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Tea Leaf Waste: Pigment Production Process and Application in Painting

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ABSTRACT

This paper explores how to transform tea dregs discarded in milk tea shops into watercolor pigments, focusing on the process and methods of pigment design, aiming to provide new ideas for sustainable material design. The study uses Chinese black tea, green tea, Thai black tea, and green tea as raw materials, and combines different chemical substances (such as acid, alkali, and mordant) for color regulation. During the experiment, the tea dregs were first boiled to extract the pigment solution, and then mordants (such as alum, citric acid, and sodium bicarbonate) were added to adjust the color tone. Subsequently, the pigment powder was precipitated, dried, and ground to form a pigment powder, which was combined with watercolor binders such as gum arabic to form watercolor pigments that can be used for painting. The results show that different types of tea dregs can produce rich color changes under specific chemical treatments, showing a variety of tones from warm brown to dark gray-blue. These pigments were used in painting experiments. The works revolve around the theme of "cycle and continuity" and emphasize the sustainable relationship between man and nature. The study not only verifies the feasibility of tea dregs pigments in artistic creation, but also provides new possibilities for the application of environmentally friendly materials in painting.

Keywords: Tea residue, sustainable development, pigment production.

Introduction

Due to the popularity of milk tea, milk tea has become one of the favorite drinks for young people. A large amount of tea waste is generated every day in milk tea shops in China and Thailand. After searching for information and field research(Li Shulin. 2020), these teas are usually discarded after being used only once. Each store discards an average of 3-5 kilograms of tea every day. In the context of sustainable development advocated by the world, more and more countries and regions are beginning to reflect on traditional resource utilization methods. In fact, traditional painting pigments usually come from minerals and plants. Mineral pigments are usually ground from natural ores. Plant pigments are extracted from leaves, flowers, fruits and other parts of plants. Although these natural pigments come from nature, their acquisition depends on a large amount of resource mining and extraction. Direct mining of mineral and plant resources in nature can meet the demand for pigments in traditional painting, but it has an impact on the environment that cannot be ignored. In order to extend the life cycle of tea and provide new possibilities for artistic creation. This article begins to study the relationship between tea and pigments.

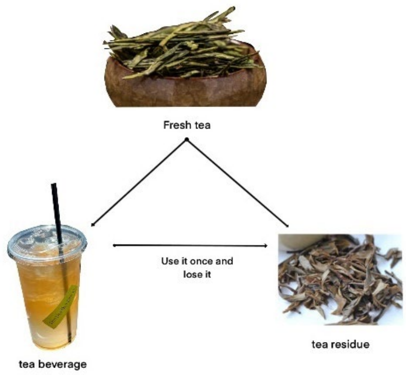


Figure 1. Tea leaves become garbage after only one use
Source: Author.

Objectives

In response to the national and international advocacy of Sustainable Development Goals (SDGs) and green economy, this paper aims to explore how to reuse tea residues in an innovative way. The research objectives are as follows:

1. Respond to sustainable design needs.
2. Design and optimize new environmentally friendly pigments.
3. Apply to practical creation and color design.

Research framework

Driven by the concept of global sustainable development, environmental protection and resource recycling have become important topics in contemporary art and scientific research. This paper aims to explore how to use these waste tea residues to make painting pigments and apply them to painting creation to express the theme of circulation and continuity.

The research framework is as follows:

