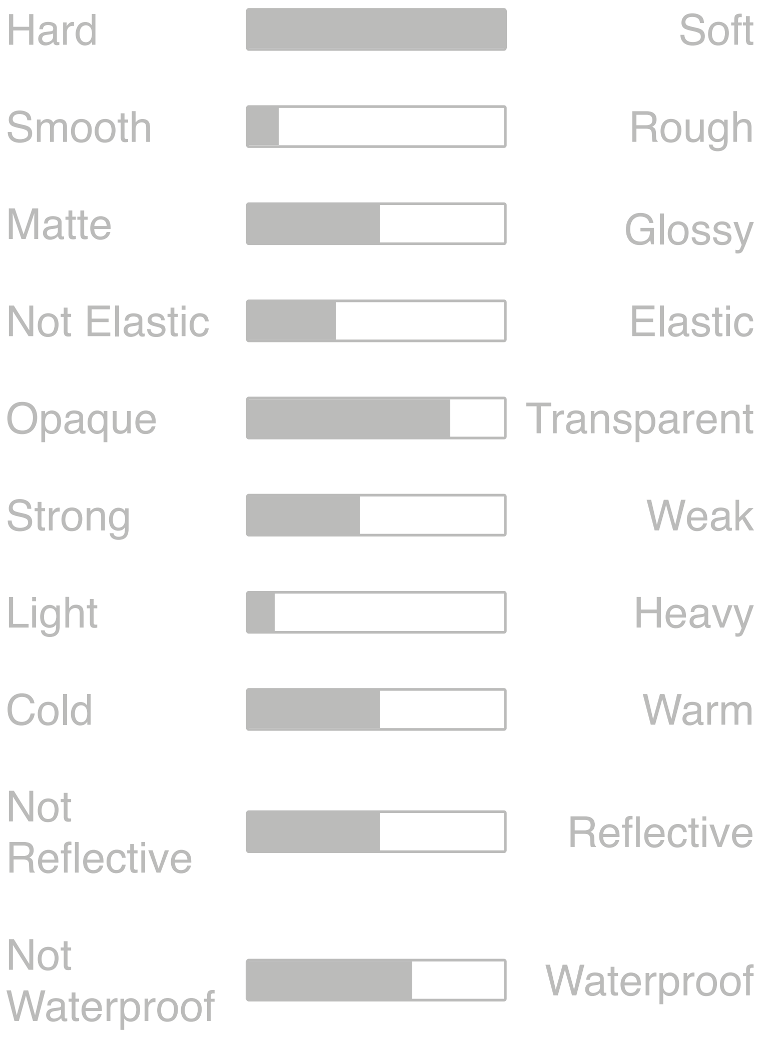
the alternative plastic packaging for Narcissus seeds.

Transparent

The algae material is transparent, which makes it a perfect alternative for plastic packagings.



Material Properties



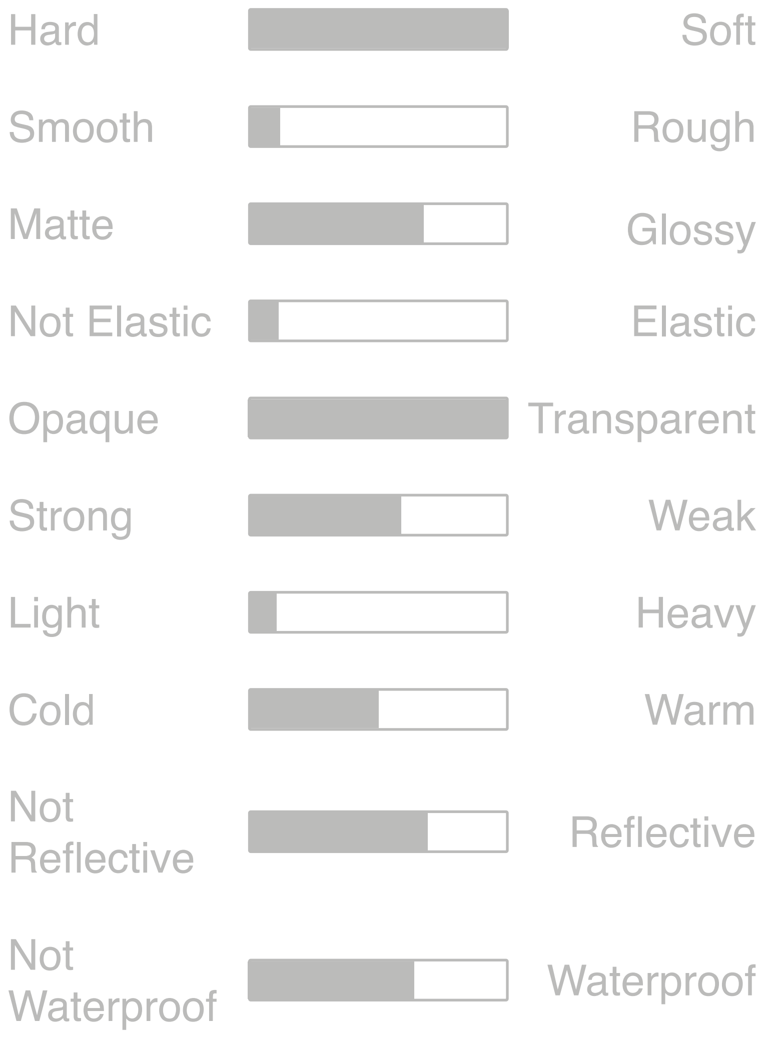
Seaweed-based Bioplastic:

the alternative plastic packaging for soybean.

Transparent

This soybean packaging is another application as a plastic alternative.

Material Properties



Seaweed-based Bioplastic:

the alternative plastic for sandwich packaging.

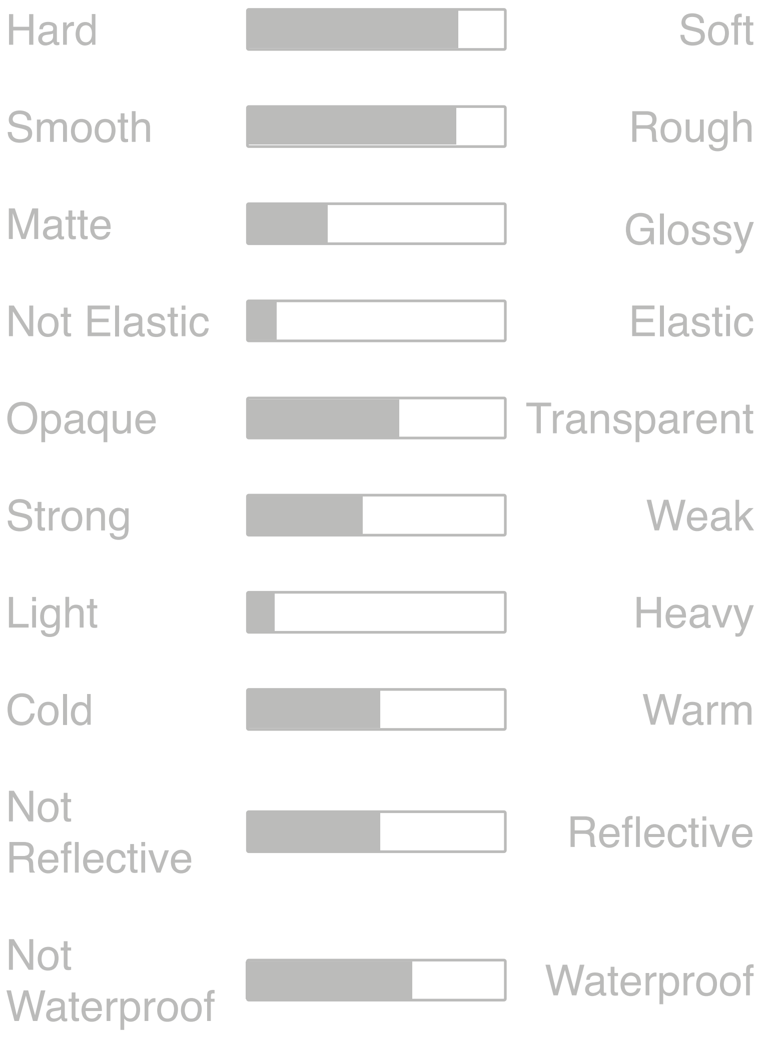
Oil Resistance

The material is oil-resistant and totally transparent, which gives me the inspiration of using it to make sandwich packaging.

SoyMe Products Line

Soy Material Economy (SoyMe) : Materials made from soybean curd residue.

Material Properties



Soybean Curd Residue Bioplastic:

the alternative plastic bag design for mask case.

Heat-sealing

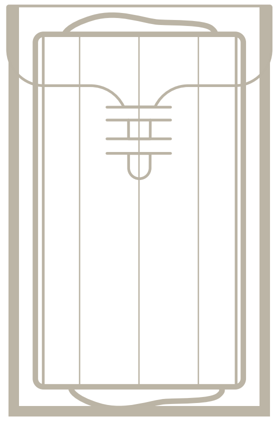
Since the material fused by heating, I take this material property as an advantage for heat-sealing. With this material property, I designed a template for the mask case which allowed people to make their own mask case themselves.

