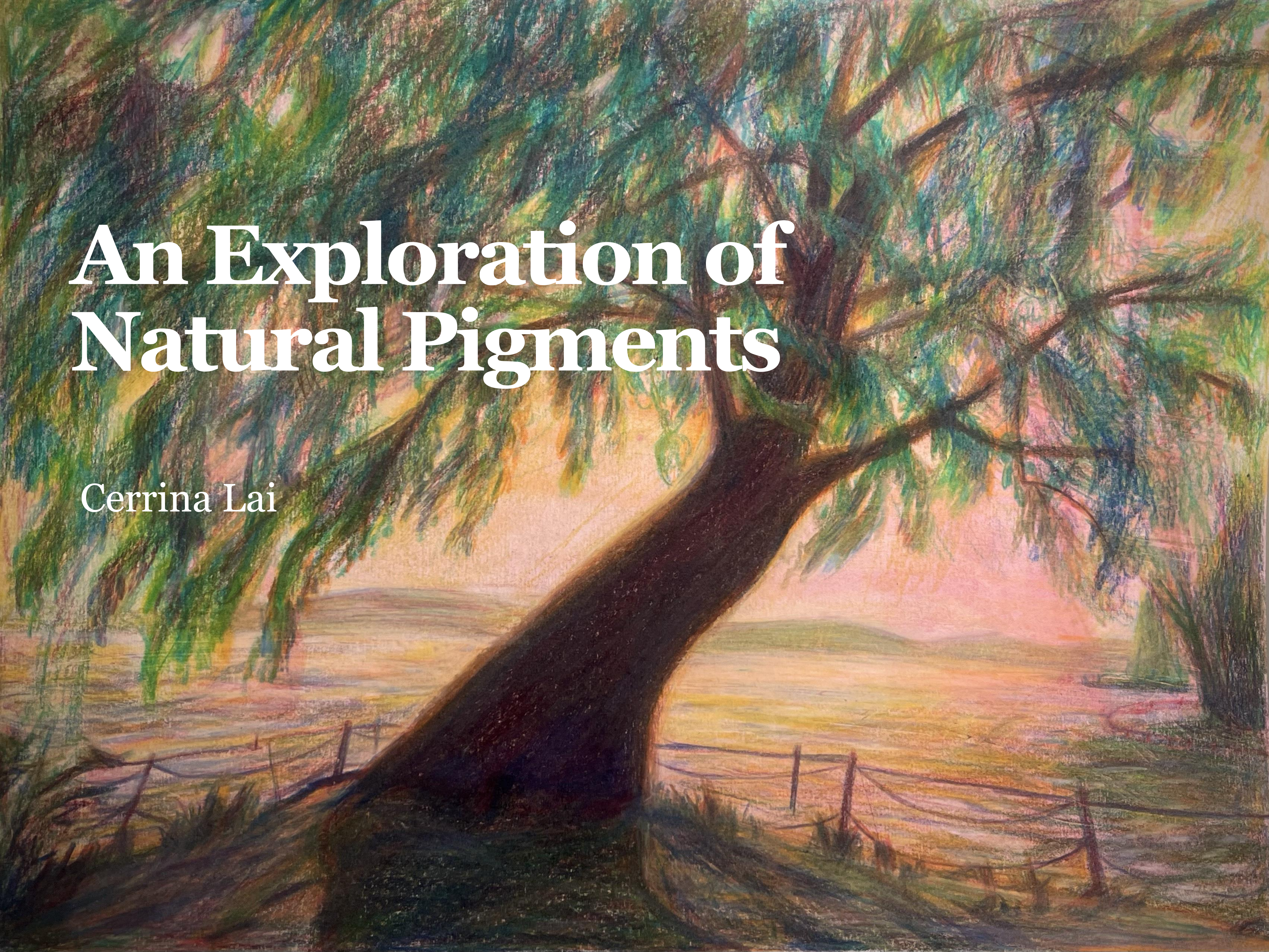
An Exploration of Natural Pigments

Cerrina Lai



I have always loved painting and often draw inspiration from nature. Learning about natural pigments sparked my curiosity, so I decided to explore this topic further. For this project, I aimed to create the three primary colors using natural sources. To produce red, I experimented with cochineal, madder root, and hibiscus flowers. For blue, I used woad and butterfly pea flowers, while saffron and marigold served as the basis for my yellow pigments. This research and hands-on process allowed me to merge my passion for art with a deeper understanding of natural materials and pigment creation.

Lake Pigments

Most natural dyes are water-soluble, which means simply mixing them with a binder does not create a usable pigment. Lake pigments address this by precipitating the dye from a natural colorant (typically an insoluble material) onto a colorless, inert, and insoluble substrate. The substrate often involves an aluminum-containing compound, such as hydrated alumina or potassium aluminum sulfate, where aluminum ions bind with the dye molecules to form a stable pigment. This process is analogous to the use of mordants in textile dyeing, which fix dyes onto fibers to enhance color fastness.[1]

Name Origin

The term "lake" originates from the Indian word "lac" or "lacca," referring to a resin derived from an insect traditionally used to produce red dye.[2] In English, "lake" became a general term for red and yellow pigments created through precipitation processes. However, in other languages, similar terms often specifically denote red pigments. Examples include *lakh* (Hindustani), *laksha* (Sanskrit), *lacca* (Latin), *laque* (French), *laca* (Spanish), *lacca* or *lacha* (Italian), and *lack* or *lach* (German).[3]

Distinction Between Real and Fake Lake Pigments

Historically, counterfeit lake pigments were created using starch or chalk as a base. Authentic lake pigments must include alum as the key ingredient to bind the colorant.[4] In the early modern period, the primary purpose of counterfeit recipes was to imitate precious natural materials. Examples include Ms. Fr. 640, which has counterfeit recipes for materials like coral, and the recipes devoted to imitating valuable materials, such as amber, pearls, ivory, and coral in Giovanni Villani's *Segreti*.[5] Counterfeit lake pigments may have been invented because alum was a scarce resource.

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[1] Jo Kirby et al., *Natural Colorants for Dyeing and Lake Pigments: Practical Recipes and Their Historical Sources* (London: Archetype Publications in association with The National Gallery, Cultural Heritage Agency, IRPA KIK, Doerner Institut, Charisma Charisma, 2014), 28.

[2] Nicholas Eastaugh, ed., *The Pigment Compendium: A Dictionary of Historical Pigments* (Amsterdam; Boston: Elsevier Butterworth-Heinemann, 2004), 215.

[3] Eastaugh, *The Pigment Compendium*, 215.

[4] Eastaugh, *The Pigment Compendium*, 215.

[5] Lores-Chavez, Isabella, "Imitating Raw Nature," accessed December 21, 2024, https://doi.org/10.7916/A9XC-M996.

Two Types of Lake Pigments

1. **Pre-18th-Century Method**
   This traditional method begins by extracting the dye in an alkaline solution (commonly lye made from wood ashes) under heat. The dyestuff is then filtered from the liquid, and an acid, such as potash alum, is added to trigger a chemical reaction that precipitates the dye. The pigment is filtered out and washed with water until the filtrate runs clear.[6]

2. **19th Century and Later Method**
   In this updated approach, the process is reversed. After extracting the dye in an acidic solution and filtering out the dyestuff, a base is added to neutralize the acidic solution, which precipitates the dye. The pigment is then obtained through filtering and washing.[7]

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[6] Kirby et al., *Natural Colorants for Dyeing and Lake Pigments*, 29.

[7] Kirby et al., *Natural Colorants for Dyeing and Lake Pigments*, 30.

Common Acid and Base

Alum

Alum, or aluminum potassium sulfate, is the most common acid used in lake pigment recipes. It is a colorless mineral historically found in Turkey. The Bay of Naples also produced some alum, but Turkey was regarded as the largest and best supplier.[8] Medieval scientists believed that different locations produced materials with unique qualities, attributed to the influence of celestial movements. According to this belief, eastern regions, where celestial bodies such as the sun first rise, were considered especially potent in producing powerful minerals. Thus, alum from Turkey was deemed superior due to its eastern location relative to Europe.[9]

The reliance on Turkish alum made it an expensive commodity, particularly since trade between the Islamic world and Europe was frequently disrupted by conflicts such as the Crusades.[10] However, in the 1450s and 1460s, alum-bearing mines were discovered in Volterra and Tolfa, within papal territories in Italy. These mines produced approximately 1,500 tons of alum annually and became a significant source of revenue for Pope Pius II. The pope established cartels and employed agents, called the Medici, to trade alum. In 1470, a deal was struck with the King of Naples to merge the alum trade from Tolfa with other southern sources. This revenue—reaching 140,000 ducats by 1471—was intended to fund a new Crusade but ultimately failed in its objective.[11]

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[8] Spike Bucklow, *The Alchemy of Paint* (New York: Marion Boyars, 2009), 23.

[9] Bucklow, *The Alchemy of Paint,* 22.

[10] Bucklow, *The Alchemy of Paint,* 31.

[11] Bucklow, *The Alchemy of Paint,* 31.

To protect local alum markets, the importation of Turkish alum was banned, and Christians caught purchasing it were labeled “perfidious” for supporting "the Infidel."[12] By the mid-16th century, European countries like England launched efforts to discover local alum. These initiatives involved extensive mining, patents, government funding, and monopolies, but they ultimately failed to produce sustainable results.[13]

In addition to mining, Europeans attempted to synthesize alum from other minerals, a practice dating back to at least the 3rd century BCE. A recipe from 1678, recorded in the *Philosophical Transactions of the Royal Society of London,* describes the process: specific stones were burned continuously for nine to twelve months, depending on the “illness of the mineral.” The residual material was fermented in stale urine or lye derived from burnt seaweed ashes. The resulting solution was then boiled to extract alum.[14]

Potash

Potash, or potassium carbonate (K_2CO_3), is a common base used for lake pigments. The term "potash" derives from its traditional production method: soaking wood ashes in water-filled pots, a process similar to that used for creating lye.[15] Potash’s properties also closely resemble those of lye, which was also used by painters to dissolve red insect dyes from textiles. Historically, potash quality was tested using simple methods. For instance, a good alkali could make a fresh egg float or dissolve a feather.[16] If these criteria were met, the potash was deemed suitable for use in dyeing and pigment making.

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[12] Bucklow, *The Alchemy of Paint,* 31.

[13] Bucklow, *The Alchemy of Paint,* 33.

[14] Bucklow, *The Alchemy of Paint,* 26.

[15] Bucklow, *The Alchemy of Paint,* 43.

[16] Bucklow, *The Alchemy of Paint,* 25.

Acid and Base I Used for All the Pigments

Figure 1. The alum used.

Figure 2. The potash used.

The alum I used is aluminum potassium sulfate. The Potash I used is potassium carbonate.

How Colors in Plants are Created

I am experimenting with various colorful flowers to create lake pigments. The vibrant hues in flowers are produced by biochromes, natural pigments that absorb different colored light with specific wavelengths. The color we perceive is a result of that specific light reflecting back to our eyes.[17]

[17] Ghazala Yaqub and Haleema Sadia, *Dyes and Pigments* (Oakville, ON: Arcler Press, 2019), 65.

Reds

Cochineal

Origin and Historic Uses

Cochineals are scale insects native to Central and South America that produce a vibrant red pigment. These insects parasitize cacti, particularly species of *Opuntia* and *Nopalea*.[18] The red pigment comes from carminic acid, a compound that makes up about 25% of the insect's body weight and acts as a defense mechanism against predators like ants.[19] Because of the name "carbonic acid," cochineal pigment is also called carmine red. Only female cochineals produce carminic acid, so they are used in pigment production.

