



Exploration of Bio-Based Materials and Sustainable Product Design: A Case Study of BioPlastic Preparation and Design

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Abstract. In the contradiction of development, increasing and shortages of sources, we are forced to start considering for the development in the future to seek for more replaceable materials or solution cases. Petrochemical raw materials are not the only way to get the same function as plastic. Rethink people's habits of manufacturing and using materials and try to turn bio-based materials into new materials of products. A new mode and pattern, or even new and alternative materials, are expected to replace the old one. Materials with "plastic" properties can also be obtained from raw materials such as sugar, algae or starch. The thesis sets the preparation of team "Bioplastic" design project and its product designs for example, introducing all kinds of ways of preparation of "Bioplastic" and discussing the possibility of bioplastic applying in product designs in the future. In the view of sustainable designs, it will compare and analyse the function between bioplastic and traditional petrochemical plastic.

Keywords: Bio-based materials · BioPlastic · Sustainability · Product design

1 Introduction

The earth is a closed system—aside from meteorites impacting the planet, there is no way of introducing new matter to the system or of taking it away [1]. So, scientists and environmentalists often emphasize that these limited resources have important value, because nothing in nature can be wasted. "Waste should simply not exist ... waste is a resource" [2]. But if we take the reverse of the current situation of our artificial industrial production environment into consideration, which is in sharp contrast to the closed system of the earth or nature, which is one of the global challenges we are facing at present. Up to now, the main production patterns are: to transport natural or artificially synthesized raw materials to large factories, and transform them to the product by high temperature, high pressure, chemical process treatment; then deliver these products to the world for the consumption. From the beginning of production to the output of products, 96% of garbage and waste are produced in this process, only 4% of them are products [3]. However, we always use these products very easily, and discard them

if we don't need them, this kind of single-lined "production- discard" pattern has reached the physical limit at present [4].

Amidst this apparently peaceful material world, a book *The Limits to Growth* [5] appeared some 40 years back showing us by modeling the consequences of unchecked economic and population growth with finite resource supplies. Nevertheless, the concern about the diminishing resources to sustain our material world is of recent origin.

"There are professions more harmful than industrial design, but only a very few... by creating whole new species of permanent garbage to clutter up the landscape, and by choosing materials and processes the pollute the air we breath, designers have become a dangerous breed... In this age of mass production when everything must be planned and designed, design has become the most powerful tool with which man shapes his tools and environments (and, by extension, society himself). This demands high social and moral responsibility from the designer."— Victor Papanek (Papanek 1985).

Such as Meadows and Papanek's worry, the raw materials are not only used up, it will also go with the pollution, rubbish and waste issues. In fact, all the evidence indicates that if we continue to develop in the current speed, we will need a second earth rapidly. How to proceed the sustainable development and how to balance the contradiction between development and pollution become the problem which has to be thought about. He re-thinks people's habits to produce and use materials, discusses about the possibility of material recombination and redesign, which can make for finding the sustainable development direction in the future.

Fortunately, we are living in the era of accelerated development of science and technology and after 2000, a large number of design experiments and innovative design cases of new solutions or alternative solutions have sprung up. On the one hand, through studying how to realize the advanced and complex system and structure by using the least resources and simple and ingenious design or combination, so as to form the interdependent relationship and closed network system with feedback mechanism. On the other hand, human beings also constantly learn to open the design door of transformation, such as, designers attempts to transform "garbage, waste" into "new resources or energy", and scientists also try to use microorganisms to treat sewage, and so on.

2 Bioplastic and Product Design

Over the past two hundred years of the human industrial revolution, we have created an unimaginable material world and have achieved a brilliant success. But at the same time, we are consuming the resources of the earth. Because since the 1950s, the plastic has appeared as a "new material". The man-made and synthetic materials occupy a dominant position in the product design and living materials for half a century. The continuous development and use of materials is like a double-edged sword, which leads us to prosperity and destruction. Nowadays, the widely used plastic not only has a bad influence on environment but also lead to traditional fossil fuels shortage and dying up.

Now we may be on the brink of a materials revolution, reflecting from the perspective of materials and the making basis of products, which may help to rebalance or even reshape the relationship between human beings and the earth, and fundamentally realize

the sustainability of future development [2]. Materials research constantly evolves to offer novel, superior materials as better alternatives to convention (e.g., bio-based materials, smart materials, recycled and/or recyclable materials, etc.) [6, 7]. Sustainable development, as defined in the United Nations (UN) report *Our Common Future* (Brundtland Commission, WCED 1987) is the “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

2.1 Bioplastic

Common plastics, like fossil fuel plastic is refined from petroleum, these plastics mainly depend on fossil fuel and generate greenhouse gas. But there is an important operation principle in the natural ecology – the diversity principle, that is to say, in an ecosystem, the more diverse the elements are, the more complex the energy and material flow methods are, the more intricate the food cycle composition is, the stronger the automatic adjustment and stability ability of the ecosystem will be; on the contrary, the duller the elements is, the simpler the structure is, the lower the resistance ability to cope with environment changes will be. The principle is not only that operated in the natural ecosystem, it is also applied in the designs of Bio-based materials and sustainable products in the future. Diversity is a kind of elastic strategy, when solving the same challenge or facing with the same problem, response in various of solutions and methods to reach the preset target. Exactly as the design practice project “Bioplastic”, prepare the material with the same property as the traditional plastics by the material recombination experiment, petrochemical materials are not the only scheme to meet people’s use demand, several different food waste materials can be transferred at present through Bioplastic project practice and constant attempt, then the alternative material like the traditional “plastic” property is obtained in many kinds of different preparation methods and ways.