Cutting Line

Sealing Line

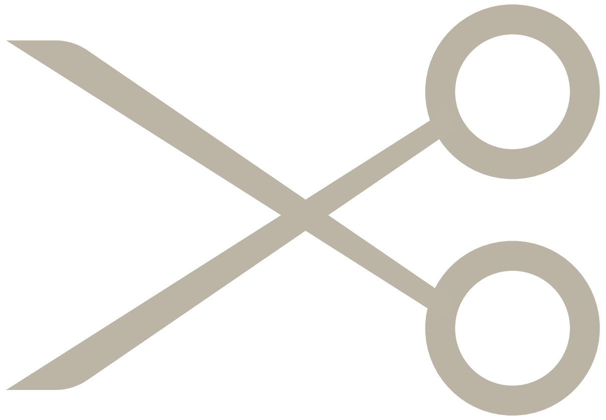
Sustainable.
Biodegradable.
Eco-friendly.
Easy to make.
Low cost.

SoyMe
Mask Case
Template

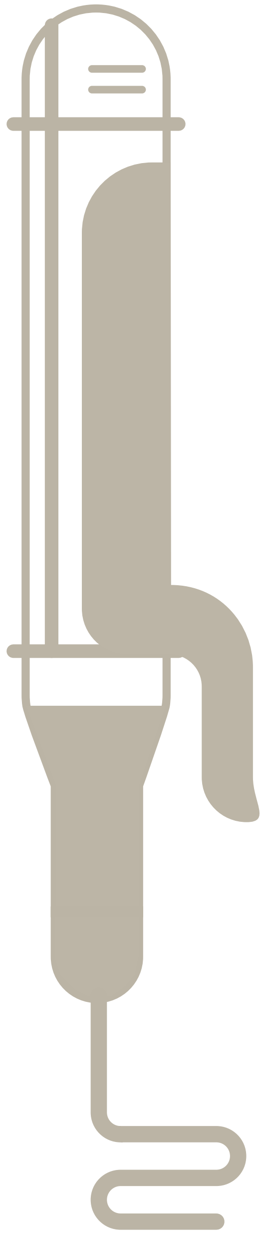


Tools & Steps

1. Buy one A3 size SoyMe bioplastic;
2. Print this template;
3. Follow the cutting line to cut the bioplastic;
4. Follow the sealing line to seal the two pieces with a curling iron or an iron.

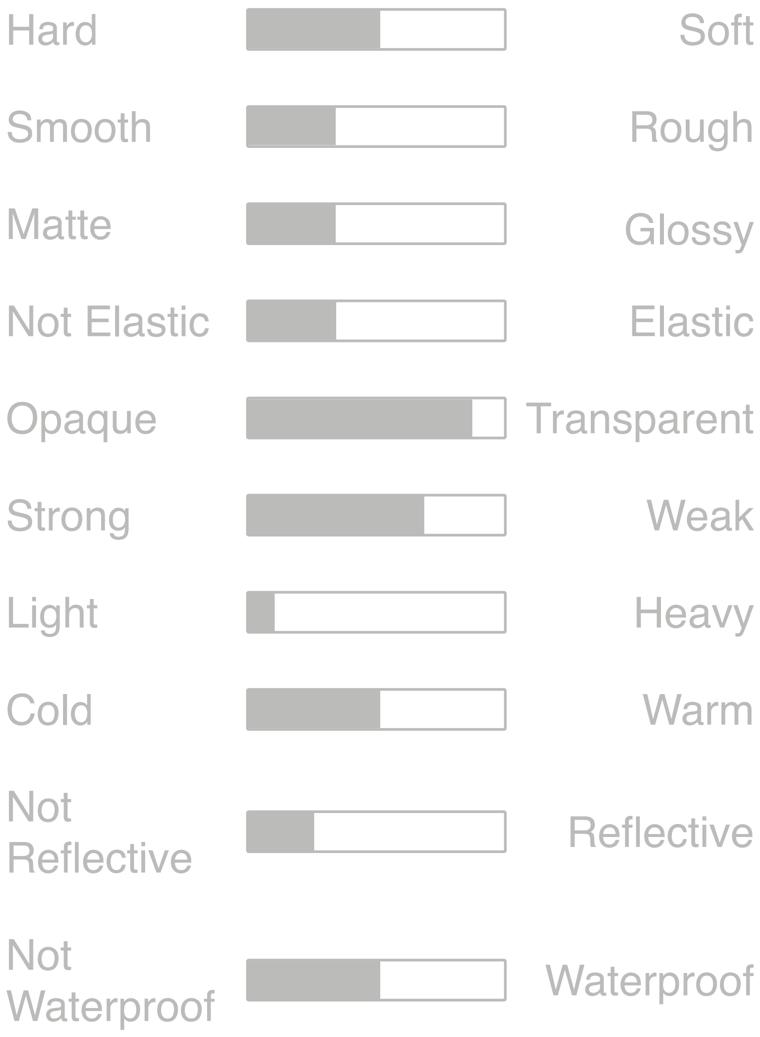


Scissor



Curling Iron

Material Properties



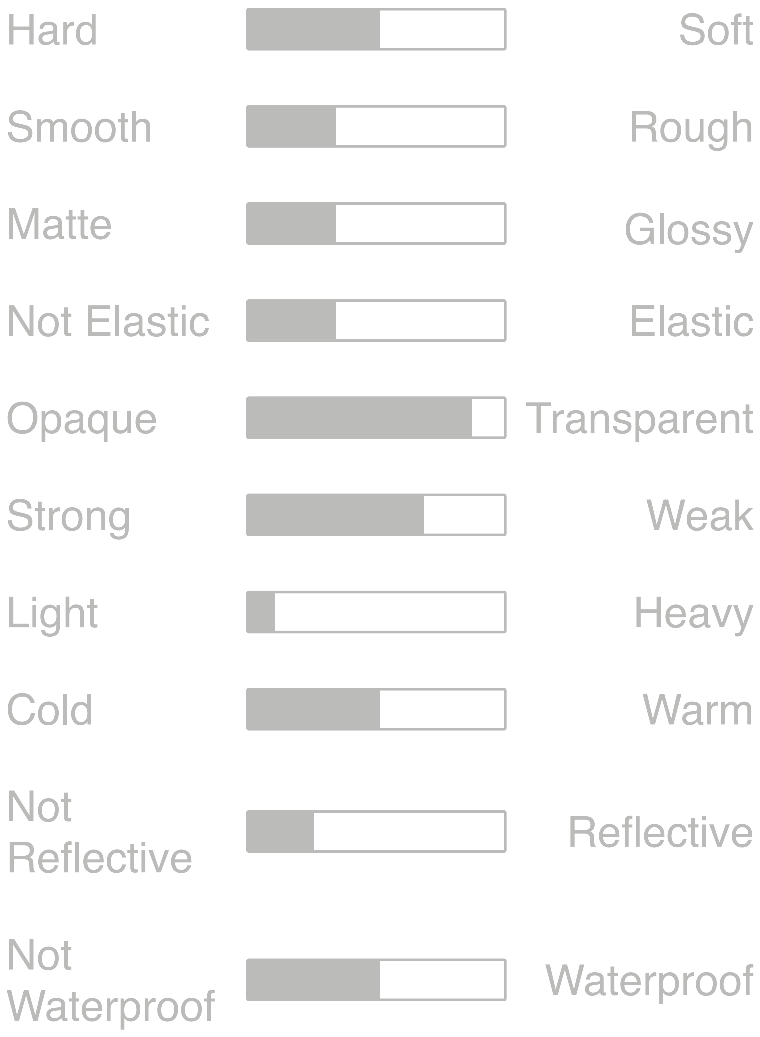
Soybean Curd Residue Bioplastic:

the alternative plastic for soap packaging.

Heat-sealing

I got inspiration from soap packaging and decided to use this material to replaced the plastic one. Therefore, I made the same soap packaging with almost the same method. And with the heat-sealing property, I successfully replaced the packaging with my biomaterial. This proves that my biomaterial is a perfect plastic alternative. Moreover, the White paper-like thread material is from the BambooMe Line.

Material Properties



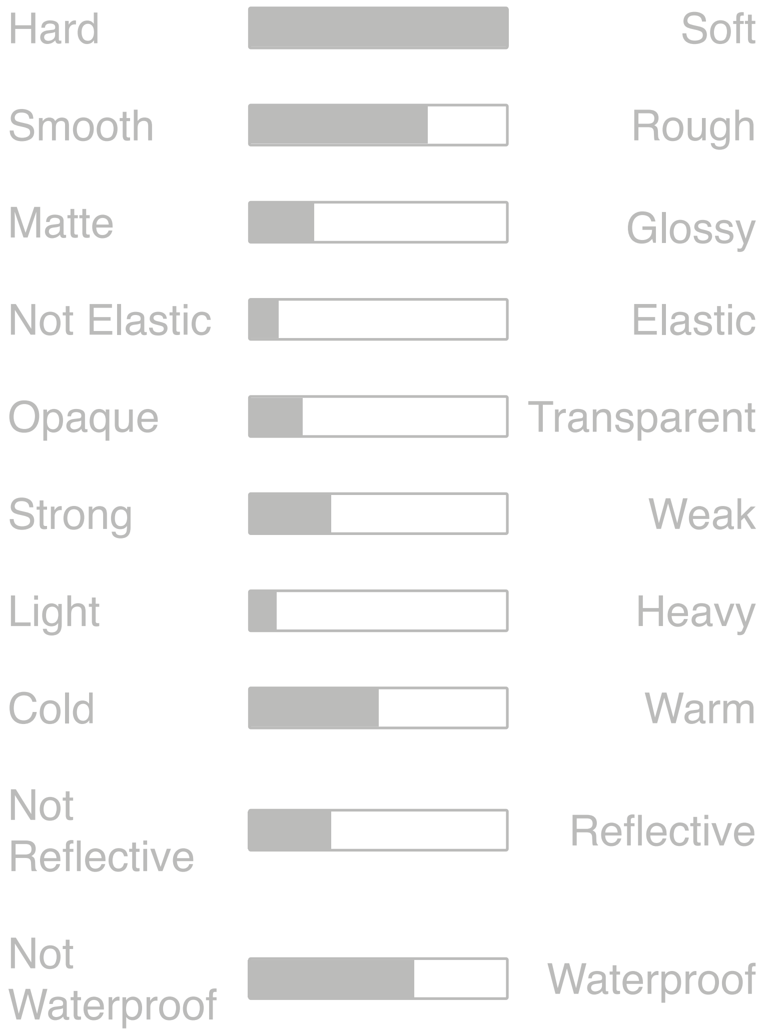
Soybean Curd Residue Bioplastic:

the alternative plastic packaging for red beans.