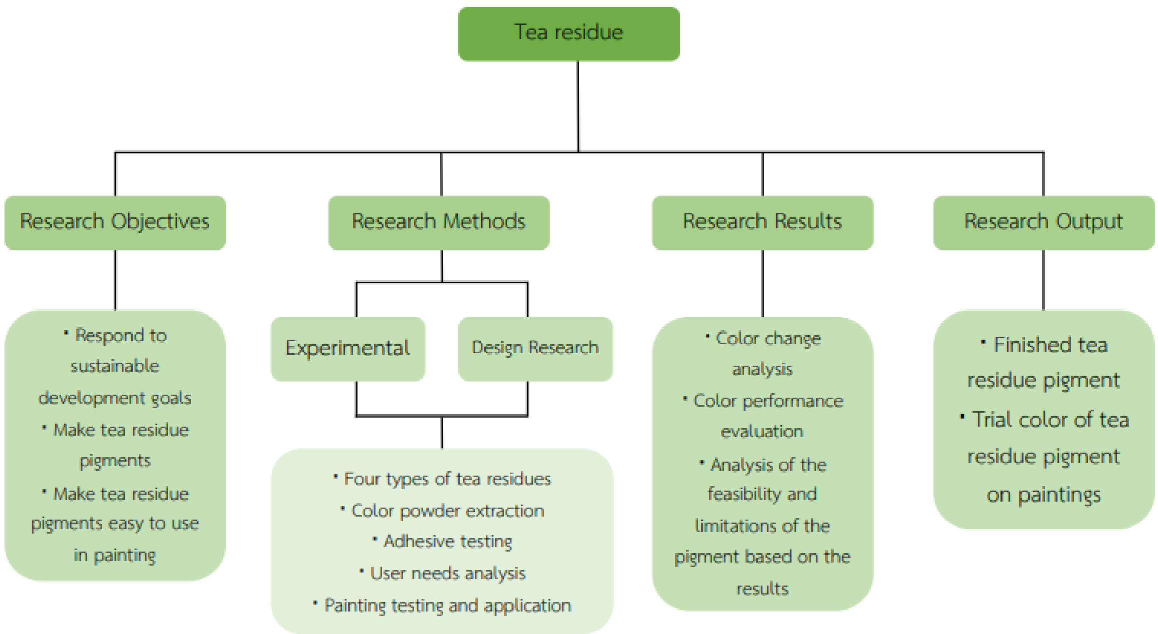


Figure 2. Research Framework
Source: Author.

Literature review

The types of tea selected in this paper are: Chinese black tea, Chinese green tea, Thai black tea, and Thai green tea. In order to ensure that the experiment can be successfully carried out at the graduate level, the scope of tea residue collection should be appropriately narrowed. The locations for collecting tea residues are set in the author's hometown of Guangxi, China and the city where the author went to school, Bangkok, Thailand. The selection criteria for tea types are the waste tea leaves used in milk tea shops.

The waste tea residues from milk tea shops are collected, sorted and classified, and then different color fixatives, color change agents, and precipitants are used for experiments. Through literature analysis, the theoretical and practical foundations for the research of tea residue pigments are laid, and their application in painting is demonstrated.

This article will analyze from the following three aspects:

1. **Pigment production.**

In the production of traditional painting pigments, the sources of pigments are usually divided into mineral pigments, plant pigments and chemical pigments. By learning and understanding the literature on the extraction methods and binders of different types of pigments, references and inspiration can be provided for tea residue pigments.

Mineral pigments: It is a pigment extracted from natural ores. After these minerals are crushed, screened, cleaned and processed, impurities are discarded and ground into fine powder, and then mixed with binders to become pigments. (LeCroy, 2022)

Plant pigments: This type of pigment is a natural pigment extracted from plants, usually obtained from leaves, flowers, fruits or bark. These plant components are crushed, boiled, extracted, etc., the pigments are separated and chemicals are added to obtain precipitates, and then made into pigments for use (Ngamwonglumlert et al., 2017) . In order to increase the stability and adhesion of the pigment, alum or other color fixatives are often added.

Chemical pigments: This type of pigment is a pigment synthesized in a laboratory, and a specific color is produced through chemical reactions. The traditional production method of chemical pigments is relatively complicated, usually involving the blending and reaction of chemical reagents. For example, some artificially synthesized blue pigments (such as Prussian blue) are produced by the reaction of metal salt solutions with other chemicals. (Solomon et al., 2011)

2. **Paint binder**

In painting creation, the choice of pigment and the application of adhesive are important factors in determining the effect of the painting. Adhesive is the medium that fixes the pigment particles on the canvas or paper. Different types of paintings use different adhesives due to their unique production processes, presenting their own unique artistic expressions.

Watercolor paintings are known for their lightness and transparency, and the transparency and fluidity of the pigments make the pictures full of vitality. Watercolor binders are mainly made of gum arabic, honey and a small amount of glycerin (Gärtner, 2021), but the binders of watercolor pigments can be composed of a variety of different media. Binders can enhance the adhesion of pigments while maintaining bright colors. The flexibility of this medium provides more experimental space for exploring tea residue pigments.

3. **Art theory.**

Art theory provides ideological support for painting creation. This study takes "cycle and continuity" as the core theme, combines ecological cycle theory (Brown, 2014)and symbol theory (Petrilli, 2017), interprets the creation from a philosophical and artistic perspective, and injects deeper meaning into the work.