Figure 3. Dried cochineals used.

Cochineals have been used as colorants since around 500 BCE by the Paracas people in highland Peru.[20] In Mexico, they were traditionally used to dye textiles, adorn royal headdresses, and make lipsticks. Today, cochineal pigments are used globally as coloring agents in cosmetics, food, and textiles.

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[18] Robin Donkin, "Spanish Red: An Ethnogeographical Study of Cochineal and the Opuntia Cactus," *Transactions of the American Philosophical Society* 67 (1977).

[19] *Why Tiny Cactus Bugs In Red Food Dye Are A $35 Billion Industry | Big Business | Insider Business*, 2023, https://www.youtube.com/watch?v=iBNySB2jpVg.

[20] Yaqub and Sadia, *Dyes and Pigments*, 13.

Cochineal in Europe

Cochineals were introduced to Europe after Hernán Cortés' conquest of the Aztec Empire in 1521. At the time, the primary red dye in Europe was kermes, a scale insect found on oak trees in the Mediterranean.[21] Cochineal pigments quickly replaced kermes because they adhered better to wool and silk, produced more vibrant colors, and were longer-lasting. Artists such as Rembrandt, Van Gogh, and Renoir began incorporating cochineal pigments into their paintings. By the 18th century, the pigment was also being used to color food.[22]

European Cochineal Lake Pigments

In Europe, there were two methods for producing cochineal lake pigments. *The Mariani Treatise,* a 17th-century Italian manuscript, compares them. One method directly produced pigment from cochineal grains, while another method involved extracting pigment from scraps of fabric dyed with cochineal.[23] Using fabric waste was the earlier method, as direct extraction of lakes only became common in the 17th century.[24]

Chemically, the carminic acid in cochineal forms a metal salt or complex, often precipitated using aluminum or tin compounds. Aluminum-based recipes produced scarlet hues, while tin-based methods yielded cherry red.[25] A lesser-known method involved using copper to create a distinctive purple pigment. For example, Salter describes "Indian Purple" as made by precipitating cochineal extract with copper sulfate:

"It is a very deep-toned Imperial green but rather cold and subdued purple, neither so red nor so brilliant as burnt carmine."[26]

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[21] Bucklow, *The Alchemy of Paint,* 22.

[22] *Why Tiny Cactus Bugs In Red Food Dye Are A $35 Billion Industry | Big Business | Insider Business.*

[23] Eastaugh, *The Pigment Compendium*, 215.

[24] Kirby et al., *Natural Colorants for Dyeing and Lake Pigments*, 33.

[25] Kirby et al., *Natural Colorants for Dyeing and Lake Pigments*, 33.

[26] Eastaugh, *The Pigment Compendium*, 192.

Process

My partner and I tried the reverse lake recipe.

Fig 4. Ground cochineal toa powder.

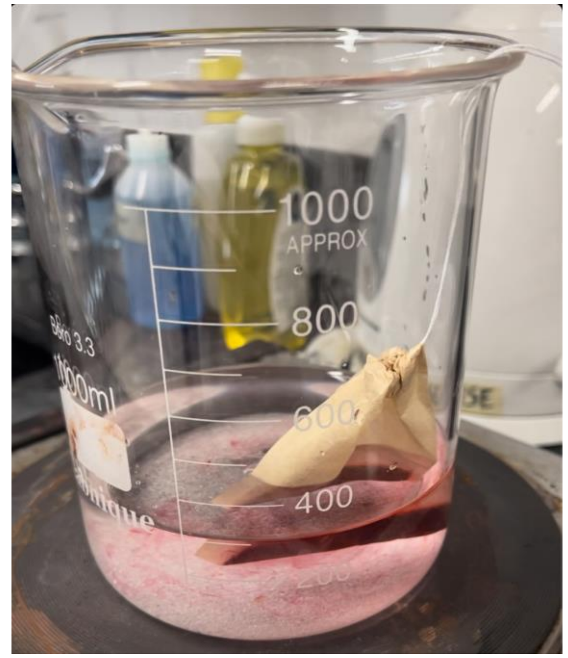

Fig 5. Boiled 4.6 g of dyestuff in a tea bag in 10 g of alum with 300 ml of water for 15 minutes.

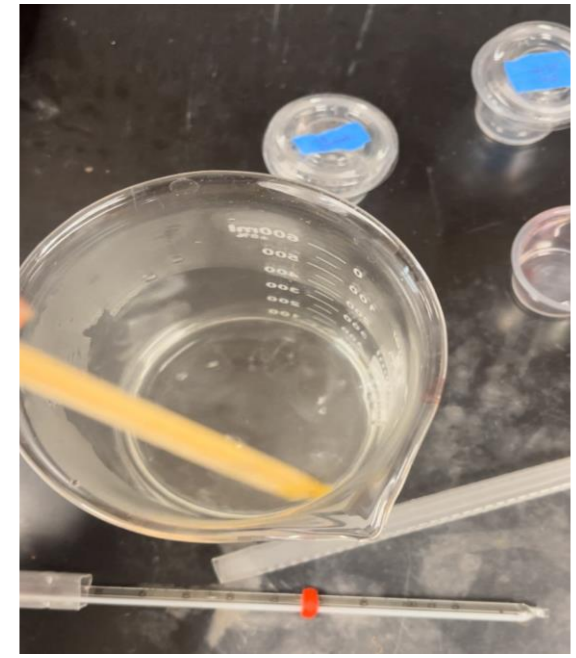

Fig 6. Dissolved 4 g of potash in 50 g of water over heat with a stirring motion.

Fig 7. After the dyestuff and alum solution boiled for 15 minutes, we gradually mixed the potash solution into it, and precipitation (bubbling) occurred.

Fig 8. The pH was close to 8.

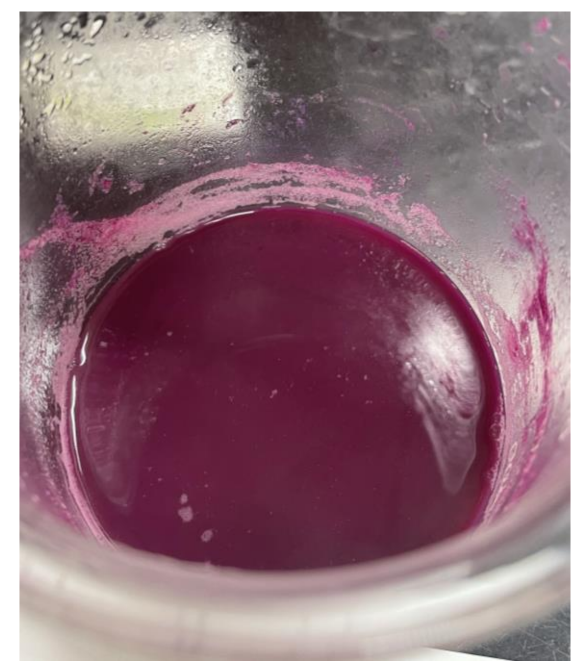

Fig 9. Stirred until there was no more bubbling (chemical reactions).

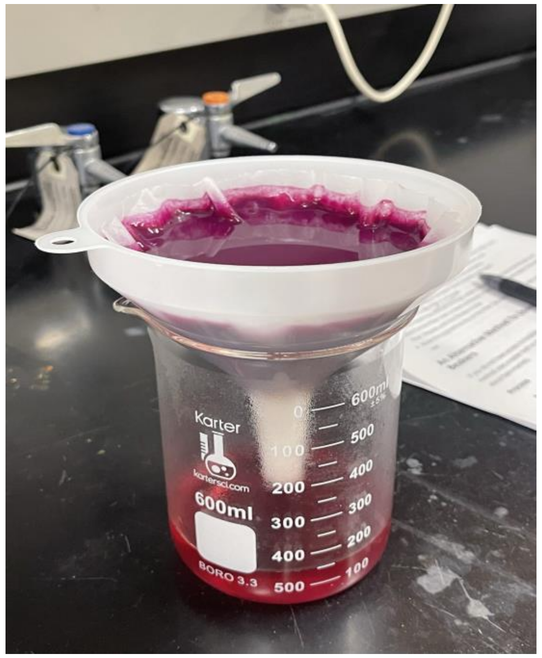

Fig 10. Dyestuff solution was poured through a funnel with filter paper.

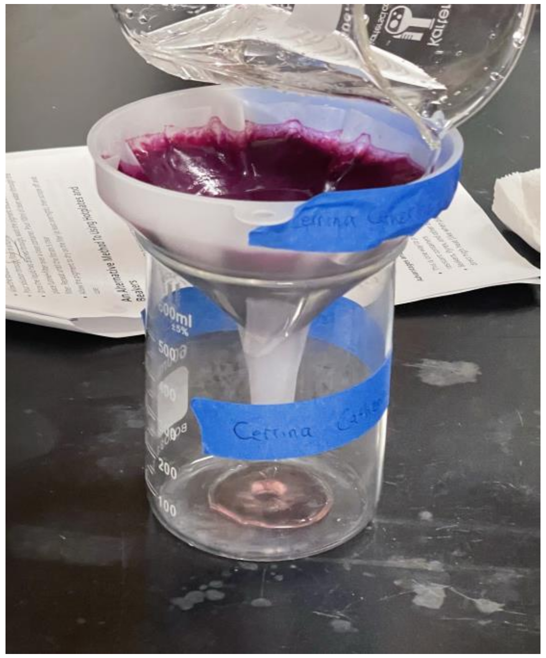

Fig 11. Washed the pigment by pouring clean water through the funnel until the filtrate was clear.

Divergence from original recipe and research:

We tried to follow the recipe provided by *Natural Colorants for Dyeing and Lake Pigments*,[27] but we messed up the proportion of ingredients a bit, so the result was different from the research. We got a pH level of eight while the original recipe calls for six to seven. This difference may also be a result of natural variations in the cochineal insects. Differences in where the bugs were sourced, and the types of cacti they feed on could potentially lead to discrepancies in their chemical composition. This theory stems from the fact that other groups in this lab also created cochineal pigment, with different groups using cochineal from two distinct bottles. Even though the groups used the same proportion of ingredients, they reported varying pH levels. The two different cochineals also created different colors: one made a lighter pinkish hue, while the other yielded a darker purplish-red. Interestingly, despite these differences, none of the groups achieved the vibrant red traditionally associated with cochineal, as described in the literature. This inconsistency raises intriguing questions about additional variables affecting the pigment.

[27] Kirby et al., *Natural Colorants for Dyeing and Lake Pigments*, 83.

Process for the remainder pigments

For the remaining pigments, I adhered to the traditional sequence method. I did some modifications for certain pigments, which I will clarify in their process section. But, the recipes followed this general structure:

1. Grind the dyestuff as finely as possible, ideally into a powder.
2. Combine 4 g of potash with 300 ml of water in a 1000 ml beaker. Place the ground dyestuff in a tea bag and boil it in the potash solution over heat for 15 to 20 minutes.
3. In a 100ml beaker, dissolve 10 g of alum in 50 ml of water while stirring over heat.
4. Remove the tea bag with the dyestuff. Gradually add the alum solution to the dyestuff mixture, stirring continuously. Stop stirring once the chemical reaction ceases (indicated by no more new bubbles forming).
5. Let the solution sit overnight.
6. Place a filter in a funnel and pour the solution through it to separate the pigment from the liquid.
7. Rinse the pigment with water until the filtrate runs clear.
8. Allow the pigment to dry on the filter, and collect it once fully dried.