Bio-based materials such as “Bioplastic” is the alternative plastic material from the regenerative biomass resource, it is not the actual plastic, but a material which has the plastic property, such as from vegetable oil, starch or microbiota, the production methods of bioplastic are various, Bioplastic part of the practice project is trying to produce organic bioplastic by food wastes actively, it can produce the alternative material for the fossil plastic currently and put forward the more and possible resolution and design practice [8]. Bioplastic project mainly pay attention to the edible wastes and scrap materials in life, such as nut shell, all kinds of egg shell and Fruit and vegetable waste, it is enlightened by the molecule cuisine, looks for feasible preparation methods by the different prescriptions and proportion of material experiment, finally the organic bioplastic with the fossil plastic characteristic can be obtained. And it designs to produce the bulk materials, sheet materials and products with the aesthetic value but without visual sense and tactile sense effect.

2.2 Preparation and Properties of Bioplastic

Nut and egg shell: The following three ideal bio-plastics were obtained through material preparation experiment of Bioplastic team project. The main raw materials of

the three organic plastics are different, but the preparation process is similar. Bioplastic mainly use nut shell and egg shell as the main raw materials. After the discarded shell and eggshell crushed, were heated and mixed with natural dyeing materials, starch gum, glycerin and other materials, and the Bioplastic mainly composed of shell and eggshell can be obtained after drying. There is not a single method of configuration and the Bioplastics with different hardness can be obtained by changing the materials or the proportion (Figs. 1 and 2).



Fig. 1. Nut shell - bioplastic. Design by Beijing Institute of Fashion Technology, Innovative Materials Research Centre, 2018



Fig. 2. Egg shell - bioplastic. Design by Beijing Institute of Fashion Technology, Innovative Materials Research Centre, 2019

Fruit and vegetable waste: There are a large number of fruit and vegetable waste every day in agricultural markets, food processing stations and plantations, which can not only be used for composting, but also the main raw material for the preparation of Bioplastics. Our team project has tried to use orange, banana, sugarcane, hawthorn, pumpkin, potato, apple, carrot and other fruit and vegetable wastes, such as skin, rotten fruits and vegetables, after many attempts, to mix them with water and edible gum, cook, and then dry them to get a kind of recycled material, which has similar characteristics of leather and flexible PVC. What’s more, products can be made by sewing (Fig. 3).

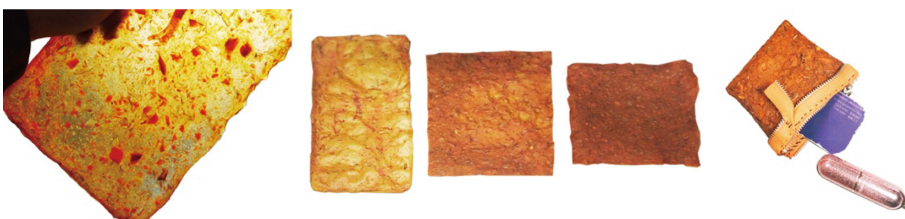


Fig. 3. Fruit and vegetable waste - bioplastic. Design by Beijing Institute of Fashion Technology, Innovative Materials Research Centre, 2018

Alga: Alga contain natural colloids, which can also be used to prepare ideal organic plastics with certain transparency. Alga, as the main raw material, added with water, starch, vinegar and glycerin, after a certain temperature mixing, Alga bio-plastics can be obtained. After drying, an organic material can be obtained, with the characteristics of softness, transparency, lightness and thinness, which can be sealed by hot pressing (Fig. 4).

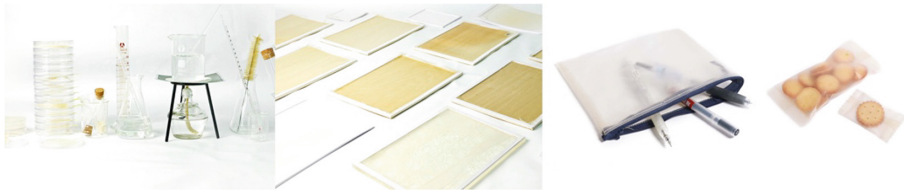


Fig. 4. Alga - bioplastic. Design by Beijing Institute of Fashion Technology, Innovative Materials Research Centre, 2019

Bio-plastics obtained by three different preparation methods have their own characteristics. The properties of these materials were compared. The comparison of material properties shall be carried out according to the five-level system by Professor Elvin Karana, [8] from the chart below for the specific comparison (Fig. 5).