Research methods

In this study, different color powder was obtained by combining tea residue with different media. It is then combined with watercolor pigment binder to produce environmentally friendly watercolor pigments. Qualitative and quantitative research methods were used to complete this study by combining questionnaires, interviews and experiments. The research methods are as follows:

1. Collection and classification of tea residue.

1.1 Collect tea residue:

The author conducted a survey in a milk tea shop and obtained tea residue. The store was asked when collecting the tea, and the tea shop discarded the tea leaves to ensure the taste was only soaked once. When collecting tea leaves, ensure that they are not contaminated and avoid mixing with other food and beverage waste.

Figure 3. Investigate tea leaves discarded by milk tea shops.
Source: Author.

1.2 Sorting:

The tea residue collected was classified according to tea varieties and sources, including Chinese black tea, Chinese green tea, Thai black tea and Thai green tea. The purpose of this step is to preserve the unique pigment properties of each tea residue. After sorting is complete, the tea residue is placed in a clearly marked container to ensure the accuracy of subsequent processing.

1.3 Dry and store:

Dry the tea leaves in a sunny and well-ventilated area to prevent mildew. The dried tea residue should be stored in a dry, airtight container to prevent moisture from re-penetrating.

Figure 4. Sort and dry tea leaves.
Source: Author.

2. Color fixing agent, discoloration agent and precipitating agent in tea residue pigment experiment.

To extract pigment from tea residue, the residue is first boiled in water to obtain a pigment solution. Then, acidic or alkaline substances are added to produce different colors. Fixing agents stabilize the color, discoloration agents adjust the tone, and precipitating agents help form the pigment.

2.1 Color fixing agent:

Color fixing agents are used in pigment production to fix and stabilize the pigment molecules in the pigment solution of tea residue to prevent them from fading or losing during drying or painting. By adding a fixing agent, the pigment molecules can better adhere to the fiber or painting surface, thus enhancing the durability of the pigment. The fixing agent used in tea residue pigments has the following substances:

Alum (Alum) : is a commonly used color fixing agent that contains aluminum ions that help stabilize the pigment and allow it to adhere to the pigment substrate. Alum can make the pigment show a brighter color, while improving the resistance of the pigment to fading.

2.2 Color changer:

Chromophores are used to regulate the hue of pigments, usually by changing the pH or introducing different metal ions to affect the light and shade of the color. Different discoloration agents will produce rich color changes, so that the application of tea residue pigment is more diversified. The discoloration agents used in tea residue pigments are as follows:

Copper sulfate: A compound containing copper that, when added, causes the pigments in the tea leaf solution to produce a greenish tint. This effect is common in many plant pigments.

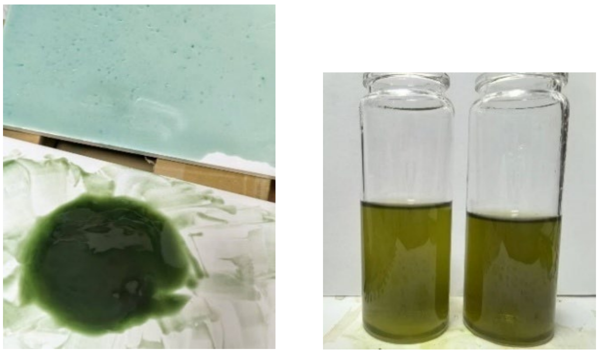


Figure 5. Blue alum was added into the tea residue pigment solution
Source: Author.

Citric acid: Citric acid affects the hue by adjusting solution acidity.

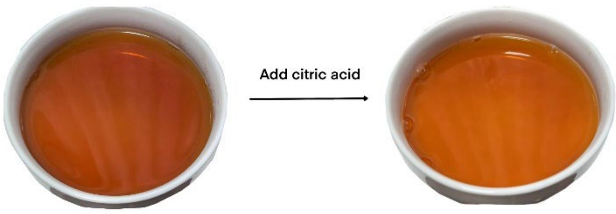


Figure 6. Adding citric acid to the black tea residue pigment solution makes the liquid brighter.
Source: Author.

Rust water: Rust water contains iron ions, can produce tan or gray black tone, suitable for more stable color pigments. When the rust water is added to the tea residue solution, the color will generally turn blue and black, which is approximately black to the naked eye.


Figure 7. Add rust water to tea residue pigment solution
Source: Author.