Circular

I image a circular system of using soybean curd residue to make material for bean packaging.

Material Properties

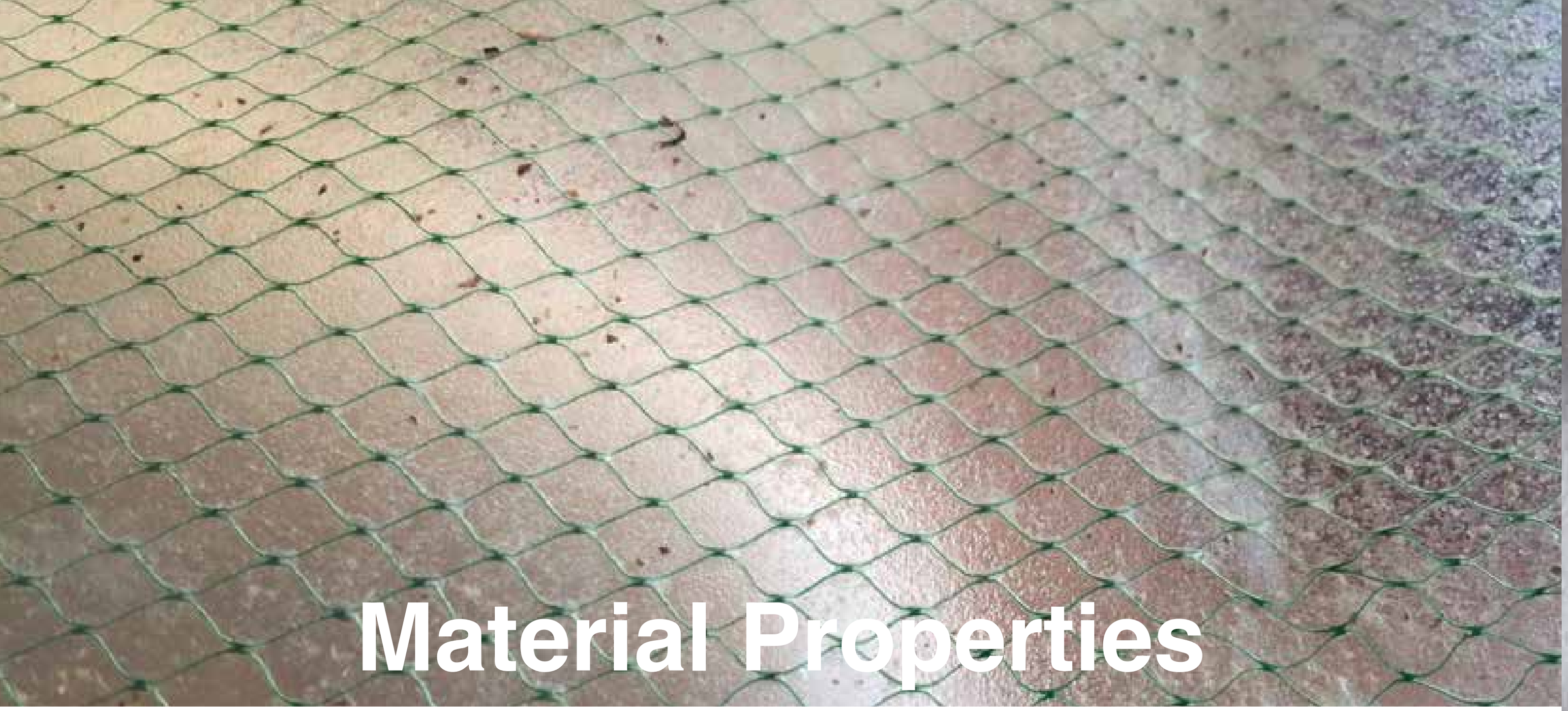


Soybean Curd Residue Bioplastic:

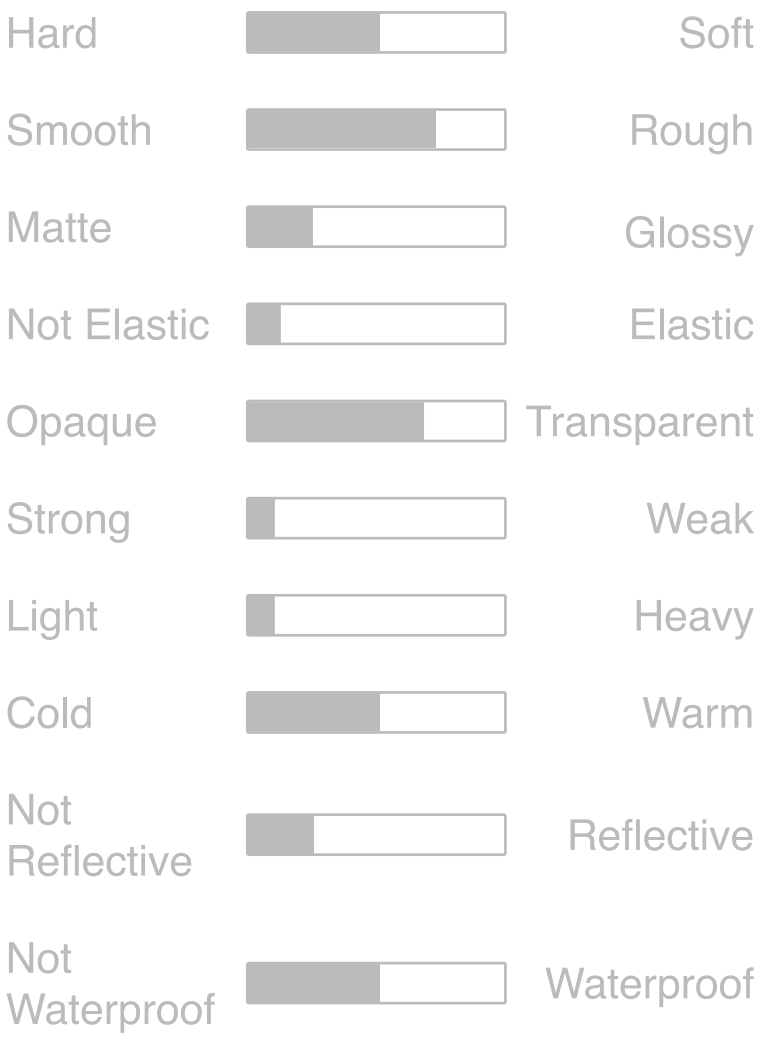
the alternative plastic packaging for soybean.