Material Characteristics \ Types of BioPlastic	Nut and egg shell	Fruit and vegetable waste	Alga
hard & soft	●○○○○	○○●○○	○○○○●
smooth & rough	●○○○○	○●○○○	○○○○●
matte & glossy	●○○○○	●○○○○	○○○●○
cold & warm	○○●○○	○○○●○	○●○○○
not elastic & elastic	●○○○○	○○●○○	○○○●○
opaque & transparent	●○○○○	○○○●○	○○○○●
tough & ductile	○●○○○	○○○●○	○○○○●
strong & weak	○●○○○	○○○●○	○●○○○
light & heavy	○○○○●	○○○●○	○●○○○

Fig. 5. Material characteristics. draw by author, 2020

The main materials of Bioplastic are obtained from food waste, alga and other raw materials, trying to achieve zero waste in the process from raw materials to processing and manufacturing to finished materials and products. The raw materials are obtained

from food wastes, and produced to materials or products, which can be corrupted or decomposed naturally in the aerobic or oxygen-free environment after using.

At the same time, these products can be recycled and entered the later life cycle of product after completing the life cycle due to the special natural components, which achieves the process from “cradle to cradle” indeed. The following application and development of BioPlastic materials have advantages and potentials in the fields of household products, bags and suitcases and building materials. The material hardness, abrasability and the surface natural pattern, texture and color are suitable for the household products or bags and suitcases; by exploring and studying food waste materials to excavate potential value, not only the waste egg shell, to look for more common materials which can be replaced by the recycling materials or wastes, it is the original intention of design of the whole “BioPlastic” project – to collect the alternative product raw materials from industrial, life wastes and waste yard, “waste should simply not exist... waste is a resource.” [2] (Fig. 6).

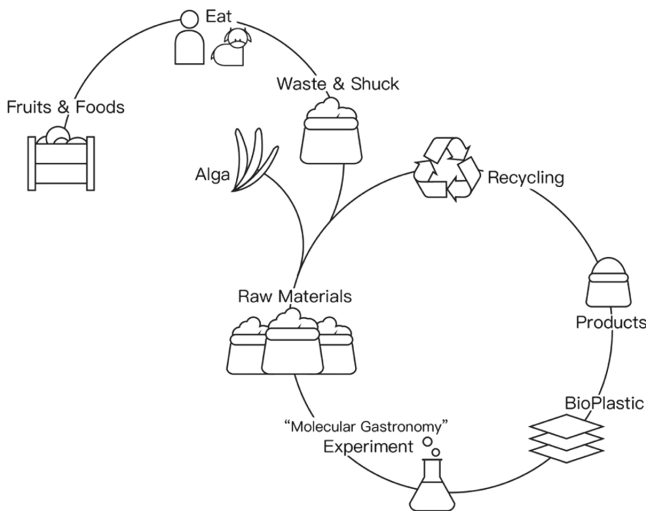


Fig. 6. BioPlastic project cycle chart. draw by author, 2020

2.3 Bio-Based Materials and Sustainable Product Design

Based on biological materials, product design is the organic unity of organic materials and design. Take the Bioplastic project as an example, through the bioplastics, following the design principles of win-win and diversity, designs, harmless to the living environment of human beings and less bad impact on the environment, can be produced. This kind of design will eventually change the production and consumption mode of the public, maximize the utilization of resources, minimize or prevent the generation of garbage, and achieve the goal of effective protection of the environment and human life and health.

Win-win principle: Win-win refers to both the natural environment on which human beings live and the needs to meet human life and daily use can be concerned. The design principle of win-win is to constantly balance the relationship between both of them in the design stage, and finally get the win-win design results. This is also in line with the basic concept of sustainable development, that is, to improve people's quality of life, while gradually reducing energy consumption.

The principle of diversity: The principle of diversity is not only the principle of natural ecosystem operation, but also the design principle of sustainable products based on organic materials. Diversity is a flexible strategy because it allows multiple solutions and ways to solve or respond to the same challenge. A diverse society will be better able to withstand natural disasters, bad growth periods, economic difficulties or cultural crises [9].

In order to meet a human need, the strategy of multi-channel and multi solution can avoid excessive dependence on a certain material or energy. For example, petrochemical raw materials are not the only way to manufacture materials with the same properties as plastics. BioPlastic is made of edible starch, alga, glycerin and other materials, whose hardness and toughness are no less than that of plastic.

3 The References Section

The research of sustainable materials in product design is not only about the simple discussion and attempt of basic materials of creation, but also the practice of products from “cradle to cradle”. On the one hand, we the source of new sustainable materials need to be paid attention to, on the other hand, we the sustainability of materials need to be paid attention to after the end of the product manufacturing process and product life cycle. This paper takes our team project “Bioplastic” as an example. It also uses bio-based materials to design the prototype of products and come up with an idea of creative design based on organic materials for sustainable product designs. It aims to lead designers to think about more ideas for continual products in the future when they face the complex nature, ecology and social problems. Materials are the foundation of design creation, and it is a design strategy to make products have sustainable characteristics. Ecological and sustainable product design is not only inseparable from the innovative design of materials, but also inseparable from the interdisciplinary cooperation.

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