BIO-DEGRADABLE PACKAGING

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MA Product Design

Confirmative Praxis Report



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OBJECTIVES

1. How to reduce the environmental impact of packaging waste

2. Making biodegradable materials

3. Verify that the material is naturally degradable

4. Application of biodegradable materials in packaging

INTRODUCTION

This report is a continuation of exploration, practice, development, validation, and conclusion based on the objectives initially set in the Exploratory Praxis. As a product designer, reflect on the over-packaging of products, the increasing amount of packaging waste, and the impact of packaging waste on the environment. Consumers have a brief relationship with packaging; their desire is focused on the product in the packaging, and once they receive it, they no longer need it (Tim, Victor, and Leanne, 2015). Usually, packaging waste constitutes an integral part of municipal solid waste (MSW). Most of these materials are not biodegradable, causing more and more environmental problems.

To reduce the environmental impact of product packaging, attention needs to be paid to sustainable packaging practices. These include the use of recycled materials, the reduction of packaging waste, and the development and innovation of environmentally friendly materials.

If a new material can be created that is not only reusable but also biodegradable, the magnitude of the problem can be mitigated. The following report details and documents the development, manufacturing, and testing of biodegradable materials. As well as the use of product packaging to demonstrate the material's sustainability, durability, and manufacturability. The process also involves testing the biodegradability of the new material, and if this fails, then there is little point in the project existing.

The report also describes the innovation, design, and production process of product packaging. It also explains the application of product packaging design and technology, including UV printing and the availability of Heat Sealer.

PACKAGING WASTE

Packaging is any material used to contain, wrap, protect, or present an item (YouTube, 2017). It is considered harmful to the environment because of the use of its materials and its disposal at the end of its useful life. Consumers are virtually unaware of the function of packaging, and once separated from the product, packaging is seen as waste, and its original function is quickly forgotten (Tim, Victor, and Leanne, 2015). This type of waste is created when packaging materials are discarded, usually after the product has been opened or used. According to statistics, ‘Over 67 million tonnes of packaging waste is generated annually in the EU, comprising about one-third of all municipal solid waste’ (Parida et al., 2018). Packaging waste is an obvious source of litter and poses a significant waste management challenge. Therefore, the packaging waste found everywhere in life was the beginning of this project.

Many materials are used for packaging, mainly wood, paper or cardboard, plastics, metals, glass, and composites. 'Plastics contribute 18 percent of the 10.4 million tonnes of packaging wastes produced annually in the UK' (Parida et al., 2018). Plastic packaging is a significant contributor to packaging waste. Single-use plastic bags, bottles, and other packaging materials can take hundreds of years to break down in the environment, damaging ecosystems in oceans, rivers, and land. Paper and cardboard are also used at higher rates, accounting for 17 percent of total global waste, second only to food and green waste (YouTube, 2017). While paper and cardboard are more biodegradable than plastics, their production leads to deforestation and energy consumption. When not properly recycled, they increase the amount of waste in landfills. Metals and glass are recyclable materials, but the energy required for extraction, processing, and production can hurt the environment (WIKIPEDIA, 2023).

Packaging has a wide variety of polymers, each of which may contain different processing additives such as fillers, dyes, and plasticizers. The complexity of these components and the contamination during their use often increases the burden of recycling and disposal. However, the generation of this packaging waste is a serious environmental problem because it seriously impacts landfills, ecosystems, and natural resources. Although the proportion of waste going to landfills is decreasing yearly, around 60 percent of the UK's municipal waste still ends up in landfill sites (Parida et al., 2018).

Recycling of packaging materials has increased in recent years, with two-thirds being recycled, but the recycling rate for most plastic packaging remains static. Designers have known for a long time that the function of packaging is to deliver products to consumers, thereby protecting and potentially enhancing them. However, over-packaging, lack of recyclability of packaging materials, and low consumer motivation to recycle have increased packaging waste and environmental problems. The fact that these packaging materials do not decompose quickly is also a critical factor that continues to lead to environmental pollution. How to reduce the environmental pollution caused by packaging waste is the breakthrough of this project.