(Filtering and washing the pigment was the same for all recipes, so I abbreviated it in the process section for most of the following colors)

Madder Root

Origin

Madder refers to a group of plants within the *Rubiaceae* family, which includes 630 genera and over 10,400 species.[28] While native to Mexico, madder plants eventually spread to Europe and Asia. The finest madder varieties are found in regions such as Asia Minor, the East Indies, the Caucasus, and the northern coast of Africa. In Europe, Turkey, Greece, Spain, France, Holland, northern Italy, and Sicily have historically been prominent producers of high-quality madder.[29]

Fig 12. Madder roots used.

Etymology

The madder plant's association with the color red is deeply rooted in various languages and cultures. In Greek, it was referred to as *erythrodanon*, *ereuthedanon*, or *teuthrion* (*erythros,* meaning red), and also as *phenix* (*phoinix,* relates to purple or crimson, derived from Tyrian purple dye production). The Romans used terms such as *rubia*, *rubidus*, and *rubeo* (from *ruber*, meaning red). In Old English, the word "madder" originated from *madere*, which has cognates in Old Norse (*ma'dra*) and Old High German (*matara*). The only modern English derivative is "madderise," which describes the oxidation process that turns wine brown.[30]

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[28] Robert Chenciner, *Madder Red: A History of Luxury and Trade* (Taylor & Francis Group, 2000), 10.

[29] Chenciner, *Madder Red: A History of Luxury and Trade,* 10.

[30] Chenciner, *Madder Red: A History of Luxury and Trade*, 3.

Historic Uses

Madder has been utilized in Europe since ancient Greek and Roman times for textiles, art, cosmetics, and medicine. Greek and Roman writers, including Pliny, Hippocrates, Dioscorides, and Theophrastus, documented its medicinal properties. The 17th-century English botanist Nicholas Culpeper detailed its medical and cosmetic uses in *The Complete Herbal*:

"It hath an opening quality, and afterwards to bind and strengthen… It stops looseness, the hemorrhoids, and the menses… The leaves and roots beaten and applied to any part discolored with freckles, morphew, the white scurf, or any such deformity of the skin, cleanses thoroughly and takes them away."[31]

The plant's medicinal benefits were also consumed as tea, from ancient Egypt to modern Germany. Additionally, feeding madder to animals stained their bones red, making it a valuable tool for studying bone growth.[32]

Beyond its medicinal applications, madder was also used to color food and medicine. Historian Joan Thirsk noted its use in dyeing medicines.[33] While kermes and cochineal were more commonly employed in food coloring, madder was occasionally used to stain food as well. For example, the 14th-century Arabic *Book of Familiar Foods* includes recipes where madder roots were used to dye fish red, giving it the appearance of meat.[34]

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[31] Nicholas Culperper, *The Complete Herbal* (Arcturus Publishing Limited, 1653), 43.

[32] Derek Richter, "LXXXII. VITAL STAINING OF BONES WITH MADDER," *Biochemical Journal* 31, no. 4 (n.d.), 591.

[33] Chenciner, *Madder Red: A History of Luxury and Trade*, 9.

[34] Chenciner, *Madder Red: A History of Luxury and Trade*, 10.

Botanical Description

Madder (i.e., *Rubia tinctorum)* has elliptical leaves arranged in groups of four to six along its long, hairy, weakly jointed square stems. The leaves are smooth on top but have a rough underside. By the plant's second or third year of growth, it produces small, star-shaped yellow flowers that bloom in pairs along the stems. These flowers eventually yield shiny black berries, which dry into peppercorn-like seeds.[35]

The red pigment of madder comes from its roots, which are rich in colorants such as alizarin and purpurin. Among the *Rubiaceae* family, only a few cultivated species are used in dyeing because they contain more alizarin than wild varieties. These cultivated madder plants are known as "dyer's madder," and the most common type is *Rubia tinctorum*.[36]

Other Wild Madder Varieties

Although mainstream practice uses cultivated madder for dyeing, a few wild madder species have been historically used for dyeing. For example, *Rubia cordifolia* (commonly called "munjeet" or *Rubia munjista Roxb*.) was a key dyestuff for Indian printed cottons exported to Europe from the 17th to 18th centuries. Another variety, *Rubia sikkimensis*, was widely used in the northeastern provinces of India to produce the "reds of Naga."[37]

Figure 13. Victorian Madder Illustration. 1846, iStock. https://www.istockphoto.com/vector/wild-madder-bedstraw-heath-victorian-botanical-illustration-gm512289658-87089091.

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[35] Chenciner, *Madder Red: A History of Luxury and Trade*, 5.

[36] Chenciner, *Madder Red: A History of Luxury and Trade*, 4.

[37] Chenciner, *Madder Red: A History of Luxury and Trade*, 8.

Madder Lake Pigment

Madder's history as a coloring agent spans millennia. Ancient Egyptians used it to decorate burial chambers and mummy bandages.[38] In the Indian subcontinent, madder was found in artifacts from the Indus Valley Civilization (2600–1900 BCE) and was extensively used in the Mughal Empire (1526–1857 CE) for printing, dyeing, and painting.[39]

Early European madder lakes were often made from madder-dyed textile waste. Recipes from 15th- and 16th-century Germany and the Netherlands describe extracting red dye from cloths using strong alkali solutions, which formed a gelatinous liquid. This solution was precipitated with alum to create the pigment.[40] Stronger lye was often required to extract madder from wool textiles, as they are highly durable.

In early European art, madder lake pigments were more common in northern Europe, while southern European painters often used lake pigments derived from shell insects.[41] Shell insect pigments, such as kermes and cochineal, became more widely used in northern Europe after the discovery of the New World in the 17th century.[42]

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[38] Yaqub and Sadia, *Dyes and Pigments*, 4.

[39] Chenciner, *Madder Red: A History of Luxury and Trade*, 289.

[40] Chenciner, *Madder Red: A History of Luxury and Trade*, 174.

[41] Chenciner, *Madder Red: A History of Luxury and Trade*, 174.

[42] Yaqub and Sadia, *Dyes and Pigments*, 4.

Process

Fig 14. Ground madder roots.

Fig 15. Boiled 2.7 g of dyestuff with 4 g of potash in 300 ml of water for 18 minutes.

Fig 16. Dissolved 10 g of alum in 50 ml of water over heat.

Fig 17. Gradually mixed in the alum solution to the dyestuff solution while stirring.

Fig 18. Chemical reactions stopped.

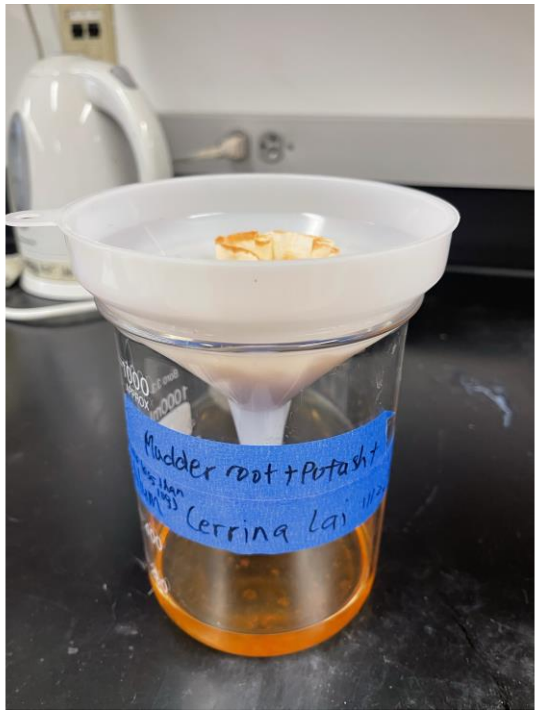

Fig 19. Filtering and washing pigment on the next day.

Fig 20. 2.7 g of madder roots created 3.01 g of pigment.

Hibiscus Flower

Origin and Historic Uses

Hibiscus flower (i.e., *Hibiscus sabdariffa*), also known as roselle or bissap, originates from tropical and subtropical regions, including Southeast Asia and the coast of Africa.[43]

Fig 21. Dried hibiscus flowers used.

These flowers hold deep cultural significance across the globe. One of their most profound connections is to Afro-Cuban identity. Hibiscus was introduced to the Caribbean from Africa during the transatlantic slave trade.[44] Enslaved people cultivated hibiscus in their kitchen gardens as part of their efforts to preserve African traditions and knowledge. Over time, it became a dietary staple in the South American and Caribbean regions.

Hibiscus also has a rich history in Asia. In India and China, the tannins that hibiscus flowers contain have traditionally been used as a hair dye.[45] Asian species of hibiscus were introduced to the Caribbean during the migration of indentured laborers. Between 1837 and 1920, European colonial powers recruited more than 2.2 million Chinese, Indians, Javanese, Malagasy, and free Africans to work on tropical plantations globally.[46]

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[43] Nanxi Li, James E. Simon, and Qingli Wu, "Determination of Anthocyanins, Organic Acids, and Phenolic Acids in Hibiscus Market Products Using LC/UV/MS," *Journal of Food Science* 89, no. 2 (February 2024): 1098–1113, https://doi.org/10.1111/1750-3841.16909, 1098.

[44] Andrés Triana Solórzano, "Plant of the Month: Hibiscus," JSTOR Daily, April 28, 2023, https://daily.jstor.org/plant-of-the-month-hibiscus/.

[45] Hongyan Cui et al., "Recent Advancements in Natural Plant Colorants Used for Hair Dye Applications: A Review," *Molecules* 27, no. 22 (November 20, 2022): 8062, https://doi.org/10.3390/molecules27228062, 8.

[46] Solórzano, "Plant of the Month."

This migration represents the Caribbean essence of creolization, further cementing hibiscus's importance to the culture. For example, the Indian species *Hibiscus tiliaceus* was used for toothbrushing, fodder for animals, garden hedges, and in religious worship in India. It was associated with the Hindu goddess Kali, symbolizing power and strength, an image that resonated deeply with Indo-Caribbean communities.[47] Today, hibiscus is consumed worldwide, primarily as food coloring or a nutritional tea for its antioxidant properties.[48]

Figure 22. Hibiscus and Bluebird. Utagawa Hiroshige, ca. 1832, The Met. https://www.metmuseum.org/art/collection/search/36733.

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47 Solórzano, "Plant of the Month."

48 Inês Da-Costa-Rocha et al., "Hibiscus Sabdariffa L. – A Phytochemical and Pharmacological Review," *Food Chemistry* 165 (December 2014): 424–43, https://doi.org/10.1016/j.foodchem.2014.05.002, 426.

Botanical Description

The hibiscus is a large genus of around 300 species within the *Malvaceae* family and the *Hibisceae* tribe.[49] This diverse genus includes both annual and perennial herbaceous flowering plants, as well as small trees and shrubs.[50] Among these, the most recognized species is *Hibiscus sabdariffa*, which I used for my pigment. *H. sabdariffa* is an annual herbaceous plant that can grow up to two meters tall.[51] Its branches are reddish-green, and its leaves are long, palm-shaped, and serrated along the edges. The plant is notable for its large red flowers with short necks, which bloom for only one to two days. Its fruits are wrinkled capsules that enclose brown seeds.[52]

Hibiscus's thick petals are vibrantly red due to the high levels of anthocyanins they contain. The potential of anthocyanin as a pigment is not widely explored, but Ozougwu and Anyakoha evaluated its efficacy as a dye.[53] Their research found that hibiscus dye exhibited reasonable lightfastness, though it showed fading when washed. Using alum as a mordant produced a warm maroon color, while other fixatives, such as tannic and citric acid, significantly altered the hue. Alum and tannic acid provided the strongest lightfastness.