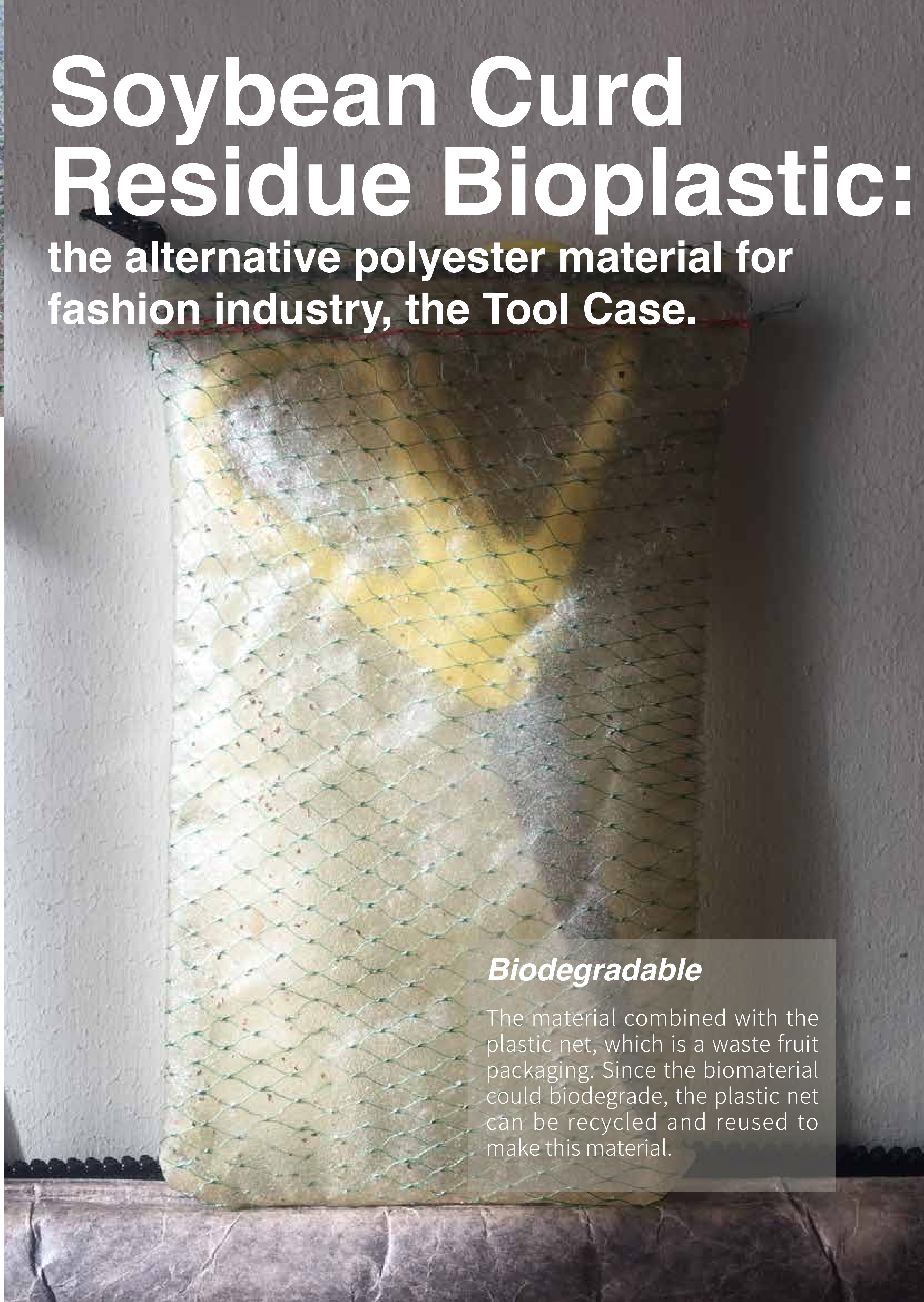
Dark Colour

The material is made of black bean and soybean mixed residue. I inspired by its dark colour. I used it to make packaging to avoid light.



Material Properties





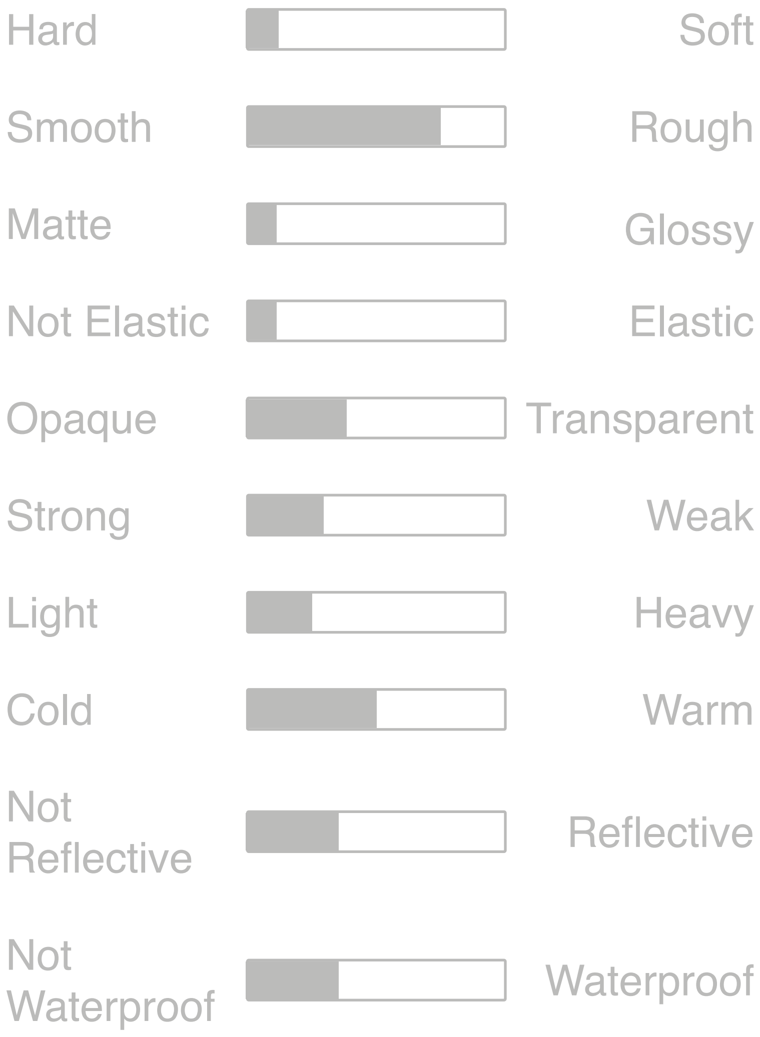
Soybean Curd Residue Bioplastic:

the alternative polyester material for fashion industry, the Tool Case.

Biodegradable

The material combined with the plastic net, which is a waste fruit packaging. Since the biomaterial could biodegrade, the plastic net can be recycled and reused to make this material.

Material Properties



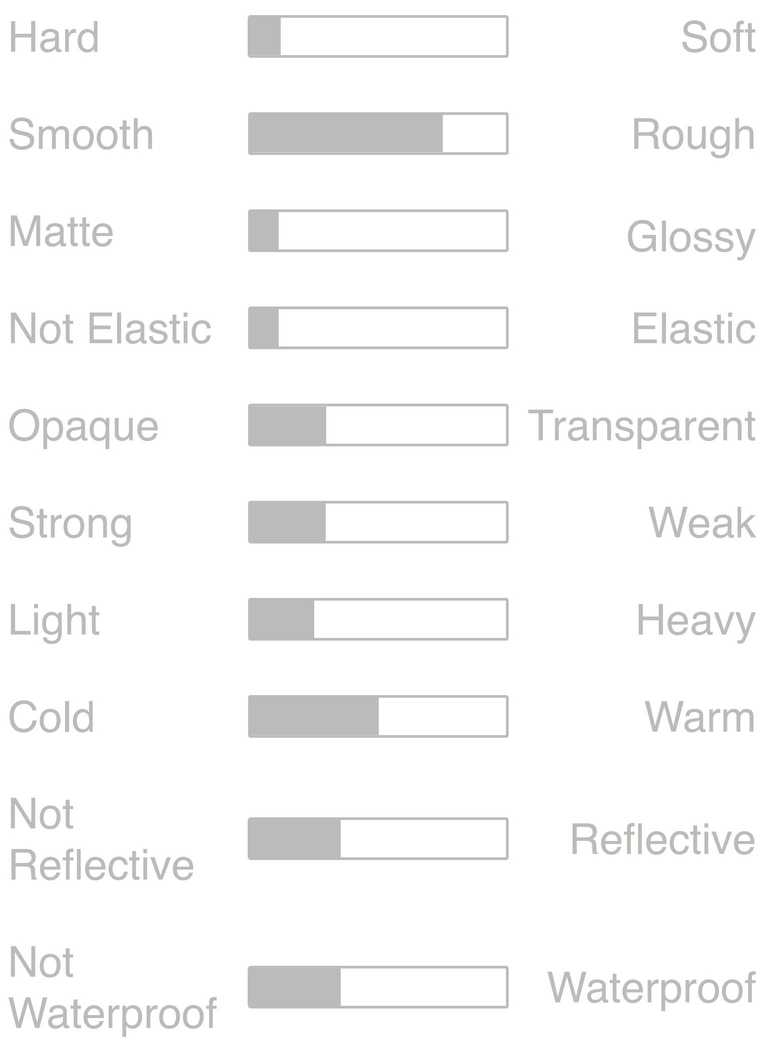
Soybean Curd Residue Bioplastic:

the alternative polyester material for fashion industry, the Salami Bag.

Pattern

This material is hard, rough and semi-transparent. It reminded me of bags made from PVC plastic. Thus I made this bag to see its application in the fashion industry.

Material Properties



Soybean Curd Residue Bioplastic:

the alternative polyester material for fashion industry, the Phone Bag 1.0.

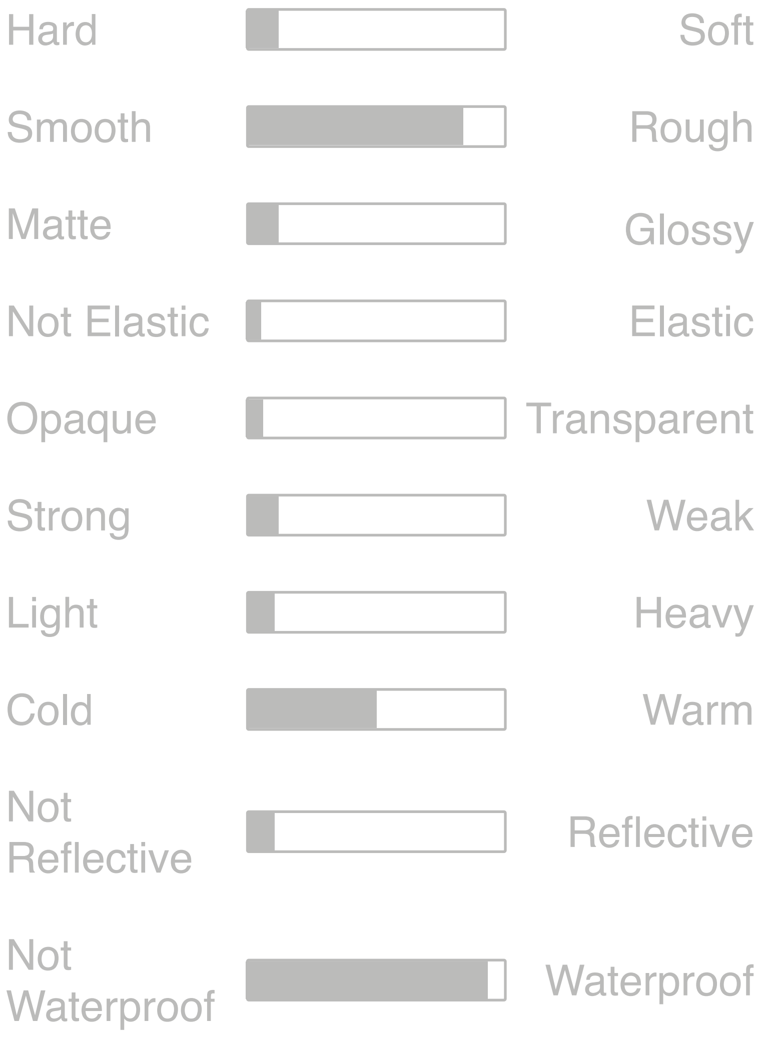
Pattern

This material reminded me of bags made from PU leather. Thus I made this phone bag.