2.3 Precipitating agent:

The precipitant helps the pigment form a precipitate in the solution, making it easier for the pigment to be extracted from the solution and converted into a bulk solid. The use of precipitant is helpful to obtain uniform particle distribution and saturated color powder in pigment production. The discoloration agents used in tea residue pigments are as follows:

Baking soda: as a precipitating agent, it can adjust the pH value of the solution and promote the pigmentation of the tea residue. In addition, an alkaline environment makes certain pigments more stable.

Calcium hydroxide: Used as an effective precipitator in pigment production, it combines with the pigment in the tea residue to form a more stable precipitating solid. Its use can produce more delicate and stable pigment particles.


Figure 8. A precipitating agent was added to the pigment solution of tea residue to form a precipitate
Source: Author.

These fixing agents, discoloration agents and precipitating agents provide a variety of possibilities for the extraction and color change of tea residue pigments, making the color of the produced watercolor pigments more diversified.

3. Extraction and filtration methods and grinding, screening.

3.1 In this experiment, there are two ways to obtain massive sediments: vacuum filtration and flat drying.

Figure 9. Vacuum filter device
Source: Author.

Vacuum filter: by the filter funnel, triangle flask and filter vacuum unit. This device can quickly drain the filtered water to obtain the sediment, but the pigment precipitate obtained in this way has low color saturation.

Figure 10. Lay flat to dry
Source: Author.

Flat drying: The liquid added to the precipitating agent is poured on the white tile or smooth glass, and the precipitation is obtained by drying for several days. This method takes more time, but the sediment can absorb the pigment in the liquid to the maximum extent, and the color expression of the sediment is better.

3.2 After extracting the pigment precipitate of tea residue, converting the precipitate into fine pigment powder is the key step, and the specific process is as follows:

Grinding process:

First, the dried tea residue pigment precipitate is ground to improve the uniformity and fineness of the particles. Manual grinding usually uses a mortar and pestle to evenly crush the precipitate. Although this method is time-consuming, it can ensure that the pigment particles are more uniform and easier to control the fineness.

Figure 11. Hand grinding
Source: Author.

Sifting refinement:

The ground pigment powder usually contains particles of different sizes, so it needs to be sieved. The sieving process can be achieved by using sieves with different apertures. In this experiment, a 200-mesh sieve was selected for sieving because finer powder is conducive to the production of pigments.

Figure 12. Hand grinding
Source: Author.

The fine powder after grinding and sifting needs to be collected and stored in a sealed container for subsequent use in making watercolor paint.

4. **Watercolor adhesive.**

When making tea residue watercolor paint, the addition of a binder is crucial. Gum arabic provides adhesion and film-forming properties, allowing the paint to spread evenly and enhance transparency. Natural ox bile improves fluidity and diffusion, ensuring uniform color. Honey helps enhance gloss and prevents the paint from cracking. Reasonable adjustment of the proportions of these ingredients makes tea residue pigments close to traditional watercolors in texture and expression, suitable for artistic creation.

Research results

1. **Reaction results of four kinds of tea leaves with different substances.**

In the process of developing tea residue pigments, this study established a set of basic design standards based on the production of various types of pigments to ensure the availability and stability of the pigments. These standards include:

Color stability: The pigments should remain relatively stable under different environmental conditions (such as humidity, temperature, and light) and should not fade or deteriorate easily.

Color range: Through the combination of different tea types and chemical reagents, explore the available color types to meet different creative needs.

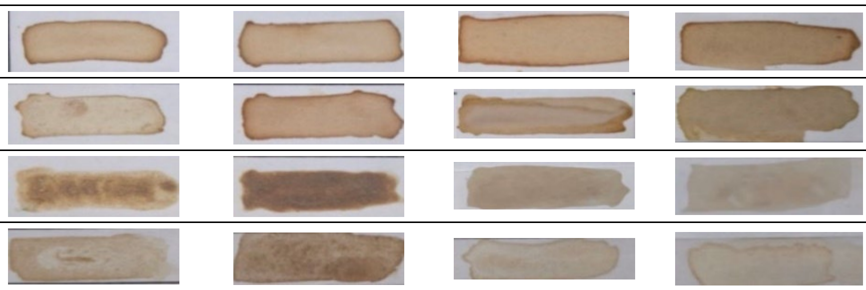
Pigment texture: The fineness and solubility of the pigment powder must meet the standards suitable for watercolor painting to ensure smooth application effects.