Figure 23. Hibiscus Cameroni-fulgens. 1844, PictureBoxBlue. https://www.pictureboxblue.com/botanical-hibiscus-drawings/.

[49] Da-Costa-Rocha et al., "Hibiscus Sabdariffa L. – A Phytochemical and Pharmacological Review," 425.

[50] S. K. Datta and Youdh Chand Gupta, eds., *Floriculture and Ornamental Plants* (Singapore: Springer Nature Singapore, 2022), https://doi.org/10.1007/978-981-15-3518-5, 484.

[51] Abdel Moneim Elhadi Sulieman, "Antimicrobial Activity of Roselle (Hibiscus Sabdariffa L.) Seed Oil," in *Multiple Biological Activities of Unconventional Seed Oils* (Elsevier, 2022), 91–100, https://doi.org/10.1016/B978-0-12-824135-6.00003-9.

[52] Datta and Gupta, *Floriculture and Ornamental Plants*, 484.

[53] Stella U. Ozougwu and Elizabeth U. Anyakoha, "Acceptability of Cotton Fabric Treated with Dye Extracted from Roselle (Hibiscus Sabdariffa) Calyces Based on Its Phytochemical Composition and Evaluation of Organoleptic Attributes," *African Journal of Agricultural Research* 11, no. 33 (August 17, 2016): 3074–81, https://doi.org/10.5897/AJAR2014.9108, 3080.

Process

The first try was not successful. There was a lack of chemical reaction despite using the standard amount for all the ingredients.

Fig 24. Heated 10 g of ground hibiscus in a tea bag in 4 g of potash and 300 ml of water for 18 minutes.

Fig 25. The color quickly turned to a dark purple.

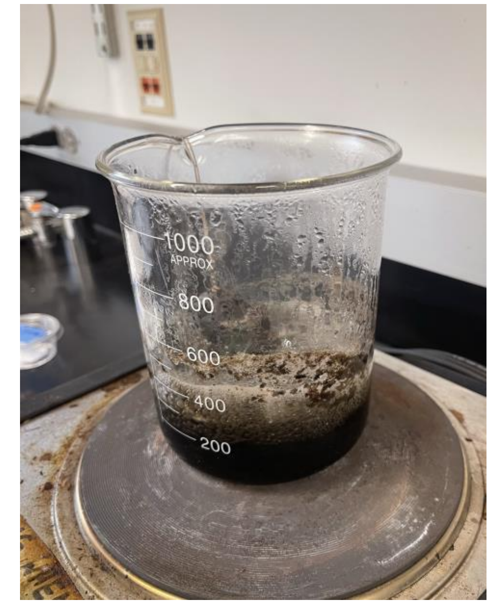

Fig 26. Some dyestuff got into the liquid, but I could not filter it out because it would also isolate out the pigment.

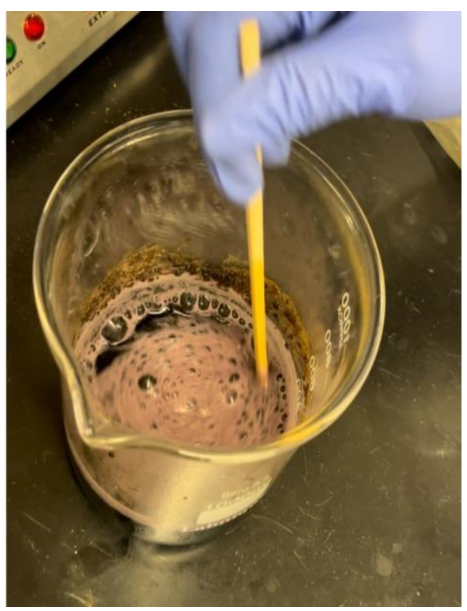

Fig 27. I added the 10 g alum solution gradually, but there was minimal bubbling, so I added one more 10 g alum solution.

Fig 28. I tested the pH after every addition of alum, but it remained around 2 to 3, so not much chemical reactions occurred.

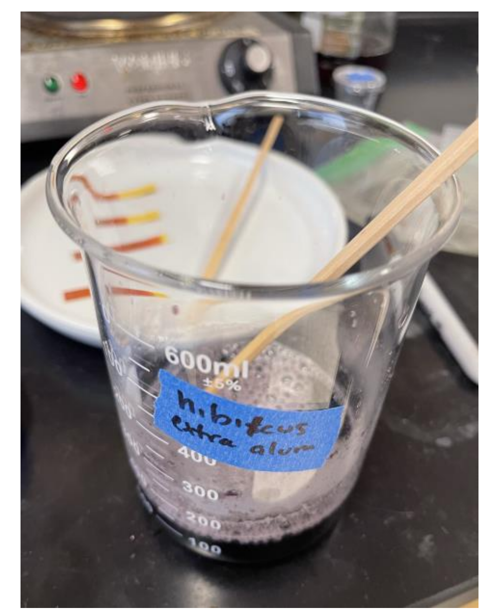

Fig 29. I poured out 100 g of the dyestuff solution to create an experiment sample, to which I added two more 10 g alum solutions.

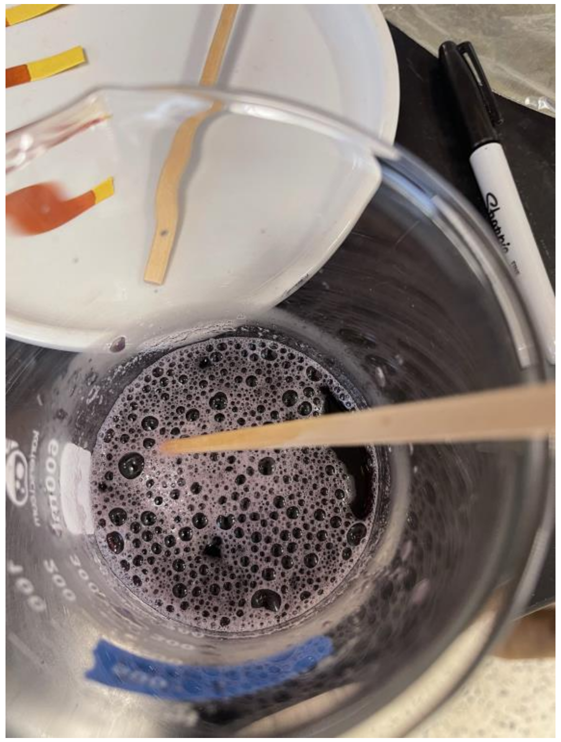

Fig 30. I added the alum solutions gradually, but there was still almost no bubbling.

Fig 31. The pH was tested after each addition, but there was no change (right side is the experiment sample; left side is the control sample).

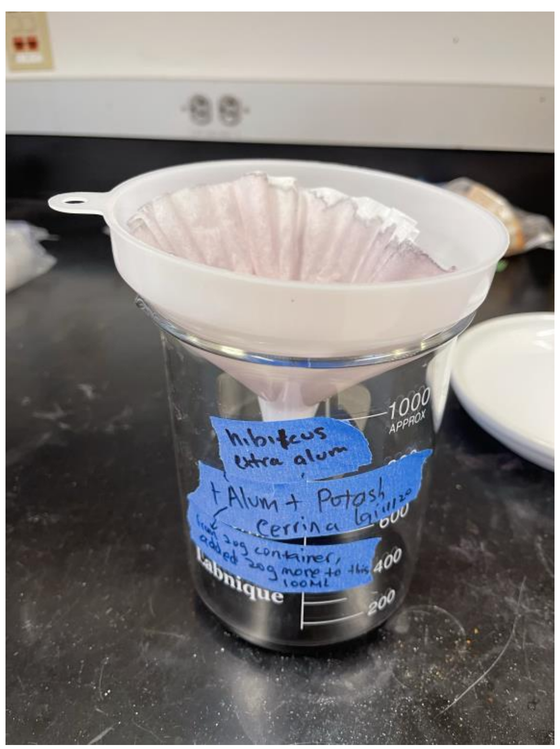

Fig 32. Pigment did not precipitate, but I filtered out the experiment sample to see what would be obtained.

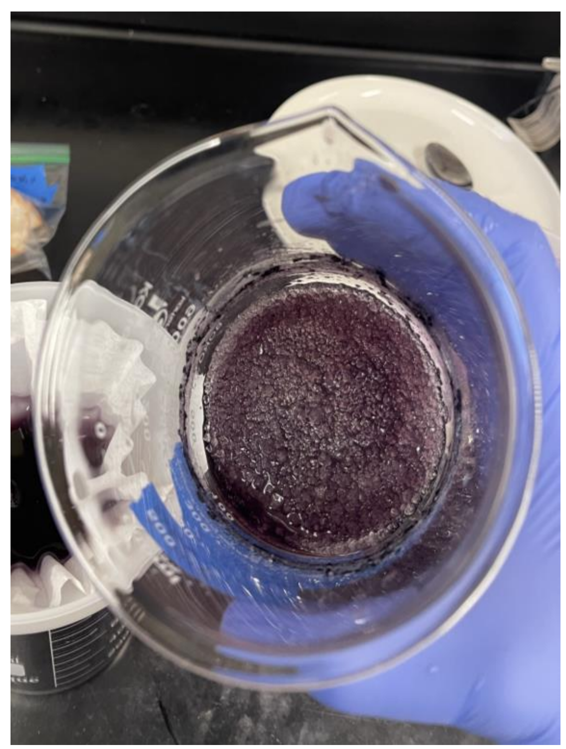

Fig 33. A lot of alum crystalized on the bottom and around the edges (control sample was similar).

Fig 34. A small amount of crystals mixed with tiny bits of dark purple/black color was obtained.

Second Batch

After the failure, I went online to search for other people's experiences with hibiscus pigment. Under a YouTube video, one comment suggested that a pH between 1-3=red, 3-5=loss of color, 6-8=purple, 8-9=blue, 10=yellow.[54] However, another comment mentioned that hibiscus in a basic solution yields a dark blue, while an acidic solution preserved the red color. The commenter explained that this is not due to the acid and base mixing together but rather a chemical reaction with the anthocyanins in the plant.

After receiving these mixed signals on whether acidic or basic solutions create a red pigment, I decided to combine the alum and the potash solution at the same time to adjust the color during the process.

Process

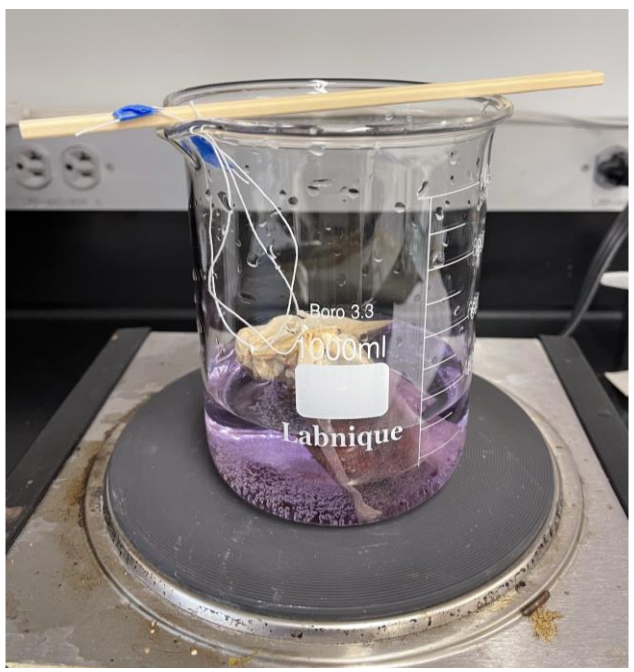

Fig 35. I put 11.1 g of whole hibiscus flower in a teabag and boiled it in 300 ml of water for 18 minutes.