Bamboo-Me Products Line

Bamboo Material Economy (BambooMe) : Materials made from bamboo fiber.

Material Properties



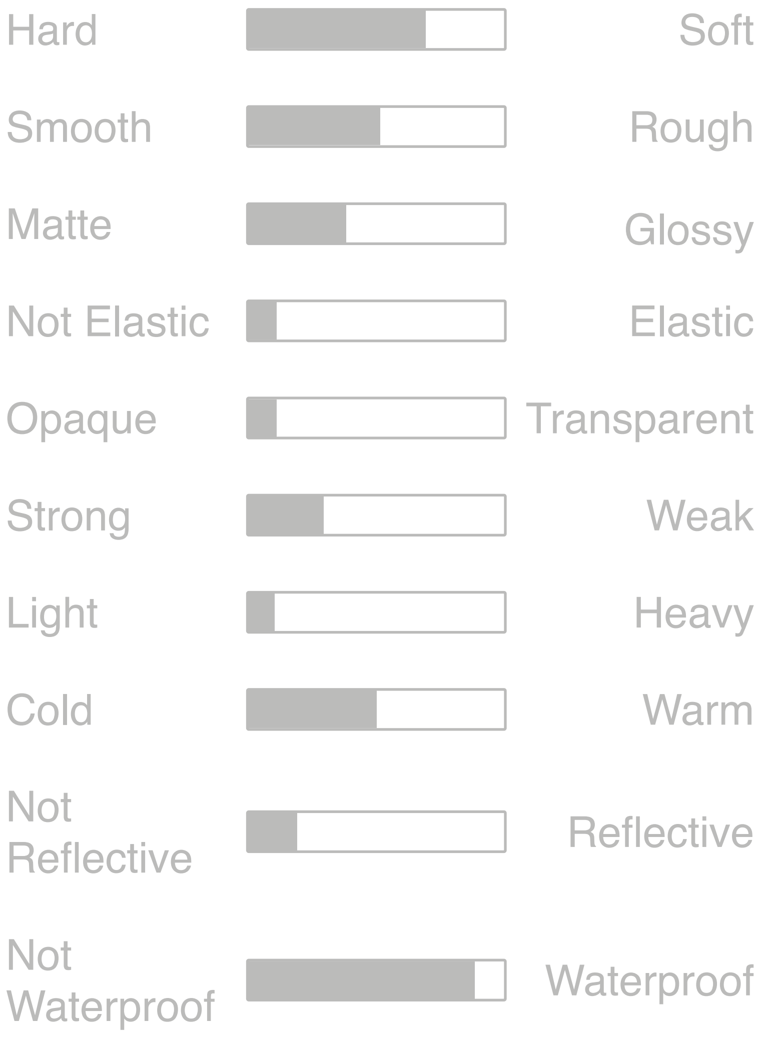
Bamboo-based Carton:

the alternative carton-like material for fruits, nuts and vegetable packaging.

Water Resistance

The BambooMe material has great water resistance. Although the water won't destroy the material, the material will become soft and easy to be formed into other shapes.

Material Properties



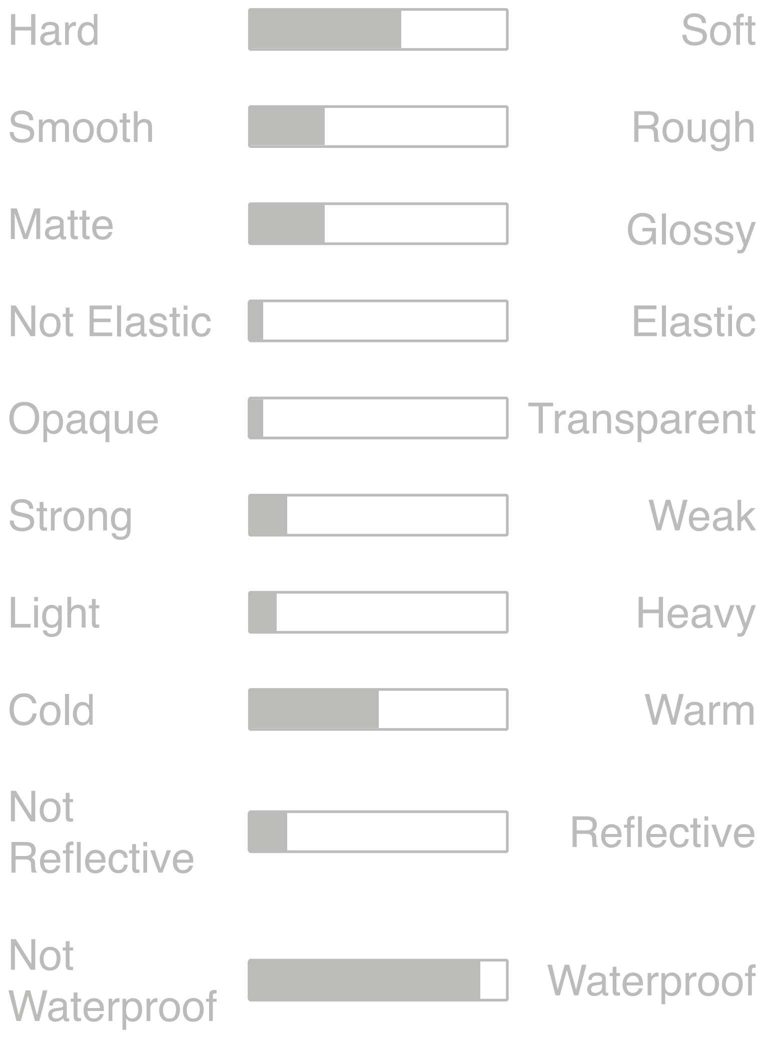
Soybean Curd Residue Bioplastic:

the alternative paper packaging for take away food.

Water Resistance & Oil Resistance

The material is oil-resistant and water-resistant. I tried to wash the material, and it stayed its shape and quality. Due to its paper-like property, I made an origami food packaging design with it.

Material Properties



Bamboo-based Suede:

the alternative vegan suede for product design.

Texture

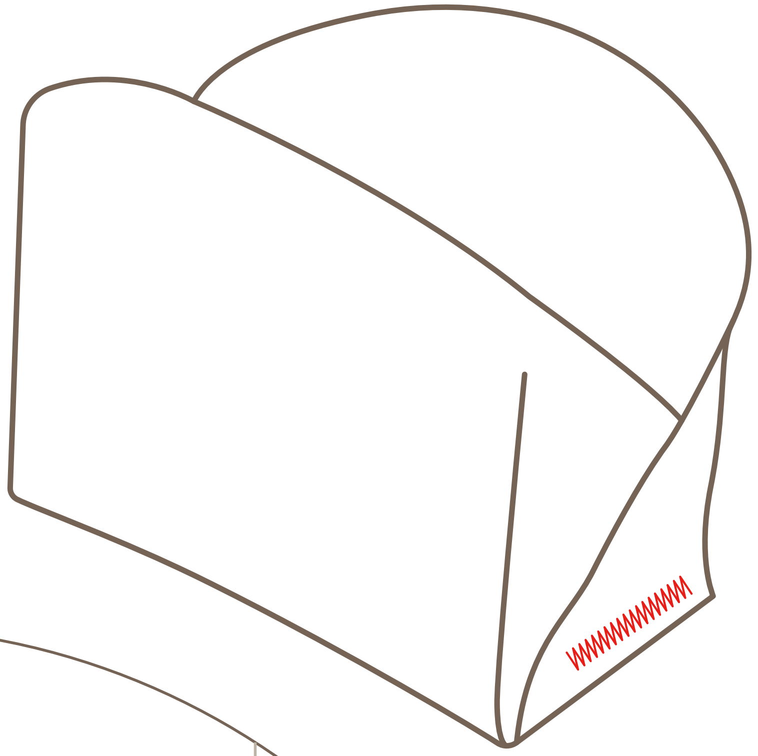
For its suede-like material texture, I decided to use this material to make some leather objects.