Biodegradable and compostable materials can be used as alternatives. It is just that they require proper disposal facilities and the environment to decompose effectively and thus reduce environmental pollution (WEFORM 2020). However, biodegradation is the breakdown of organic matter by microorganisms. It is a natural process. On the other hand, composting is a human-driven process where biodegradation occurs under specific circumstances (WIKIPEDIA, 2023).

Therefore, making a reusable and biodegradable material was the goal of this project. From an environmental point of view, it needs to have a short degradation cycle. It would reduce the environmental pollution caused by landfills and also reduce the waste of resources in the production process. Designer Elena Amato has already created a sustainable alternative to plastic packaging using bacterial cellulose. The material dries to become stiff and strong, like a mixture of paper and plastic (Natashah, 2019). Thus, biodegradable materials are not nonsense.

WHY CHOOSE BIODEGRADABLE MATERIALS?

Biodegradable materials naturally break down into non-toxic substances, minimizing harm to the ecosystem (WEFORM 2020). Many biodegradable materials, such as corn starch, straw, and bamboo, come from renewable resources. Biodegradable materials typically produce a smaller carbon footprint than traditional materials, promoting sustainable development (WIKIPEDIA, 2023). For example, some materials use less energy and emit fewer greenhouse gases during production. Biodegradable materials, such as soil, water, and composting facilities, can naturally degrade in different environments. This helps to reduce environmental pollution from waste. Some biodegradable materials, such as compostable plastics, can be composted in industrial plants. Not only does this reduce the need for landfills, but it also sends organic matter back into the soil, making it fertile (Liza, 2023).

As environmental awareness increases, consumers increasingly seek environmentally friendly packaging products. Choosing biodegradable materials can align with consumer preferences and enhance a product's environmental image. Many regions and countries have regulations and policies that restrict the use of non-biodegradable materials. Companies can comply with these regulations and demonstrate their environmental commitment by choosing biodegradable materials (Parida et al., 2018). Continued research and development in materials science and technology is producing new and improved biodegradable materials (Visit and Steve, 2023). This is an opportunity for this project to explore sustainability further. Innovations in this field offer environmentally friendly alternatives and continue to meet performance requirements.

In addition, some biodegradable materials may require specific conditions to decompose efficiently, and improper disposal may still lead to environmental problems, which is also a challenge for this project. Therefore, selecting sustainable materials and the correct disposal methods are crucial.

SELECTING RAW MATERIALS

Take inspiration from Elena Amato's Bacterial Cellulose Tablet. It was developed using water, bacteria, and scoby cultures. It uses a small variety of raw materials and is easy to dry and manipulate for development. The search began for raw materials that could be used as biodegradable packaging. This included designs inspired by packaging made from pea skin as lignocellulose, sustainable packaging made from straw, and biodegradable, finished product-efficient cosmetic replacement packaging developed by On Repeat (ON REPEAT, 2023). This led to the initial exploration of material development.

Corn starch is considered a high-quality renewable resource. It is derived from the corn crop, the world's largest cultivated cereal crop, and can be harvested annually. (Corn kernels are soaked in hot water and sulfur dioxide to break them into protein, fiber, and starch. Next, the kernels are ground, and corn starch is extracted from the corn oil.) Corn starch consists of chains of carbon molecules forming long-chain polymers when citric acid is added—Polylactic Acid, the basic unit for producing plastics. Using corn starch as a feedstock for bioplastics is sustainable as it reduces dependence on fossil fuels (ZERO WASTE, 2022).

Therefore, in the experiments before the praxis, an attempt was made to develop the first biodegradable material of the project using corn starch, vinegar, water, and glycerine as raw materials. (Glycerine, also known as glycerol, is a simple polyol compound. It is a colorless, odorless, non-toxic, viscous liquid with a sweet taste. The glycerine backbone is found in lipids called glycerides. It is commonly extracted from plants and animals and is widely used as a sweetener in foods and as a humectant in pharmaceutical formulations, among other things (WIKIPEDIA, 2023). However, through repeated production, biodegradable materials made from corn starch are fast

film-forming. However, it dries entirely slowly, has poor flexibility and weak availability, and oily liquid adheres to the surface. It isn't easy to make product packaging as a biomaterial. While considering whether the material is degradable or not, the availability of the material was the priority in the project's development. This led to a second material development.