Compatibility: The pigments should be compatible with common watercolor media (such as gum arabic) to ensure fluidity and adhesion during use.

These design standards not only guide the pigment production process, but also provide a reference for future optimization in different application scenarios.

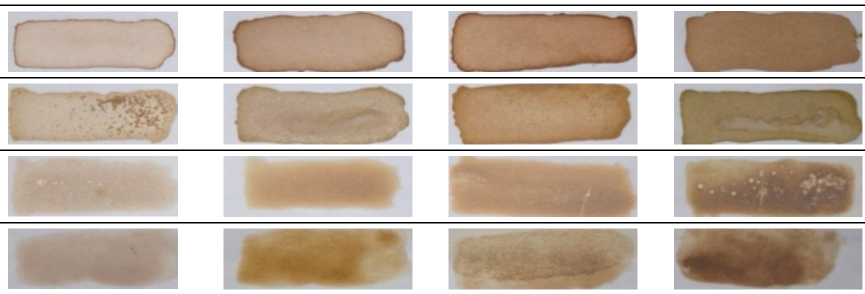
The author selected Chinese black tea, Chinese green tea, Thai black tea and Thai green tea to react with different substances. Explore the reaction between tea residue pigment solution and acid-base substances and iron ions. The following are the four types of tea reacted with 8 groups of experimental substances, and a total of 32 experimental results were obtained.

Table 1. Reaction results of four kinds of tea with alum and slaked lime respectively



① Alum + Slaked lime	Chinese Black Tea	Chinese Green Tea	Thai Black Tea	Thai Green Tea
Original Color				
+ Alum				
+ Slaked lime				
+ Watercolor Binder				

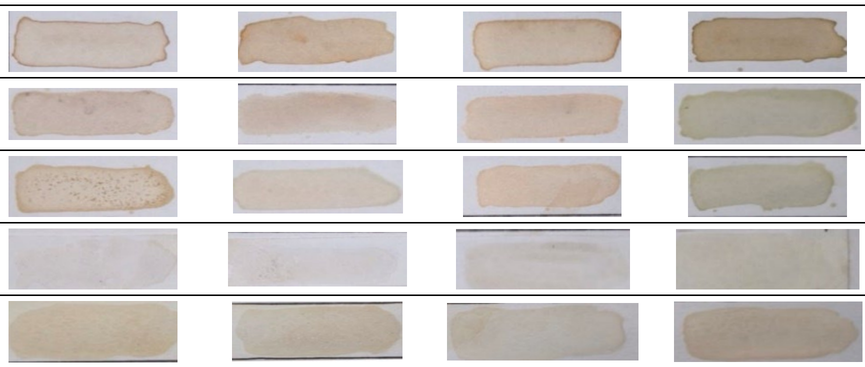
Table 2. Results of reaction of four kinds of tea with alum and edible alkali respectively



② Alum + Edible alkali	Chinese Black Tea	Chinese Green Tea	Thai Black Tea	Thai Green Tea
Original Color				
+ Alum				
+ Edible alkali				
+ Watercolor Binder				

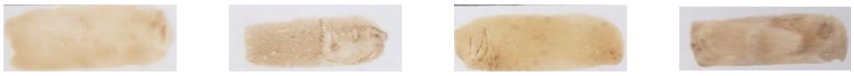
The same color fixative and different precipitants were added in the two experiments in Table 1 and 2. The experimental results show that when the same alum color fixative was added, the pigment precipitate produced by adding slaked lime is darker than the pigment precipitate produced by adding edible alkali.

Table 3. Reaction results of four kinds of tea with citric acid and hydrated lime respectively.



③ Citric acid + Slaked lime	Chinese Black Tea	Chinese Green Tea	Thai Black Tea	Thai Green Tea
Original Color				
+ Citric acid				
+ Alum				
+ Slaked lime				
+ Watercolor Binder				

Table 4. Four kinds of tea were boiled with alum and then cooled with edible alkali

④ Alum (heated) + Edible alkali	Chinese Black Tea	Chinese Green Tea	Thai Black Tea	Thai Green Tea
Solution + alum (heat until it does not change color)				
+ Edible alkali				
+ Watercolor Binder				

In the experiment in Table 3, the acidic color change agent and slaked lime were added, and the color became lighter and closer to white. The solution with the acidic color change agent did not react significantly with the edible alkali precipitant, and no pigment precipitate was produced. In the experiment in Table 4, the author added alum to four types of tea and boiled them together. After cooling, edible alkali was added. The precipitate obtained was brighter in color than the precipitate in Table 2.