- - - ✂ Cutting Line

—— Folding Line

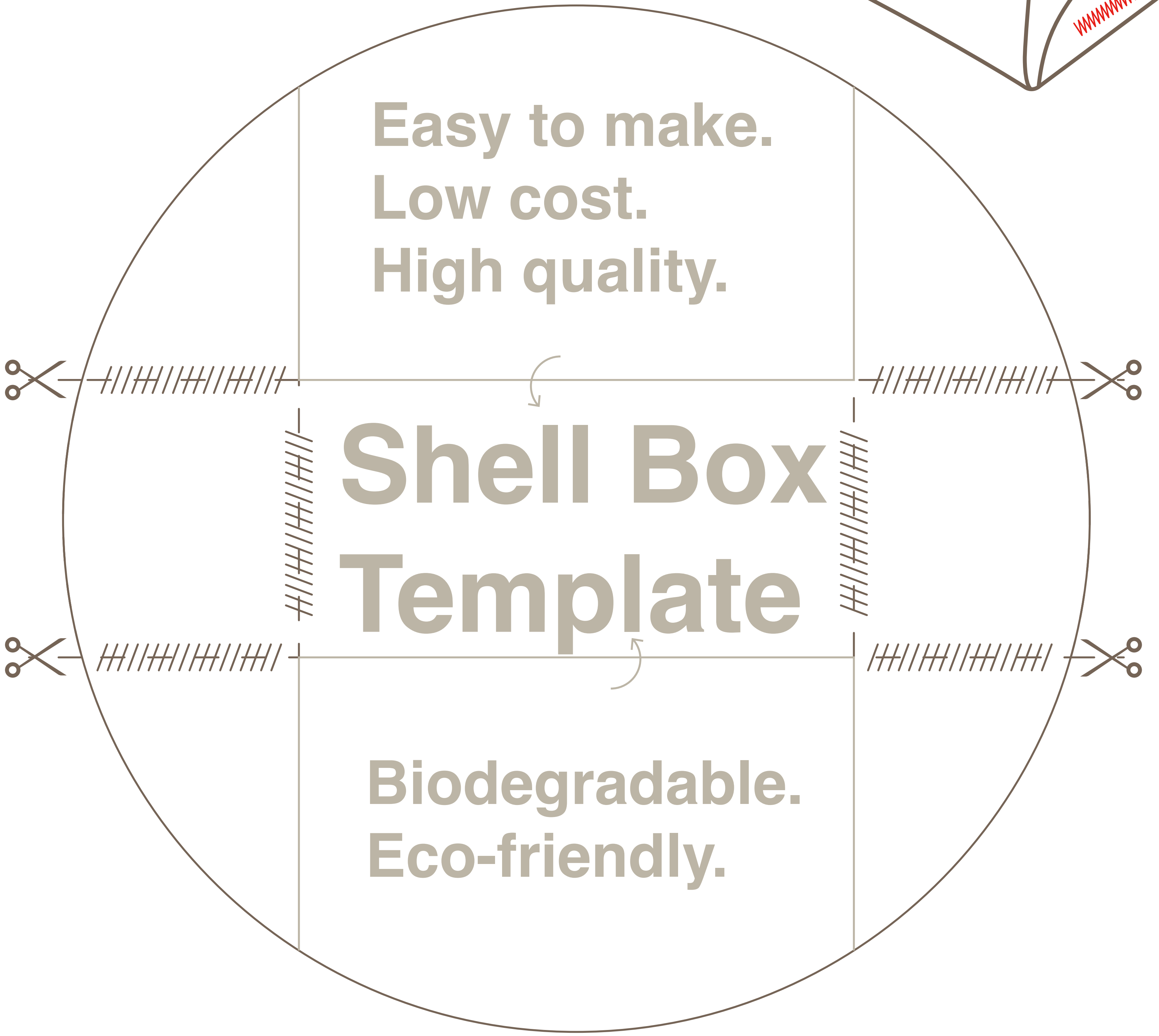
////////////////// Coincide Line

WWWWWWWWWWWW Sewing Line



Tools & Steps

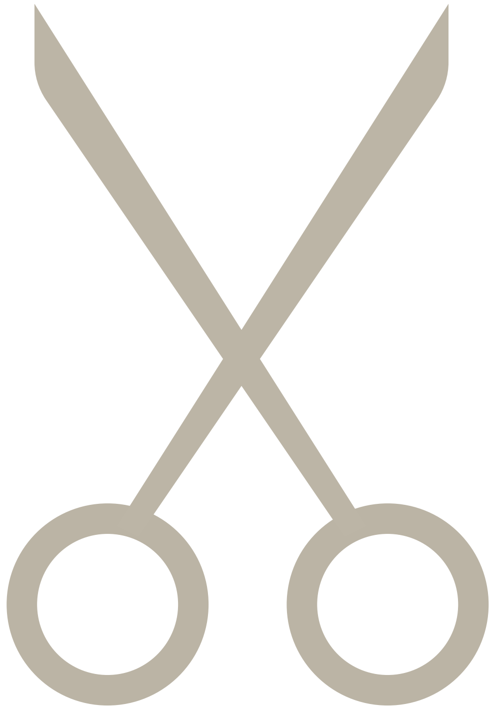
1. Buy one 18.5*18.5 cm size BambooMe material;
2. Print the template;
3. Follow the cutting line to cut the material;
4. Follow the folding and coincide line to fold the piece;
5. Sew the piece like the illustration.



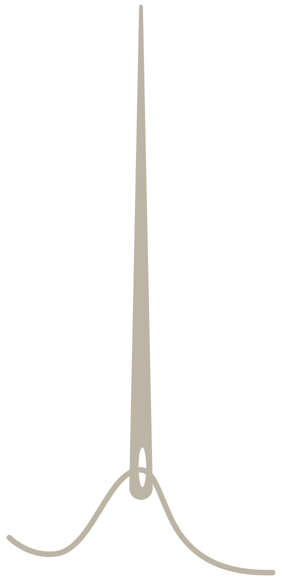
Easy to make.
Low cost.
High quality.

Shell Box Template

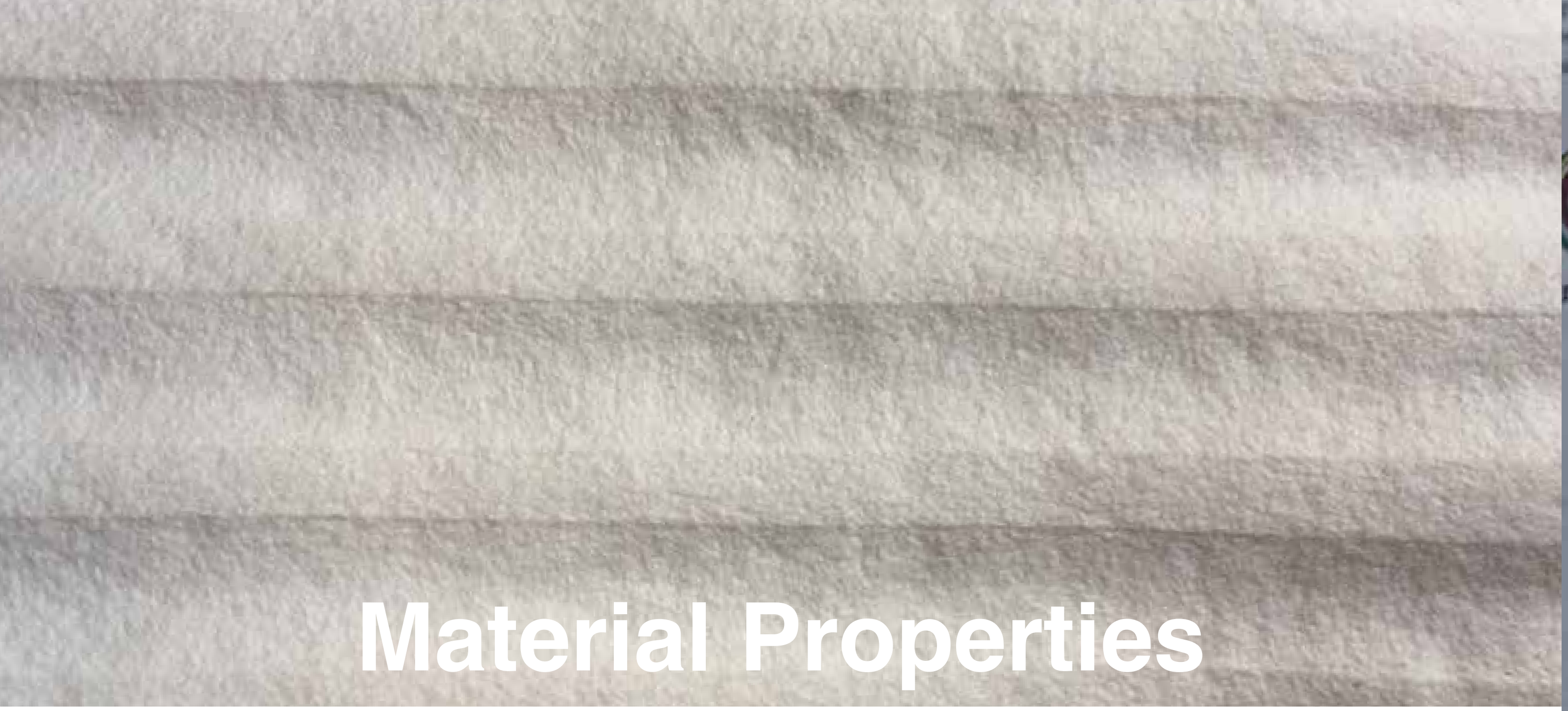
Biodegradable.
Eco-friendly.