A new inspiration was gained through jelly making, where the jelly powder is made from collagen, sugar, flavorings, and other additives found in animal bones and connective tissues. A colorless substance forms a gel-like texture when mixed with hot water and cooled. So, a second attempt was launched using water, jelly powder, and glycerine as raw materials. After a week-long experiment, the second experiment was also declared a failure. The biodegradable material, mainly made of jelly powder, is smooth, transparent, elastic, and has specific packaging properties. However, because of the sugar content in the jelly powder, the material is sticky after drying, and it is not easy to use as product packaging because the material is prone to cracking, poor plasticity, and poor sustainability. The project did not end with failure. Through reflection and further exploration, find if there is an alternative material to jelly powder. This was a potential obstacle for the project and a breakthrough. There are also some lessons learned from the two failed developments. For example, it was possible to become more proficient in making the materials and using the proportions of the materials, which also paved the way for Confirmative Praxis.

The selection of materials and material ratios were further investigated by exploring case studies of existing biomaterials such as tea dregs bioplastics, spirulina biomaterials, agar, and Himalayan balsam biofilms (MATERIOM, 2023). Gelatin was identified from the case studies. The project was further developed. It was found that gelatin has the same texture as jelly powder but different properties. Gelatin is a translucent, colorless, odorless food

ingredient usually derived from collagen in animal body parts. It is commonly used as a gelling agent in foods, beverages, and medicines (WIKIPEDIA, 2023). It requires hydration to solidify. Activated by heat, it also forms a jelly consistency when cooled (Andrew, 2024). Although gelatin contains only animal protein in a single structure compared to jelly powder, this is one of its advantages. It contains no other additives and has a specific stability. Whether gelatin can replace jelly powder is worth trying. So, one of the raw materials in the second development of the jelly powder was replaced with gelatin, and there was a third group of water, gelatin, and glycerol as the raw material for developing biodegradable materials. (Water is an inorganic compound. It is a transparent, tasteless, odorless, and virtually colorless chemical (WIKIPEDIA, 2023). Thus, all three materials are natural ingredients without mining, oil, etc. And there are no other additives. All three ingredients are edible.

By repeatedly adjusting the ratio of raw materials and many tests. In June 2023, the first of the more successful gelatin biodegradable materials was produced. It dries quickly at room temperature, has strong plasticity and flexibility, is not easy to crack, and has a smooth surface. Its thickness and flexibility can be varied with the ratio of raw materials.