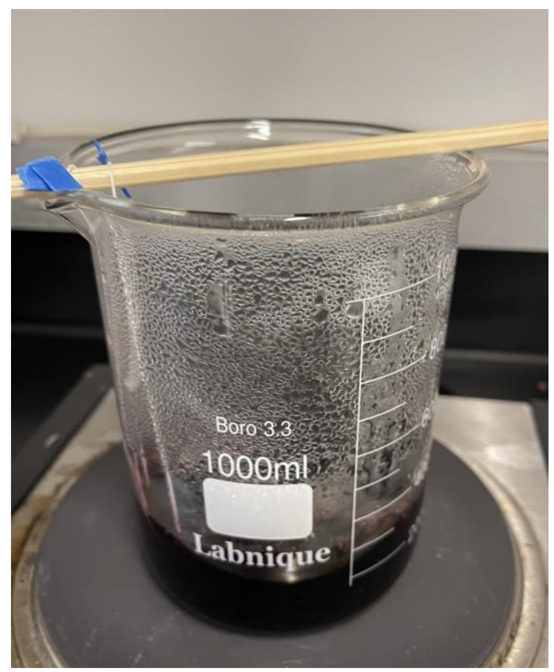

Fig 36. It turned to a dark purplish red after the boil.

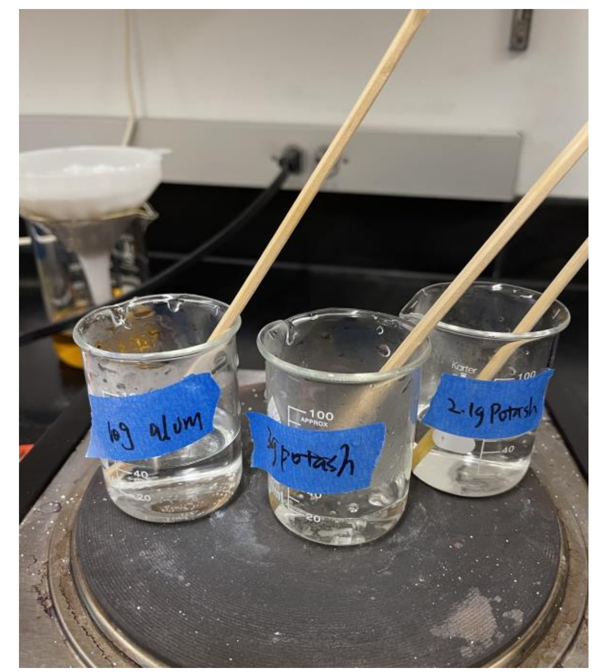

Fig 37. I dissolved 8 g of alum in 40 ml of water and 3 g of potash in 20 ml of water over heat.

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[54] *Hibiscus Dye, Pigment & Paint Fail*, n.d., https://www.youtube.com/watch?v=QuaTtdZjPHk.

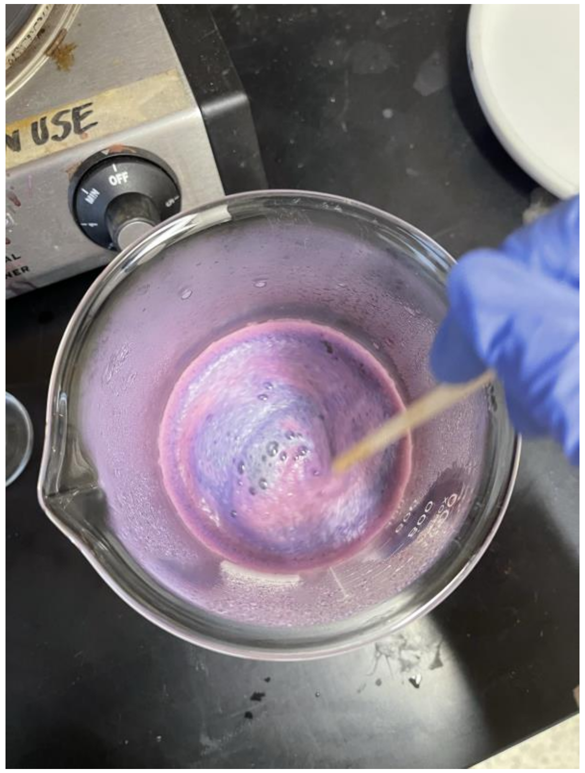

Fig 38. I alternated adding the potash and alum solutions, stirring throughout the process. The addition of alum produced pink bubbles, while the potash turned the color dark purple. There was more reaction than the first try, but it was still weaker than those observed in previous pigments.

Fig 39. Potash also made the solution more grey. Small amounts of grey bubbles appeared in the middle of the purple bubbles after each pour.

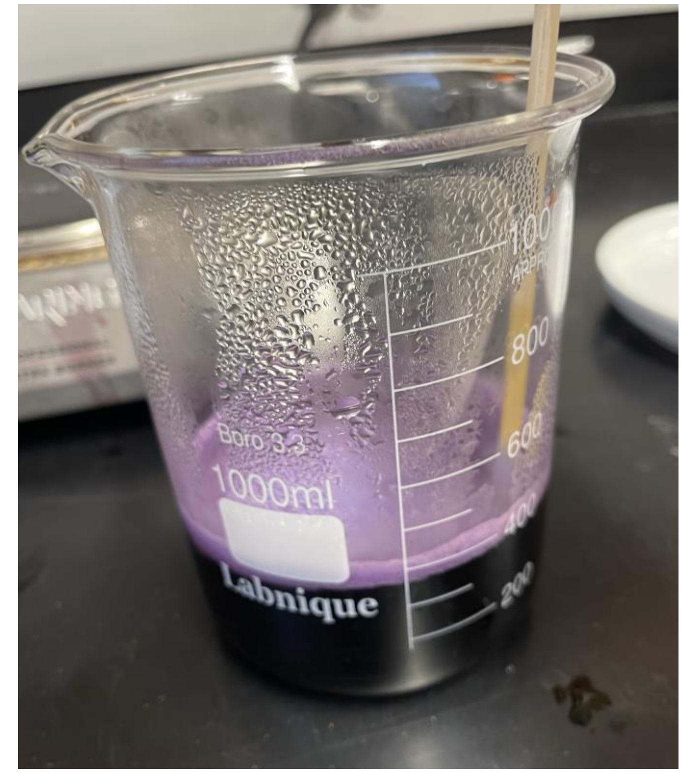

Fig 40. I mixed all the potash and alum in and stirred until new bubbles stopped forming.

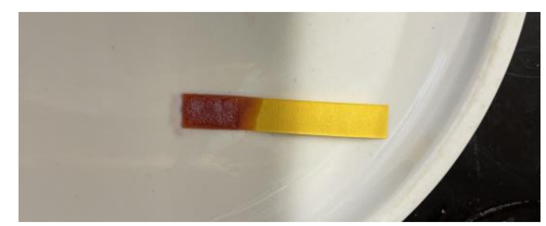

Fig 41. The final solution's pH was still around 2 to 3.

Third Batch

I tried again using the same method as the second batch but with a different ratio of the ingredients.

Process

Fig 42. I used 8 g of whole hibiscus flower and boiled it in 300 ml of water for 15 minutes. Meanwhile, I melted 3 g of potash in 20ml water and 9 g of alum in 40 ml water.

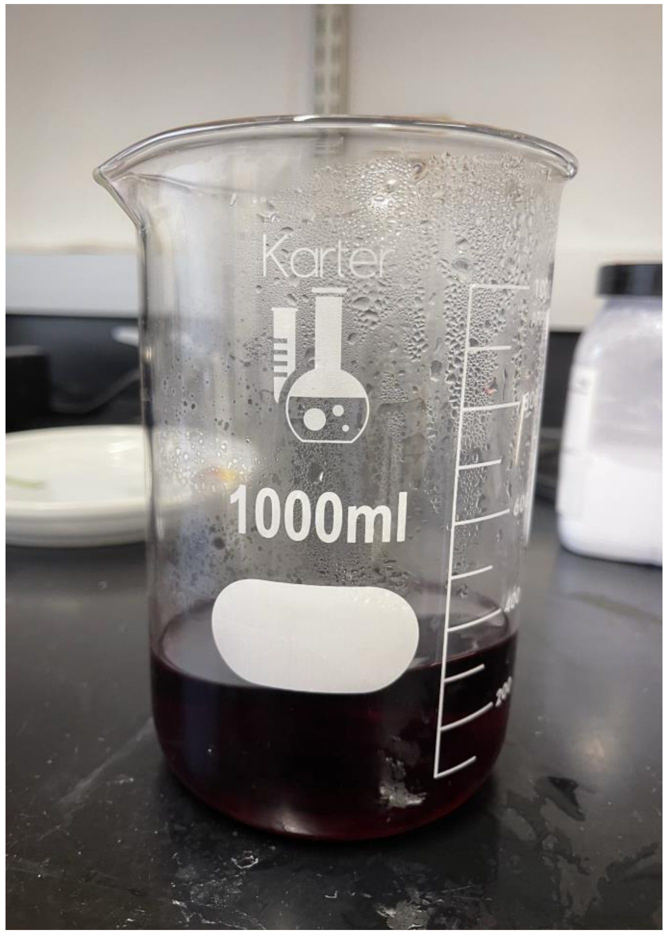

Fig 43. After boiling, the color was a dark purplish red.

Fig 44. I added the alum and the potash solutions interchangeably at a gradual pace (left a bottom for both solutions). The potash created a dark purple like the second try, but the alum did not make any pink bubbles. It did make the solution lighter and greyer.