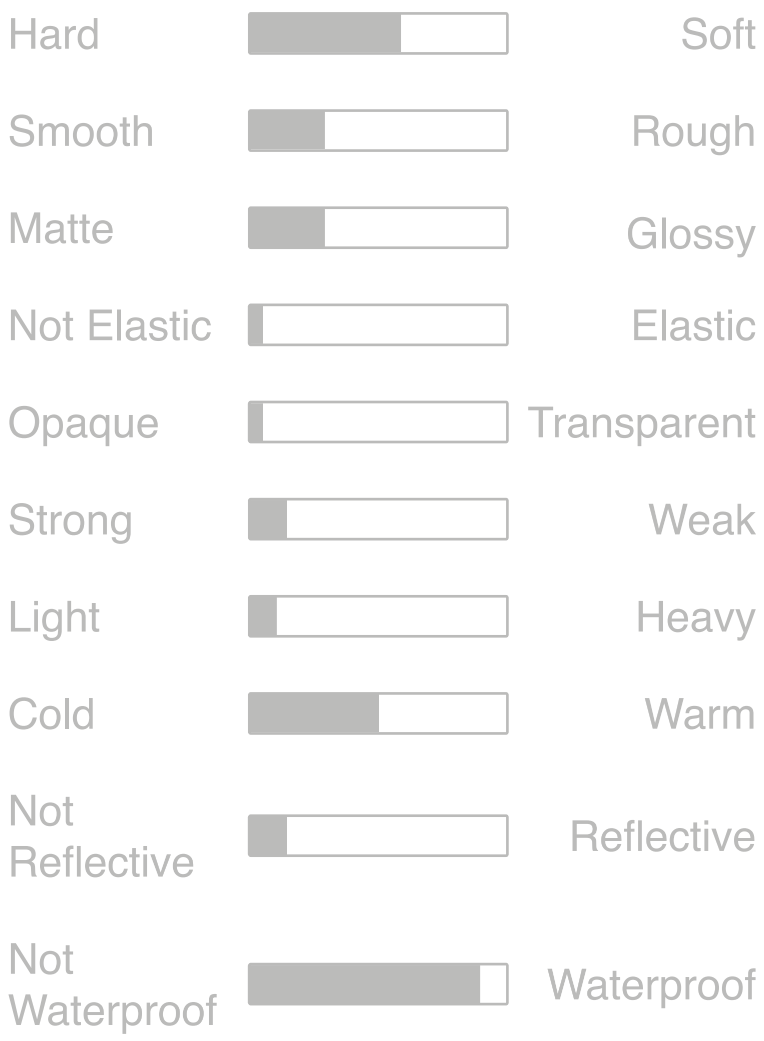
Scissor



Needle & Thread



Material Properties



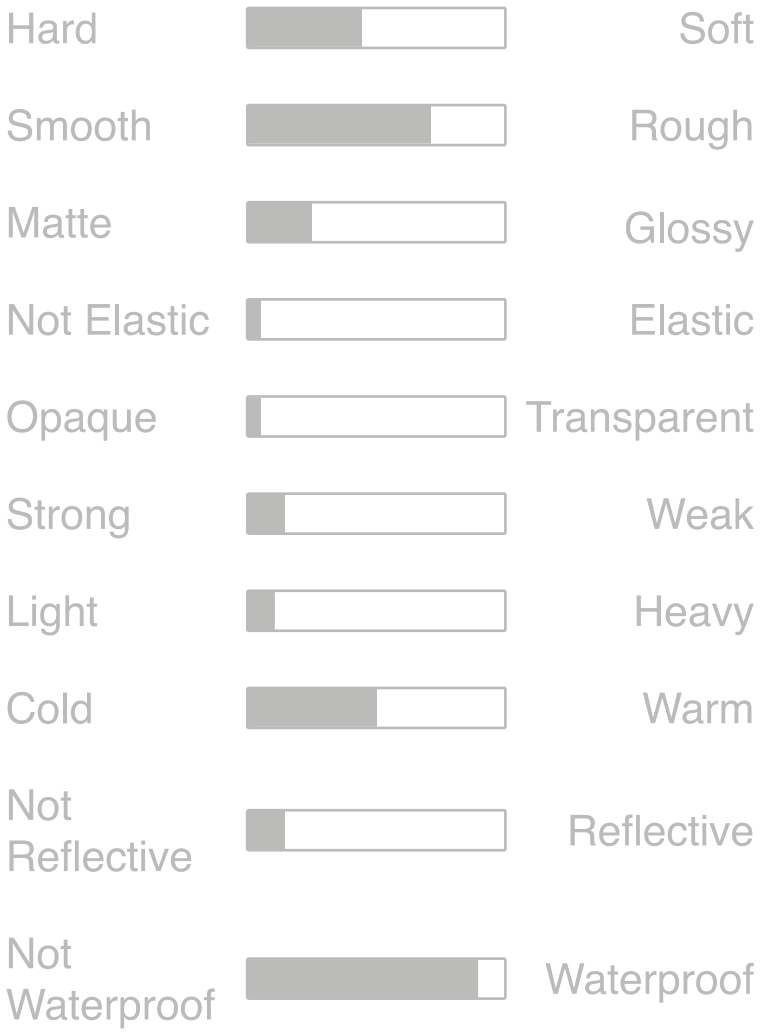
Bamboo-based Suede:

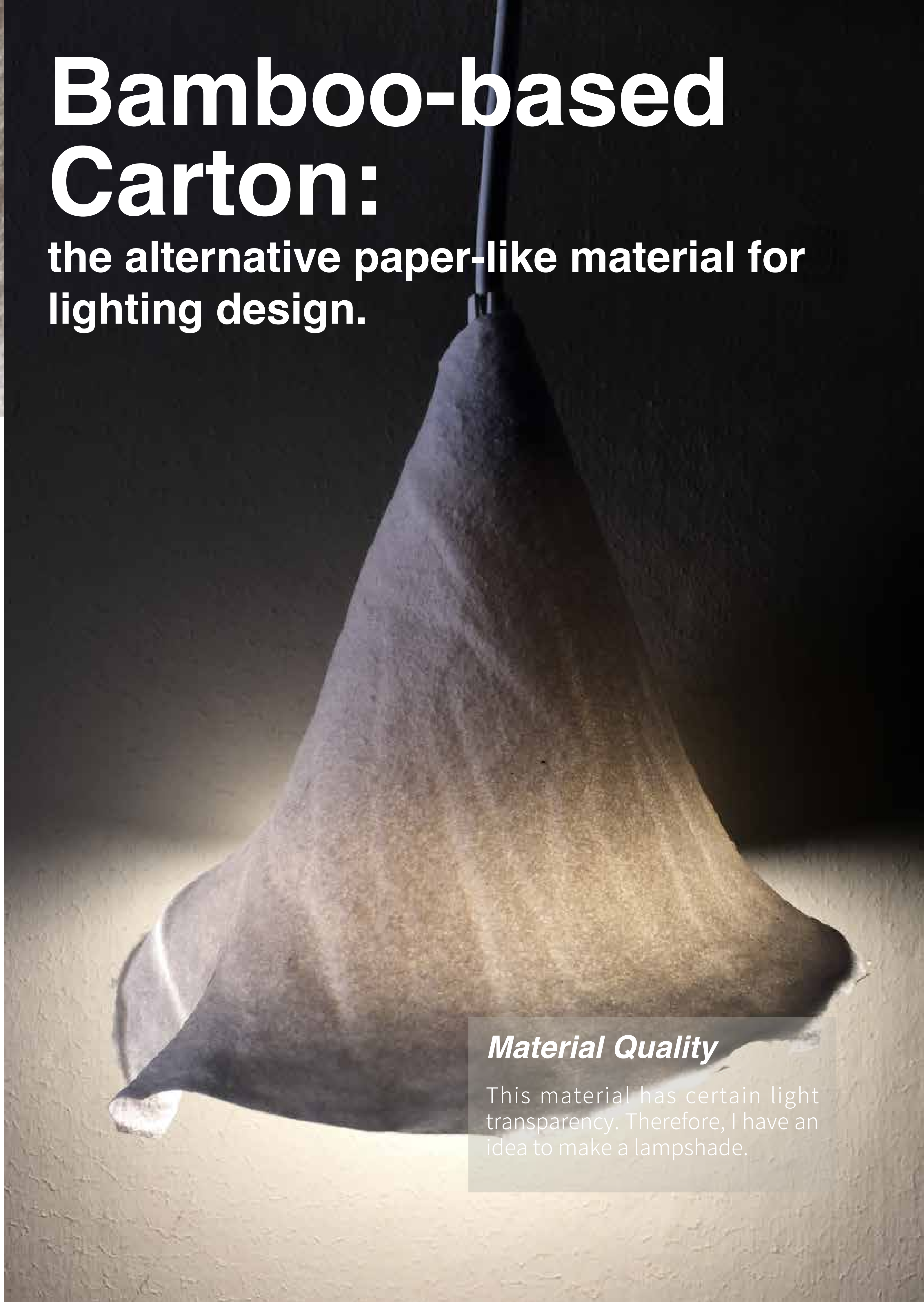
the alternative vegan suede for fashion industry.

Water Resistance

Since this material is water resistance, strong, and suede-like texture, I made a phone bag to explore its application in fashion industry.