Table 5. The reaction results of four kinds of tea with blue vitriol, slaked lime and edible alkali

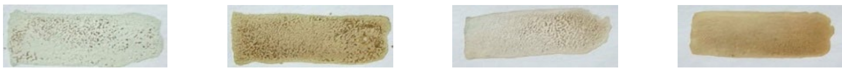
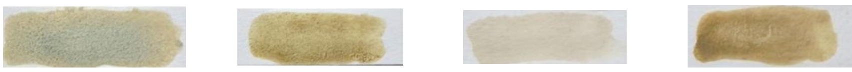
⑤ Chalcanthite	Chinese Black Tea	Chinese Green Tea	Thai Black Tea	Thai Green Tea
Original Color				
+ Chalcanthite				
Plan 1				
+ Slaked lime				
+ Watercolor Binder				
Plan 2				
+ Edible alkali				
+ Watercolor Binder				

Table 6. The reaction results of four kinds of tea with rusty water, slaked lime and edible alkali

⑥ Rusty water	Chinese Black Tea	Chinese Green Tea	Thai Black Tea	Thai Green Tea
Original Color				
+ Rusty water	Darkening reaction is not obvious			
Plan 1				
+ Slaked lime				
+ Watercolor Binder				

⑥ Rusty water	Chinese Black Tea	Chinese Green Tea	Thai Black Tea	Thai Green Tea
Plan 2				
+ Edible alkali				
+ Watercolor Binder				

Table 5 is a reaction experiment of four kinds of tea with blue vitriol, and then add slaked lime precipitant and edible alkali precipitant to observe the color of the precipitate. The hue of the precipitate with both precipitants is green, and the product with slaked lime precipitant is darker. After adding watercolor binder to the precipitate with edible alkali precipitant, it is yellow at first and then turns green after oxidation. Table 6 is a reaction experiment between tea residues and rusty water. The rusty water will make the solution darker, but after adding the precipitant, the color will turn yellow and brighter.

Table 7. Watercolor paint color card

+ Watercolor Binder	Chinese Black Tea	Chinese Green Tea	Thai Black Tea	Thai Green Tea
① Alum + Slaked lime				
② Alum + Edible alkali				
③ Citric acid + Slaked lime				
④ Alum (heated) + Edible alkali				
⑤ Chalcanthite + Slaked lime				
⑥ Chalcanthite + Edible alkali				
⑦ Rusty water + Slaked lime				
⑧ Rusty water + Edible alkali				

Figure 13. Watercolor paint
Source: Author.

2. Application in painting

In the field of art and design, users' demands for painting pigments are mainly concentrated in terms of color expression, ease of use and environmental protection. The tea residue pigments discussed in this study show certain advantages in these aspects, but there is also room for improvement. In terms of color expression, different teas combined with chemical regulators can provide unique natural tones, and have a certain degree of transparency and layering. Compared with traditional watercolor pigments, their color range is more limited, but tea residue pigments can be used as a special series of colors. In terms of ease of use, appropriate adjustment of the binder formula can improve the fluidity and reactivation of the pigment to meet the needs of watercolor painting, but the color consistency and adhesion of different batches still need to be optimized. In addition, in terms of environmental protection, tea residue pigments, as sustainable materials, reduce harmful chemicals and are in line with the concept of green design. However, due to the limitations of natural raw materials, its production efficiency and storage stability still need further research.

During the design process, the author used different teas and chemicals to control the hue, saturation and transparency of the pigment, making it suitable for actual painting creation while deepening the understanding of color control.

Each step in this process actually reflects the design methodology of the pigment (Lilley, 2009): from the acquisition of "waste" such as tea residues, the selection of chemical substances, to the final grinding and preparation of pigments, it reflects how to transform resources into materials with creative value through design means. Through this process, designers can choose the most suitable pigment type and color combination according to different artistic needs, so as to realize artworks that meet their design concepts.