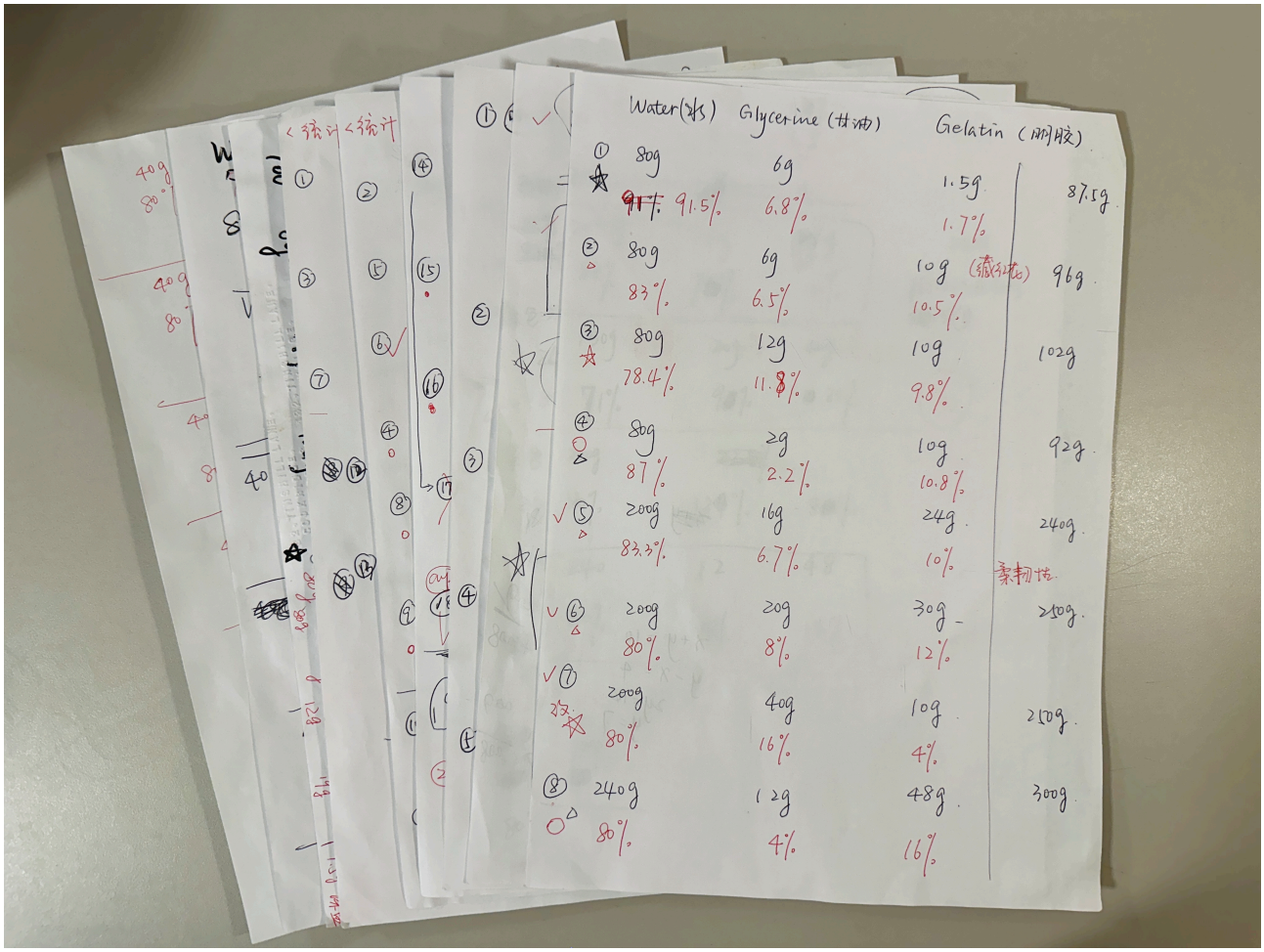


Figure 1: More than 70 Experiments

The rule of proportioning raw materials is found through repeated practice in making the material. The more glycerine content, the better flexibility, and the softer the material, but not easy to shape. On the contrary, the less glycerine content makes the material relatively less flexible; it is slightly complicated but more straightforward to shape and easy to use as packaging. And through the proof of time, without the influence of external causes, its shape, flexibility, etc., can be maintained for more than six months.



Figure 2: Flexibility Comparison

The success of the third set of experiments means that an essential goal of the project has been accomplished. However, verifying that the material is biodegradable is at the heart of this project. If the material does not degrade naturally, then the development of this material will be declared a failure.

EXPERIMENTS

The degradation efficiency of biodegradable materials is affected by several factors, such as temperature, humidity, oxygen content, and microbial species. Microorganisms are an essential factor in biodegradable materials. They secrete different enzymes that recognize and degrade the molecular chains of biodegradable materials. The interaction of multiple enzymes gradually breaks down these molecular chains. This allows the material to gradually break down into smaller molecules or fragments for absorption and utilization (WIKIPEDIA, 2023). The decomposition of biodegradable materials produces simple compounds such as water, carbon dioxide, methane, and organic matter (SCIENCE, 2023). These products are natural substances that already exist in the environment and have less impact on the ecosystem. According to a survey, common packaging materials available in the market, such as paper take 2-5 months to degrade, Plastic-coated paper milk cartons take five years, Tin cans take 50-100 years, Aluminium cans take 80-100 years, Plastic bags take 500 years to eternity, and so on (SCIENCE, 2023). If compared with the degradation cycle of the packaging materials mentioned above, the degradation cycle of this material is considered a successful experiment if it is less than the minimum of 2-5 months. Therefore, small samples of biodegradable materials were placed in water, soil, and seawater to observe their degradation cycles under the same temperature, light, and oxygen conditions.