Material Properties





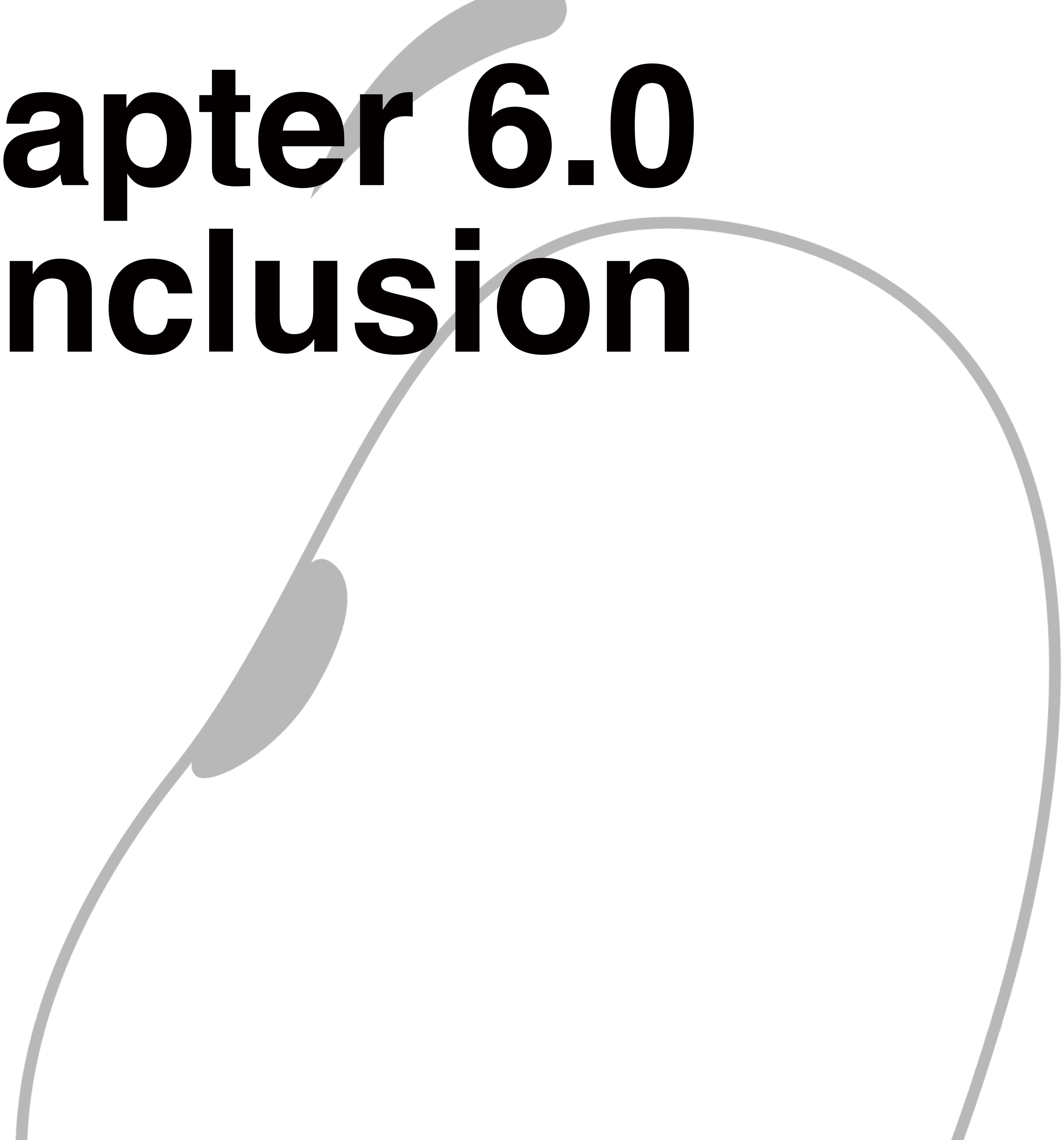
Bamboo-based Carton:

the alternative paper-like material for lighting design.

Material Quality

This material has certain light transparency. Therefore, I have an idea to make a lampshade.

Chapter 6.0
Conclusion



As Susanne (2015) stated that, ‘the twentieth century belongs to the expansion of the global economy, then the twenty-first century is flourishing of a materials economy’. Exploring for a more sustainable future society becomes a common mission for all human beings. Designers who focus on material-driven innovation would be more likely to use an experimental approach to design and embody new materials or reframe the conventional one. (Parisi, Rognoli and Sonneveld, 2017)

This thesis has two researching goals. The first is to make biomaterials from low-value matters. The second is to explore the potential application areas of biomaterials got from the first goal. In this thesis, I have presented the value-add possibility of soybean curd residue, the by-product from the soymilk industry, as well as the bamboo fibre. The biomaterial results of soybean curd residue and the bamboo fibre have proved themselves as a plastic alternative in the packaging industry and their unique aesthetic value in the fashion industry.

The research has followed two methodologies to develop biomaterials, DIY Material and Material Driven Design. DIY Material is a methodology to define the features of the materials and the fabrication process. And Material Driven Design is used to explore the application possibilities of biomaterials. Material Benchmarking is a tool from Material Driven Design. It helps designers to get a general insight into the application area. During the research project, I made more than 50 pieces of biomaterials and over 16 products. This thesis research has a significant meaning for me. From this research, I have learned a lot. Of course, I learned how to make biomaterials, and how to explore the application of materials. What is more, I build up my own experimental system and become fearless of being failed. One failure becomes a correct answer to rule out a wrong choice.

I also believe that this research has a profound impact not only on these two industries but also the human behaviour. Firstly, this research could inspire and accelerate the transition into a circular economy. The traditional factories do not consider waste as a part of their system. They simply throw the unwanted scrapes away to landfill. Business owners know that even the unwanted waste part, they paid. Therefore, many redesigns happen at the beginning of the manufacturing process, like better cutting pattern design, better manufacturing process arrangement, etc. The reason back for these redesigns is to reduce waste. However, the waste is still there. Factories still miss the most important part, transmit the waste in raw material for other industries. This research has provided two potential application of waste as raw material in another industry. Secondly, this material research will also change human behaviour. The PLA was discovered around 1890 but applied in the packaging industry in the 1960s. Since its large application in the packaging industry, the takeaway food industry also showed incredible growth. This application of plastic has changed people's behaviour of eating as well as their diet. Therefore, with the application of biomaterial in all industries, people's behaviour will also be affected. For example, people might have different ways to deal with packaging garbage. Instead of throwing packaging in trash bins, people will bury it in the garden and make it biodegrade.

Material researchers need quite a lot of information about ingredients, DIY processes, new technologies and even scientific knowledge. Unfortunately, the information is hard to get. And I also found that it is better for the material researchers if they could hold collaborations with the researching industries. My research does not get real resource from the bamboo supply chain. For further research and development, I have to contact the supply chain and find out the real opportunity there.

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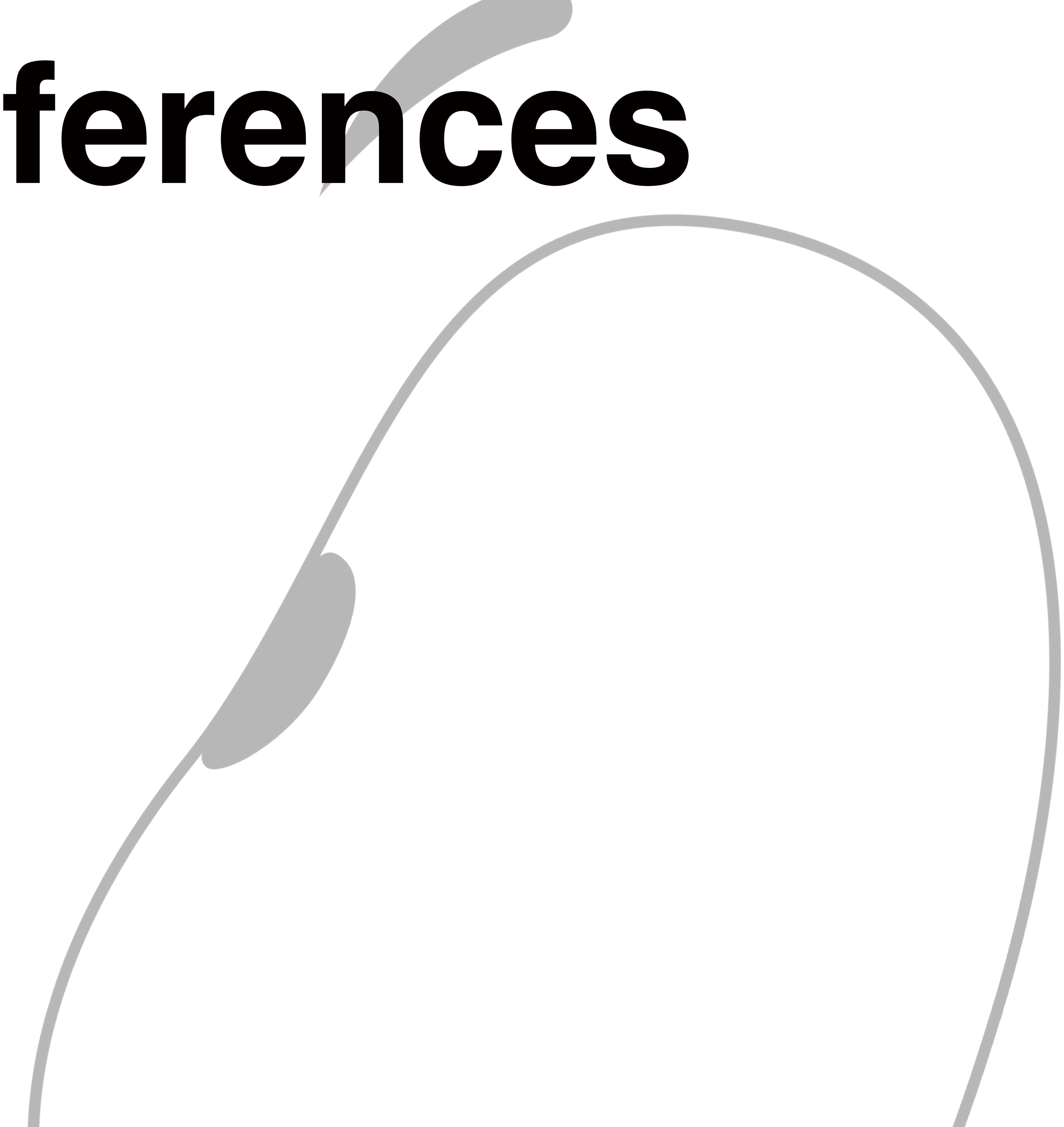

Introduction

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