Comparison Between Second and Third Batch solutions

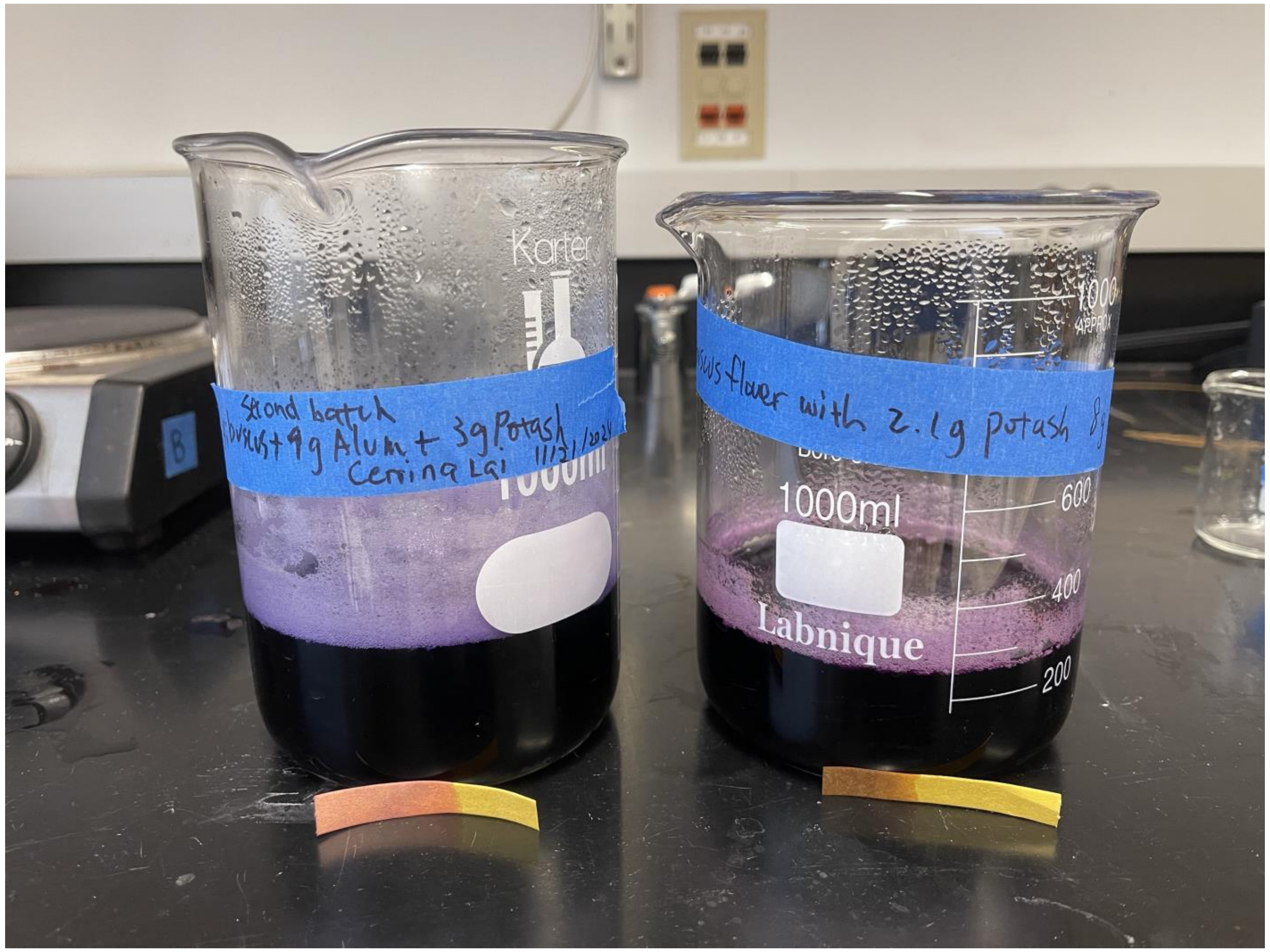

Fig 45. Comparison between second and third batches.

The third batch has a pH of around two and is a blue-purple color while the second batch with a pH of around three is a red-purple. The pH levels align with the acid-to-base ratios, which are 3:1 for the third batch and 2.67:1 for the second. Note that hibiscus flowers are slightly acidic in nature, which I did not account for when I put different amounts of dyestuff in the two trials. The dyestuff solutions suggest that acid makes hibiscus pigment turn a cool purple while more base produces a warmer red. Interestingly, however, the bubbling process suggested the opposite (alum made pink bubbles while potash created purple bubbles).

Final products

Even though the second batch did bubble, there was not much precipitation, and no pigment was collected. The third batch did precipitate a bit—only 1.49 g of pigment was made from 8 g of hibiscus flower.

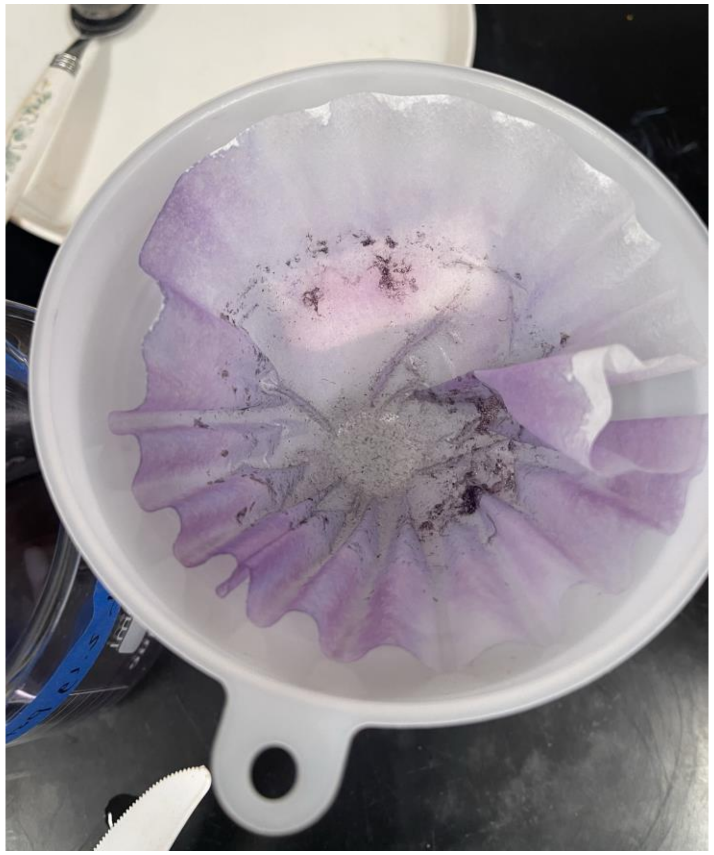

Fig 46. Filtering second batch.

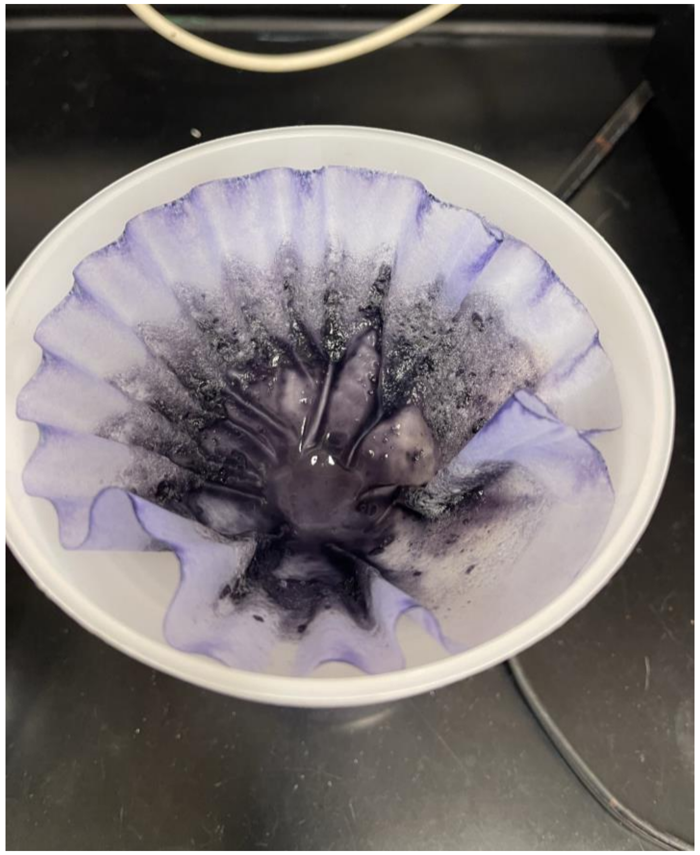

Fig 47. Filtering third batch.

Fig 48. Third batch dried pigment.

Yellows

Marigold

Origin and Historic Uses

Marigold is a member of the *Tagetes* family and originates from the Americas, particularly Mexico and Central America. They have been used for medicinal, ornamental, and spiritual purposes across various cultures.[55] Some varieties, such as the Mexican mint marigold, have psychoactive properties and can cause hallucinations when consumed in large quantities.[56] The Aztecs and Maya, for instance, used marigolds to enter trance-like states in religious ceremonies before human sacrifices to the Fire God, Huehueteotl.[57]

Fig 49. Dried marigold used.

[55] Rayees Ahmad Mir, Mohammad Abass Ahanger, and R. M. Agarwal, "Marigold: From Mandap to Medicine and from Ornamentation to Remediation," *American Journal of Plant Sciences* 10, no. 02 (2019): 309–38, https://doi.org/10.4236/ajps.2019.102024, 309.

[56] Sonia Uyterhoeven, "Tip of the Week: Marigolds Have Many Virtues," Plant Talk, August 10, 2009, https://www.nybg.org/blogs/plant-talk/2009/08/tip-of-the-week/mary's-gold-and-other-gems/.

[57] Alexandre Helwani, "Marigold, the Bloom of Immortality," The Perfume Chronicles, October 31, 2019, https://www.theperfumechronicles.com/chronicles/marigold.

In Mexico, marigolds hold spiritual and medicinal significance. On the Day of the Dead, marigold flowers are commonly used to decorate ofrendas (home altars), where they are believed to guide the souls of the deceased back to the altar.[58] This practice originates from the Aztec harvest festival, where marigolds were woven into large heaps to attract the souls back to Earth. According to Aztec beliefs, the Goddess of the Dead, Mictecacihuatl, cherished flowers, and the marigold tributes could help her allow the souls to return for one day. Marigolds' bright yellow color was supposed to illuminate the souls' path back to Earth.[59] Additionally, marigolds are used in various traditional Mexican medicine recipes, treating conditions such as kidney stones and eye diseases.[60] Marigolds also hold great cultural significance in India, where they are used to decorate prayer spaces, weddings, and are offered at temples.[61]

Etymology and European Uses

The name "marigold" is a hybrid term combining Hebrew and Anglo-Saxon elements. The English word "gold" praises the flower's brilliant yellow hue, while the term "Mari" is derived from the Hebrew "Miriam," a name associated with the Virgin Mary.[62] This spiritual connotation is reflected in alternative names for marigold in religious literature, such as "lady's tresses" or "lady's slipper."[63] This association is also found in other Anglo-Saxon-related cultures such as how the German name for marigold, *Totenblume*, means "flower of the dead."[64]

Marigold was introduced to Europe in the sixteenth century by Spanish explorers from the Aztecs. In Europe, their use reflected both their religious associations and health benefits. Peasants often offered marigolds to Virgin Mary, and the British used marigolds to decorate graves. Marigolds became widely known for their medicinal properties in Europe as well.[65]

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[58] OLLU Librarian, "Research Starters: Dia de Los Muertos / Day of the Dead: Marigolds," 2022, https://libguides.ollusa.edu/diadelosmuertos/marigolds.

[59] Helwani, "Marigold, the Bloom of Immortality."

[60] Mir, Ahanger, and Agarwal, "Marigold," 309.

[61] Mir, Ahanger, and Agarwal, "Marigold," 309.

[62] David I Macht, "CALENDULA OR MARIGOLD IN MEDICAL HISTORY AND IN SHAKESPEARE," *Bulletin of the History of Medicine* 29, no. 6 (1955): 491–502, 492.

[63] Macht, "CALENDULA OR MARIGOLD IN MEDICAL HISTORY AND IN SHAKESPEARE," 492.

[64] Macht, "CALENDULA OR MARIGOLD IN MEDICAL HISTORY AND IN SHAKESPEARE," 492.

[65] Macht, "CALENDULA OR MARIGOLD IN MEDICAL HISTORY AND IN SHAKESPEARE," 493.

Botanical Description

Marigold plants typically grow between sixty to ninety centimeters tall, with a range of colors including yellow, orange, red, and orange-brown. Their leaves are pinnately divided, and the flowers form globular heads.[66] The scent of marigolds is citrusy, green, and subtly spicy, with the leaves rich in oil, which is often extracted to make essential oils.[67]

Marigolds thrive in temperate climates with fertile, sandy soil and sufficient moisture and sunlight. The most common varieties include the African marigold (*T. erecta*) and French marigold (*T. patula*).[68]

The yellow-orange color of marigold is primarily due to the carotenoid pigment lutein. The lutein content in marigold flowers can vary significantly, ranging from four mg/g in greenish-yellow flowers to 800 mg/g in orange-brown varieties.[69] Lutein is commercially used in eye ointments due to its antioxidant properties.[70]

Figure 50. Marigolds. 1737-1739, PictureBoxBlue. https://www.pictureboxblue.com/elizabeth-blackwell-curious-herbal/.