As can be seen in Figure 3, biodegradable materials decompose fastest in seawater over three weeks. However, if large quantities of biodegradable materials were disposed of in the sea for degradation, there would be a mountain of rubbish on the seashore. Even if the material is biodegradable, the decomposition process still involves the release of substances that can harm aquatic life. It may also upset the natural balance of the habitat. This is the paradox of the project up to this point. Although the degradation cycle is fast, the project's original purpose must be met. It is tough to ensure that the material is biodegradable while minimizing environmental pollution. Is there a trade-off between these two core objectives?

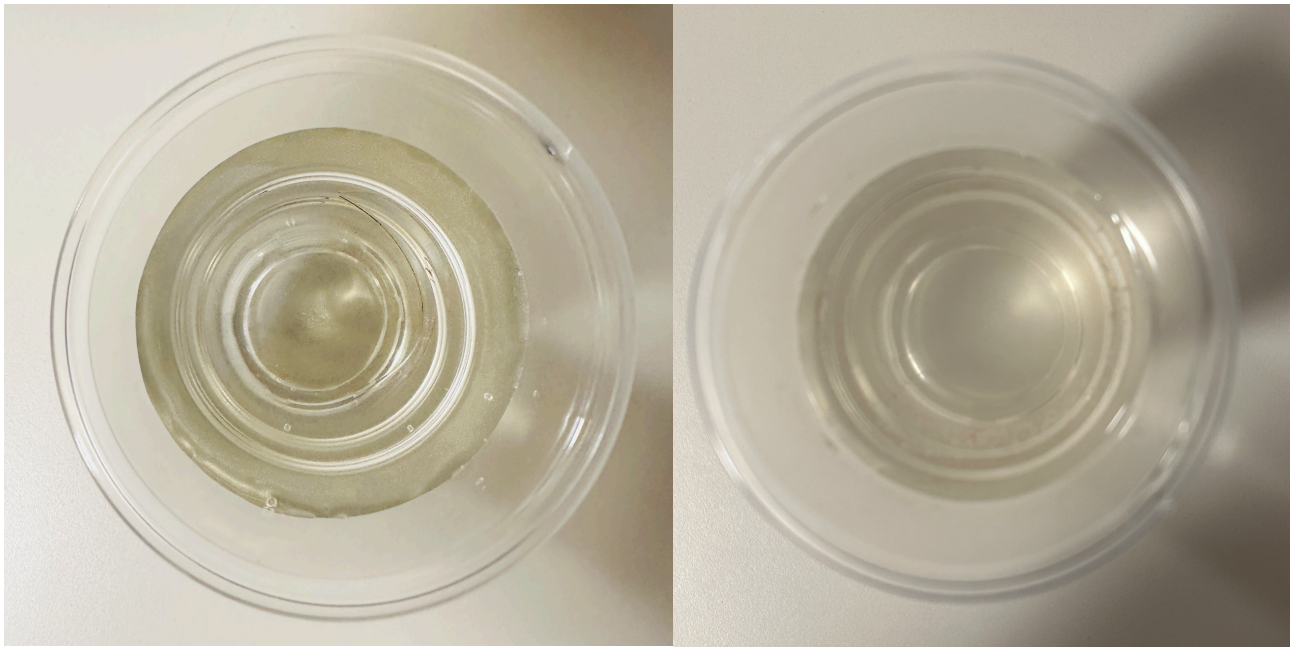


Figure 3:
Experiments on the degradation of small samples of biodegradable materials in seawater
From 12 Oct 2023 to 3 Nov 2023

Secondly, as shown in Figure 4, the degradation cycle of biodegradable materials in water is also relatively fast, ranging from 1 month to 4 months. This data side-steps the fact that the project can continue. Although water itself is not biodegradable, it plays a crucial role in the biodegradation of materials. Many substances, including organic wastes and various materials, can be broken down by microorganisms in water. The necessary conditions are provided for microbial activity (WIKIPEDIA, 2023).