In terms of creation, the content of the picture expressed by the author is about natural cycles, material regeneration and the relationship between man and nature. The paintings in this study are not only used to show the visual effects of tea residue pigments, but the content of the paintings is also a philosophical reflection on the concept of sustainability and natural cycles. (Brown, 2014) The simple color presentation is difficult to fully express the deep meaning of waste recycling, and the use of tea residue pigments can strengthen the concepts of "recycling" and "continuation" conveyed by the works, making them more symbolic in addition to visual presentation. These works can be regarded as a practical verification of tea residue pigments, showing their feasibility in artistic

creation through practical application, and further exploring the relationship between man and nature. And to convey the philosophical meaning of "recycling" and "continuation" through works. Some symbolic patterns (Petrilli, 2017) and color field painting theories (Somers, 2022) involved in the paintings are expected to convey the ideas of "continuation" to the audience, including the harmonious and symbiotic relationship between man and nature.

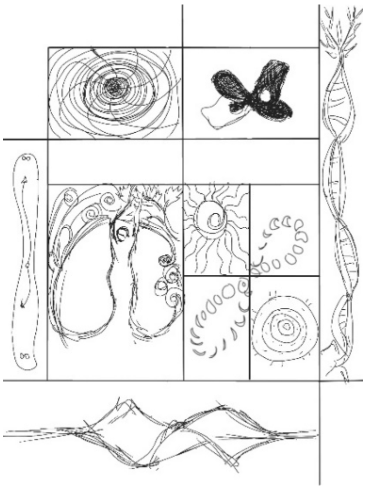


Figure 14 (Left). Draft of painting.
Source: Author.

Figure 15 (right). Painting simulation effect diagram
Source: Author.

At the same time, this article provides new perspectives and practical experience for sustainable product design. By converting discarded tea residues into pigments, this study not only demonstrates the possibility of waste utilization, but also provides designers with an environmentally friendly material choice. Tea residue pigments not only have sustainability and recycling value, but also can show unique aesthetic effects and visual expressiveness in actual design.

Summary and discussion

This study explored the possibility of converting tea dregs discarded from milk tea shops into watercolor pigments and verified their application effects in design practice. The results showed that different types of tea dregs combined with various chemicals can generate pigments with unique color properties and visual effects. This process reveals the potential of tea dregs as a sustainable material in practical design, and further proves the great value of using waste to produce pigments in painting material design. Tea dregs pigments not only provide an environmentally friendly alternative, but also show unique color levels, bringing new possibilities for artistic creation.

In addition, this paper also involves the concepts of ecological cycle and sustainable design, showing how to promote the recycling and reuse of waste through design methods (Odoh et al., 2014), providing innovative practical references, and promoting the practical application of green design materials. However, some challenges were also exposed during the research process, such as the stability of different chemical media, the durability of pigment colors, and the efficiency of the extraction process. It is worth noting that some experimental results show that the color change rules of some tea dregs pigments are similar to those of traditional plant dyes, while some have unexpected color reactions, which may be related to the chemical interactions of different components in tea. These new findings reveal the complexity of tea dregs pigments in art and material research, and also provide directions for further exploration in future research.

In response to these issues, future research should focus more on optimizing pigment performance, such as improving the efficiency of pigment extraction, enhancing the durability and stability of pigments, and studying the adaptability of different media (such as paper and cloth) to tea dregs pigments to enhance the practical application value of this natural pigment. In addition, it is necessary to explore in depth how these new findings can be combined with existing sustainable design theories and color theories, or whether there are theoretical contradictions and breakthroughs, so as to promote more systematic research and innovation.

Recommendations and conclusion

This study suggests that the production method of tea residue pigments can be promoted to the field of art education as a practical case of sustainable art creation, and it can also be combined with ecological education to cultivate environmental awareness. In addition, future research can be extended to other types of waste organic matter to explore more possibilities, such as coffee residues or fruit peel dyes, thereby promoting the diversified application of waste recycling.

This study also tested the color durability of tea residue pigments to evaluate their long-term application potential in paintings. The experimental results showed that under natural storage conditions, these pigments basically did not undergo obvious color changes within one year, showing good stability. However, future research still needs to further explore their durability performance under different environmental conditions (such as light, humidity, and temperature) to ensure their color stability over a longer period of time and optimize their practical application value as artistic pigments.

Figure 16 (Left). 2024 Color Card Record.
Source: Author.

Figure 17 (right). 2025 Color Card Record
Source: Author.

This study used tea residues as the core material, successfully tested environmentally friendly watercolor pigments, and demonstrated its potential through artistic creation. This not only verifies the feasibility of waste recycling, but also opens up a new direction for artistic creation. The study responds to the call of the global Sustainable Development Goals (SDGs) through practice, while reflecting the harmonious relationship between man and nature.

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