[66] H. B. Sowbhagya, S. R. Sampathu, and N. Krishnamurthy, "Natural Colorant from Marigold-Chemistry and Technology," *Food Reviews International* 20, no. 1 (March 2004): 33–50, https://doi.org/10.1081/FRI-120028829, 34.

[67] Sowbhagya, Sampathu, and Krishnamurthy, "Natural Colorant from Marigold-Chemistry and Technology," 34.

[68] Sowbhagya, Sampathu, and Krishnamurthy, "Natural Colorant from Marigold-Chemistry and Technology," 34.

[69] Gayle K. Gregory, Tung-Shan Chen, and Thomas Philip, "Quantitative Analysis of Lutein Esters in Marigold Flowers (Tagetes Erecta) by High Performance Liquid Chromatography," *Journal of Food Science* 51, no. 4 (July 1986): 1093–94, https://doi.org/10.1111/j.1365-2621.1986.tb11248.x, 1.

[70] Sowbhagya, Sampathu, and Krishnamurthy, "Natural Colorant from Marigold-Chemistry and Technology," 34.

Marigold as a Natural Colorant

Zhang and Wang conducted an analysis of marigold pigments, isolating the pigment using ethanol through a process of distillation, condensation, and precipitation. At a neutral pH (pH of seven), the extract produced a bright yellow color, which deepened to brown as the pH increased. The pigments were found to be stable under daylight and heat. Lutein itself is most stable within a pH range of three to nine. At extreme pH levels or under prolonged light exposure, lutein loses color due to isomerization. The pigment stability improves when combined with higher concentrations of arabic gum or mesquite gum.[71]

[71] Sowbhagya, Sampathu, and Krishnamurthy, "Natural Colorant from Marigold-Chemistry and Technology," 38.

Process

Fig 51. Ground marigold for 30 minutes; the fibers were tough to grind down.

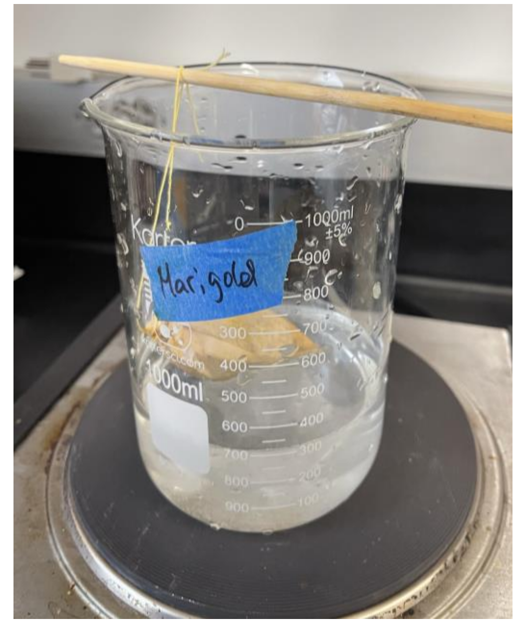

Fig 52. Boiling 7.4 g of marigold with 4 g of potash in 300 ml water for 18 minutes.

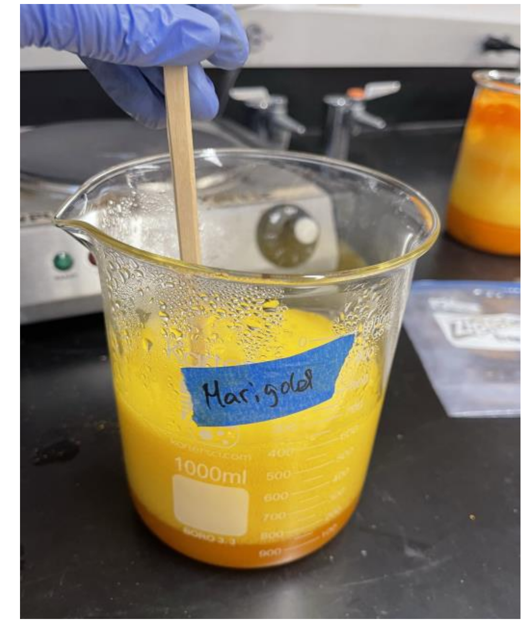

Fig 53. I gradually added the 10 g alum solution, and there was a lot of bubbling.

Fig 54. The bubbles had a gradient.

Fig 55. Washing the pigment.

Fig 56. 7.4 g of marigold yielded 2.69 g of pigment.

Saffron

Origin and Historic Uses

Saffron is an ancient plant, with some of the earliest depictions found in the frescoes of the Minos Palace on Crete, dating back to 1600–1700 BC. Its origins are debated, with theories suggesting it may have come from the Middle East, the islands of southwest Greece, or Central Asia.[72]

Historically, saffron has been valued not only for its culinary uses but also for its powerful medicinal properties. The Roman scholar Pliny the Elder described saffron as a "panacea" in *Naturalis Historia XXXVII*.[73] Saffron has been used to treat conditions such as spasms, digestive issues, and respiratory ailments. It was also known for its sedative and antispasmodic properties. Midwives had used saffron during childbirth since the Middle Ages.[74] Additionally, its pain-relieving properties were used to treat fractures and other physical injuries.[75]

Fig 57. The saffron used.

[72] Ibtissam Mzabri, Mohamed Addi, and Abdelbasset Berrichi, "Traditional and Modern Uses of Saffron (Crocus Sativus)," *Cosmetics* 6, no. 4 (October 25, 2019): 63, https://doi.org/10.3390/cosmetics6040063, 1.

[73] José Bagur et al., "Saffron," 6.

[74] María José Bagur et al., "Saffron: An Old Medicinal Plant and a Potential Novel Functional Food," *Molecules* 23, no. 1 (December 23, 2017): 30, https://doi.org/10.3390/molecules23010030, 6.

[75] José Bagur et al., "Saffron," 6.

Saffron's vibrant golden-yellow hue also made it a prized material in the arts. It was used in many ancient works, such as a second-century colored table created by the Akkadians. [76] Saffron was particularly favored by artists and illuminators for its ability to mimic gold. [77] This imitation could be achieved either by creating a varnish or a pigment that replicated gold. For example, the medieval Latin manuscript *Mappae Clavicula* included a recipe titled "How to Color Tin Leaf," which combines saffron with linseed oil, orpiment (a golden yellow arsenic sulfide), and gum to produce a varnish that is brushed over a tin leaf to imitate gold.[78] These varnishes were often brushed over manuscripts and artworks to give them a lustrous golden sheen. Similarly, in the fourteenth and fifteenth centuries, illuminators used saffron as a key ingredient in recipes for gold-like pigments, which included other substances such as mercury, tin, and sulfur. [79]

Figure 58. The saffron gatherer fresco (Knossos). ca. 15th Century BC, Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Blue_Boy_collect_saffron,_Minoan_fresco_from_Knossos,_AMH,_145375.jpg.

[76] Eastaugh, *The Pigment Compendium*, 331.

[77] Eastaugh, *The Pigment Compendium*, 331.

[78] Marjolijn Bol, *The Varnish & the Glaze: Painting Splendor with Oil, 1100-1500* (Chicago, IL: University of Chicago Press, 2023), 63.

[79] Eastaugh, *The Pigment Compendium*, 171.

Botanical Description

Saffron belongs to the *Iridaceae* family. It grows from a mother bulb, which can produce one to three daughter bulbs. The plant typically reaches a height of ten to twenty-five centimeters, and its flowers bloom in the autumn, usually in late September. The flowers have a sub-ovoid shape, with six violet petals—three internal and three external—that converge at the upper part of the ovary. The flower's inferior ovary contains a nine to ten-centimeter-long style with stigmas. The red stigmas, which are longer than the petals, are the parts of the plant harvested for saffron.[80]

Saffron's yellow color comes from the carotenoid pigment crocetin, a compound that possesses antioxidant, anti-inflammatory, and antitumor properties. Li et al. studied the stability of crocetin and its derivatives as a pigment. They used those extracted from gardenia fruit, and found that exposure to high temperatures, prolonged heating, and extensive light exposure can degrade the pigment, reducing both its color intensity and stability.[81]

Figure 59. Saffron crocus, Crocus sativus and yellow crocus. 1596–1610, *Rawpixel*. *https://www.rawpixel.com/image/561873/saffron-flower-and-yellow-crocus*.

[80] Ibtissam Mzabri, Mohamed Addi, and Abdelbasset Berrichi, "Traditional and Modern Uses of Saffron (Crocus Sativus)," *Cosmetics* 6, no. 4 (October 25, 2019): 63, https://doi.org/10.3390/cosmetics6040063, 2.

[81] Na Li et al., "Stability Assessment of Crocetin and Crocetin Derivatives in Gardenia Yellow Pigment and Gardenia Fruit Pomace in Presence of Different Cooking Methods," *Food Chemistry* 312 (May 2020): 126031, https://doi.org/10.1016/j.foodchem.2019.126031, 8.

Saffron vs. Safflower

It is important to distinguish saffron from safflower, as confusion often arises in historical pigment literature. While saffron (*Crocus sativus*) is derived from the *Iridaceae* family, safflower (*Carthamus tinctorius*) belongs to the *Asteraceae* family and produces a reddish-yellow dye.[82] Safflower is native to southern Asia and has been cultivated since ancient times in regions such as China, India, Persia, and Egypt.[83]

Safflower is sometimes referred to as "bastard saffron" due to its use as a substitute in pigment recipes. The term "saffron" has occasionally been misapplied to safflower in historical texts. For example, the 1804 recipe by Alston mentions "saffron flowers prepared in saucers," but he is actually referring to safflower because saucer pigment is a specific color made from safflower. [84] Saffron is much more expensive than safflower because its harvest process is more labor-intensive. It takes approximately 400 hours of labor and between 150,000 to 200,000 flowers to produce one kilogram of saffron.[85]

Figure 59. Safflower stock photo. 2016, iStock. https://www.istockphoto.com/photo/safflower-gm530210624-93389555.

Figure 60. Saffron stock photo. 2022, iStock. https://www.istockphoto.com/photo/saffron-flowers-gm1440609062-480547612.

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[82] Eastaugh, *The Pigment Compendium*, 331.

[83] Eastaugh, *The Pigment Compendium*, 330.

[84] Eastaugh, *The Pigment Compendium*, 330.

[85] Mzabri, Addi, and Berrichi, "Traditional and Modern Uses of Saffron (Crocus Sativus)," 1.

Process

2.9 g of ground saffron was first boiled in 4 g of potash with 300 ml of water for 18 minutes.

Fig 61. I mixed the 10 g alum with 50 g water solution into the dyestuff solution gradually. An immediate reaction occurred (the most aggressive out of all the colors).

Fig 62. The bubbles separated in color.

Fig 63. The top was a bright orange.

Fig 64. The bubbles were divided into two sections by an orange line.

Fig 65. The next day, there was some separation in the solution (all the colors had a little separation; saffron separated the most).

Fig 66. 2.9 g of saffron created 2.5 g of pigment.

Blues

Woad

Origins and Historic Use

Wood (*Isatis tinctoria*) is a flowering plant that belongs to the *Brassicaceae* family. It is native to Central Asia, southeastern Russia, and southwestern Asia.[86] Known for its dual use as a blue dye and medicine, woad's significance is embedded in its name. The genus name *Isatis* derives from the Latin *isazein* and Greek *isadso*, both referring to wound treatment, while *tinctoria* originates from the Latin *tinctorius*, meaning "pertaining to dyeing or staining."[87]

Fig 67. The woad ball used.

[86] Jasmine Speranza et al., "Isatis Tinctoria L. (Woad): A Review of Its Botany, Ethnobotanical Uses, Phytochemistry, Biological Activities, and Biotechnological Studies," *Plants* 9, no. 3 (March 1, 2020): 298, https://doi.org/10.3390/plants9030298, 2.