Figure 4:
Experiments on the degradation of small samples of biodegradable materials in water
From 13 Oct 2023 to 12 Dec 2023

As shown in Figure 5, the material degraded slowly in the soil over three to six months. But it also fulfills the project goal set at the beginning. Biodegradable materials can decompose in nature in a shorter period. This significantly reduces the ecosystem impact of the waste generated by the packaging.



Figure 5:
Experiments on the degradation of small samples of biodegradable materials in soil
From 15 Sep 2023 to 5 Jan 2024

Therefore, the development and production of materials and degradation experiments are the central part of the praxis, but demonstrating the practical application of the materials is also a way of proving their viability. Thus, the initial goal of the praxis is achieved.

APPLICATION OF MATERIALS

Demonstrating how biodegradable materials can be applied in the design and manufacture of product packaging requires several considerations. Firstly, what products are packaged using biodegradable materials is particularly critical. What products are suitable for the material? What product packaging can be replaced by the material to achieve better value? What products have packaging that can be reused? Since the material can be biodegradable, what product packaging can take full advantage of this to complete the packaging mission and simultaneously complete the degradation? And so on.

To test the availability of materials, the initial packaging needs to be chosen from the types common in life. While selecting the popular packaging, one can consider whether the packaging can be simplified. Reduce the use of packaging materials. Although the raw materials are all edible, it is impossible to be sure whether the materials can come into direct contact with food after mixing. This will also be the direction of continued research after Confirmative Praxis is over. Therefore, which level of packaging to make the product is also critical to this goal. Primary packaging entails direct contact with the product and the consumer's interaction. Secondary packaging is the outer packaging that holds and protects multiple primary packages. It provides security for the product, especially for transport or storage (Michael, 2023). Tertiary packaging is then the outermost packaging of the product.

Elena Amato says, ‘*We want to reach a wider market, and the product has to be simple.’* (Natashah, 2019). This has inspired me to a certain extent that a product's packaging doesn't have to be so complicated.

To achieve a wide range of test materials. Five groups of different types of products were selected to create their packaging, and each of the three levels of packaging was explored. Firstly, the primary packaging was chosen for household and tool products - soaps and paper clips (non-drinkable and non-edible). Secondly, the box was chosen, a widely used and reusable product packaging. It can be used as secondary packaging for any product. A familiar shape was selected as an example to test its feasibility. For the final tertiary packaging, a reusable coffee cup bag was chosen. It is an innovative design for consumers to carry their coffee.

In exploring the application of using biodegradable materials to make packaging, repeated production, and testing is the most effective way to practice. As a result, five biodegradable packages were produced, as shown in Figures 6-9.

As shown in Figure 8, inspiration was obtained through the degradation experiment of materials in soil. Make packaging for seeds.
The first-level packaging directly holds the seeds. After taking out the seeds, the packaging is directly discarded in the soil for degradation.



Figure 6



Figure 7



Figure 8



Figure 9

COLORING WITH NATURAL INGREDIENTS

Color is the visual expression of a brand and is an integral part of product packaging, which comes in a wide variety of colors. It triggers thoughts, emotions, and feelings about a product and directly impacts purchasing decisions. This is because 85% of consumers buy products based on color (BIZONGO, 2023). This makes choosing the right color for the packaging even more important. Changing the material's color is fundamental before making the biomaterial packaging. This ensures that the project's original purpose is met and that no additives are added to give the material a single structure as far as possible. At the same time, it is possible to make the material colorful. So we chose to use waste ingredients, such as fruit peels, tea leaves, tea dregs, etc. They are all-natural colors. It can ensure the safety of the material and reduce the production cost simultaneously.

During mixing, try adding natural colors such as orange zest, lemon zest, coffee, rose, chrysanthemum, saffron, and honeysuckle to get different colors. If a darker color is required, boil natural ingredients such as orange peel in water for a more extended period to darken the color before adding it to the mixture. It is also possible to get more colors by mixing them using natural color tints. For example, the soap packaging uses the soap's color itself. The bags for coffee cups also use the color of coffee. Boxes, which are widely used as packaging, use the original color of the raw material without adding additional natural coloring.

MATERIAL AND TECHNOLOGY

Packaging needs to display the brand and information about the product. So, printing directly on the packaging without applying labels became another challenge with the inspiration of embossing texture. Tried using an embossing engraver, but it didn't work well. It has some limitations on the thickness of the material. So I tried UV printing again as it is very accommodating and can print on paper, board, aluminum, foam board, and other materials. The technology can print almost anything if the material suits the printer. As a result, biodegradable materials are very smoothly printed using its technology (Kerry, 2018).

To break down as few hazardous substances as possible after degrade, attempts are made to produce packaging without adding other materials. However, this also poses a potential obstacle to the project's progress. How to stick biodegradable materials together. A plastic bag can be molded through a hot air blower as a source of inspiration. Further attempts were then made. There are bold ideas that pay off. The dried biodegradable materials can also be bonded with the Heat Sealer, eliminating the need for glue or other adhesives when sealing packaging. This helps reduce the utilization of other materials and environmental pollution.

This proves that biodegradable materials work well with existing technologies to achieve the desired results.

CONCLUSION

In the fast-moving fashion industry, consuming packaging materials is beyond imagination. Much of the packaging is virtually disposable, unwrapped, and discarded by the consumer. The negative impact of packaging waste on environmental issues is also a growing concern for socially responsible designers, brands, and companies. New alternative materials are constantly being sought. That's why I explored this project.

Before the end of the project, I reflected on whether all the objectives set before the start of the project had been accomplished. Firstly, whether ways were found to reduce the environmental impact of packaging waste, biodegradable materials can break down naturally in various environments, which is particularly beneficial in reducing the impact of packaging waste on the ecosystem. However, this goal was accomplished, hence the later development of the project. But this solution is not the only one; sustainable design is an ongoing process that requires constant improvement and adaptation to the practice of new technologies. I will continue to research this, and as society develops and technology advances, there will be more and more ways to improve this issue.

Second, the creation of biodegradable materials. Continued research and development in materials science and technology facilitates the creation of new and improved biodegradable materials. Materials are developed and made without practice after practice and the experience gained from failures. This has led to developing a biomaterial that approximates paper and plastic. Unexpectedly, only three raw materials were used, and all of them were edible. However, verifying whether this material can be used as a primary packaging for food in direct contact with food is impossible. However, it is a

new target for me to verify and research. Moreover, the material is easy to process and reduces energy consumption in the production process.

Thirdly, it was verified that the material could be naturally degraded. This is the core of this project. Through three sets of experimental results, it can be concluded that the material can be successfully degraded in the natural environment. Among them, the material has the fastest degradation cycle in seawater. However, the cumulative impact of widely disposing of such materials in the ocean can also cause pollution, which is still a severe problem. This is also an issue that I initially overlooked when designing the experimental environment. It also reminds me to be more rigorous in my future explorations. However, the data from the other two sets of experiments remain positive.

Fourth, use biodegradable materials in packaging. Reducing the environmental impact of packaging waste also focuses on designing sustainable packaging and promoting reuse. As the first generation of product packaging made from this material, the main focus has been replacing existing packaging materials and innovative design. Five products have been successfully designed and produced in continuous testing. I plan to use the material to create packaging for different types of products and to apply the material to other products. This is another goal for the end of the practice.

Overall, the project explored, researched, made, experimented, and solved problems. The initial challenge of the project was completed and achieved. Mastered the manufacturing process of biodegradable materials and applied them to product packaging. From initial material development to final material application, every stage of the practical method is carefully considered. In the future, I hope that more biodegradable packaging will replace existing packaging. Reduce the environmental impact of packaging waste. I will also continue to research.

COLORING WITH NATURAL INGREDIENTS

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