[87] Speranza et al., "Isatis Tinctoria L. (Woad)," 2.

Woad has been valued for its medicinal properties across many cultures. In traditional Chinese medicine, the root—known as *banlangen*—is widely used to boost immunity and treat colds and sore throats.[88] The earliest recorded European medical use dates back to 460 BCE, when Hippocrates documented its efficacy in treating wounds, ulcers, and hemorrhoids. Later, Galen (129–216 CE) and Pliny (23–79 CE) praised woad's anti-inflammatory properties, such as healing snake bites. Europeans also used woad leaves to treat typhoid, measles, and flu, while its roots were employed for scarlet fever.[89]

Woad has an equally rich history as a source of blue dye. Ancient Egyptians used woad to color mummy wrappings. It was introduced to Europe around 4000 BCE and became the primary source of blue pigment.[90] The Romans recorded using woad for religious practices, and Pliny the Elder mentioned Briton women painting their bodies with woad's indigo during rituals. Woad was also used by Celtic and Germanic tribes to paint their bodies and dye their hair for spiritual purposes. Additionally, Julius Caesar's *De Bello Gallico* describes the Celts making blue tattoos by rubbing woad on pricked skin to create a fearsome look in battles.[91]

Woad remained Europe's main indigo source until the late 16th century.[92] Its short growth period required timely harvesting of leaves, which were often processed into dried balls for future use. The European woad industry declined in the 17th century with the import of *Indigofera tinctoria* from India, which was a more efficient and cost-effective source of blue dye. The introduction of additional indigo-rich plants from the Caribbean and Americas after the New World Discovery further marginalized woad cultivation in Europe.[93]

Modern Applications

Today, woad is primarily ornamental in Europe and occasionally used in cosmetics for its moisturizing properties. In some rural areas of Sicily, Italy, woad flower buds are boiled and added to omelets or salads.[94]

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[88] K.G. Gilbert, "SECONDARY PRODUCTS | Dyes," in *Encyclopedia of Applied Plant Sciences* (Elsevier, 2003), 1174–79, https://doi.org/10.1016/B0-12-227050-9/00138-1.

[89] Speranza et al., "Isatis Tinctoria L. (Woad)," 4.

[90] "The War Between Woad and Indigo - The Origins of Color - The University of Chicago Library," accessed November 30, 2024, https://www.lib.uchicago.edu/collex/exhibits/originsof-color/organic-dyes-and-lakes/war-between-woad-and-indigo/.

[91] John Edmonds, *The History of Woad and the Medieval Woad Vat*, Historic Dyes Series 1 ([Little Chalfont: J. Edmonds, 1998), 55.

[92] Edmonds, *The History of Woad and the Medieval Woad Vat, 27*.

[93] Edmonds, *The History of Woad and the Medieval Woad Va, 29.*

[94] Speranza et al., "Isatis Tinctoria L. (Woad)," 2.

Botanical Description

Woad has greyish-yellow or brownish-yellow roots, which are cylindrical and wrinkled with rootlet scars. The dark green basal leaves form a whorled, tubercular shape, while the narrower cauline (above-stem) leaves grow upward along the stem, which can reach up to 120 centimeters tall.[95] The plant produces yellow flowers borne on short racemes, and its purple-brown pods contain one to two seeds, which ripen in summer.[96] Woad is a short-lived perennial species that is often treated as a biennial plant. It is typically sown in early spring and harvested in the summer during its vegetative phase, as its leaves have a short growth period limited to winter.[97]

Figure 68. Dyer's wood. 1863, iStock. https://www.istockphoto.com/vector/dyers-wood-isatis-tinctoria-victorian-botanical-illustration-1863-gm882494894-245578303.

Indigo Extraction Process

The blue pigment in woad leaves comes from two indigo precursors: indican and isatan B. When oxidized, these compounds form indigotin, the blue dye. The traditional extraction process, known as vat dyeing, involves fermenting dried woad leaves.[98] The leaves are rehydrated and left to compost aerobically, during which they are turned regularly. The resulting material—a dark, clay-like substance—is dried and used as dye. Modern methods involve steeping fresh leaves in water, alkalizing the solution, and oxidizing it to extract pure indigo.[99]

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[95] Speranza et al., "Isatis Tinctoria L. (Woad)," 3.

[96] Gilbert, "SECONDARY PRODUCTS | Dyes."

[97] Gilbert, "SECONDARY PRODUCTS | Dyes."

[98] Edmonds, *The History of Woad and the Medieval Woad Vat*, 22.

[99] Gilbert, "SECONDARY PRODUCTS | Dyes."

Process

I boiled 8.7 g of ground woad ball in 4 g of potash with 300 ml of water for 18 minutes. The solution was dark brown/black and had an unpleasant fermented scent.

Fig 69. Ground woad ball.

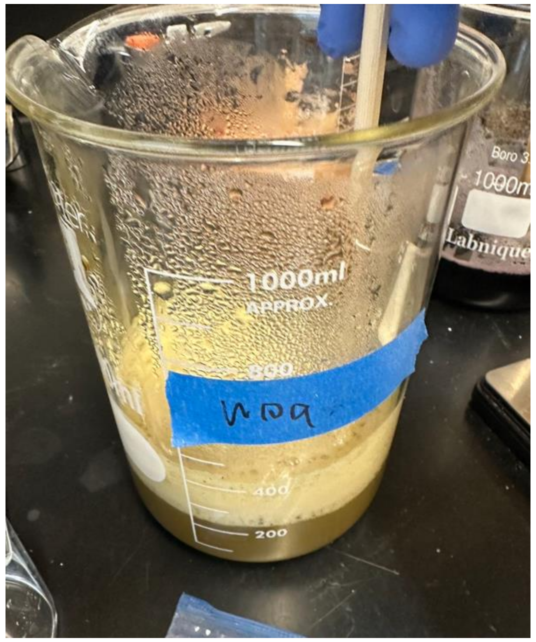

Fig 70. Chemical reactions after adding the 10 g alum solution in gradually.

Fig 71. Adding alum significantly lightened the woad solution from almost black to tan.

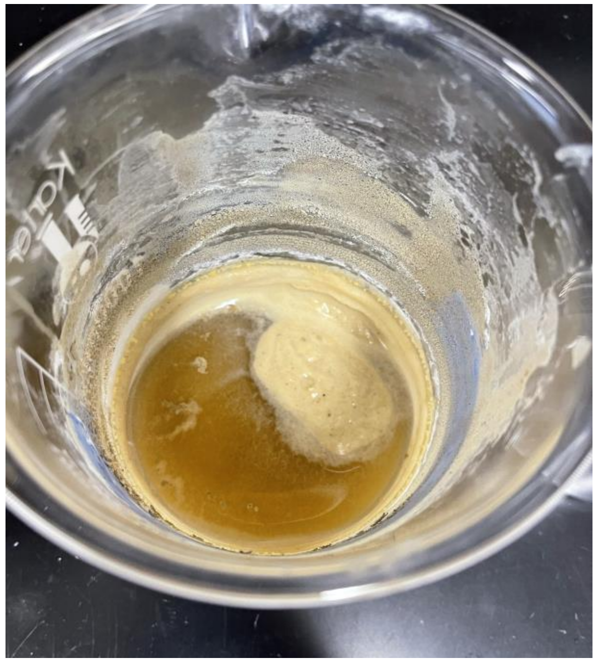

Fig 72. The solution on the next day.

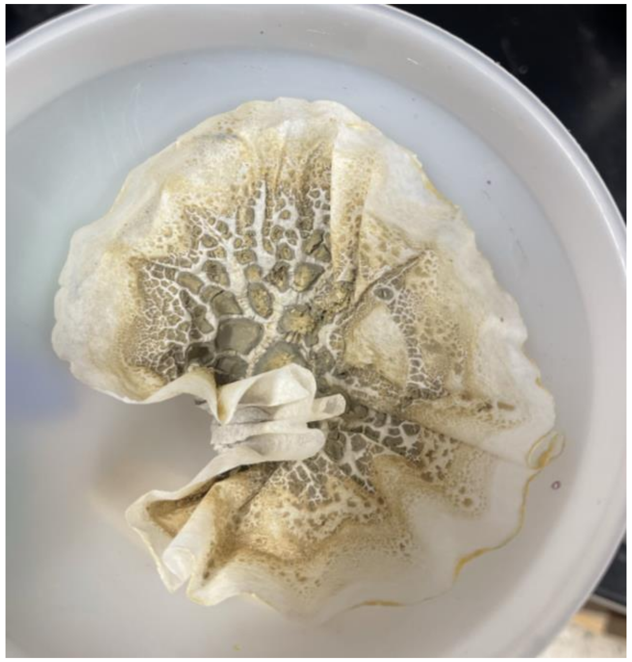

Fig 73. 8.7 g of woad created 2.49 g of pigment. The color dried as a medium grey with yellow concentrating in the center.

Butterfly Pea

Origin and Historic Uses

Butterfly pea (*Clitoria ternatea*), also known as blue pea, belongs to the *Fabaceae* family. It is native to Southeast Asia, particularly Thailand, Malaysia, and Vietnam.[100] Over time, butterfly pea has been naturalized worldwide, in areas such as China, India, South and Central America, and the East and West Indies.[101] They thrive the most in tropical and subtropical regions.

Fig 74. Dried butterfly pea flower used.

Traditionally, butterfly pea has been used as medicine and food dye. Its medicinal uses are notable across various cultures. In India, butterfly pea flower is consumed to enhance memory-related brain functions.[102] These flowers also contain numerous other health benefits, including antioxidant, antidiabetic, anticancer, anti-inflammatory, and blood sugar-regulating properties.[103] Because of these qualities, it is commonly enjoyed as a nutritional tea.

As a food dye, butterfly pea is widely used in Southeast Asia. For instance, the Peranakans (Straits Chinese) have used it to color rice cakes and rice blue, a tradition also shared by other Asian cultures.[104] My first experience with butterfly pea flowers was in Hong Kong, where I tried a latte tinted with its vivid blue hue.

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[100] Mandy Smith, "Butterfly Pea - A Natural Food Coloring," 2022, https://extension.psu.edu/butterfly-pea-a-natural-food-coloring.

[101] S. Michael Gomez and A. Kalamani, "Butterfly Pea (Clitoria Ternatea): A Nutritive Multipurpose Forage Legume for the Tropics - An Overview," *Pakistan Journal of Nutrition* 2, no. 6 (October 15, 2003): 374–79, https://doi.org/10.3923/pjn.2003.374.379, 375.

[102] Gomez and Kalamani, "Butterfly Pea (Clitoria Ternatea)," 378.

[103] Juswardi Juswardi et al., "Antocyanin, Antioxidant and Metabolite Content of Butterfly Pea Flower," *JURNAL PEMBELAJARAN DAN BIOLOGI NUKLEUS* 9 (July 31, 2023): 349–60, https://doi.org/10.36987/jpbn.v9i2.4064, 354.

[104] Timothy Pwee, "Butterfly Pea," 2016, https://www.nlb.gov.sg/main/article-detail?cmsuuid=c0b030f8-63ea-4144-b4c6-134193a5c57b.

Botanical Description

Butterfly pea is a perennial herb that typically grows between 90 to 162 centimeters tall. Its thick horizontal roots can extend up to two meters and support purple stems from which pods emerge. Each pod usually contains six to eight brown or black seeds. The plant has pinnate leaves with five to nine leaflets, forming dense, lush greenery.[105]

The flowers are violet, measuring six to twelve centimeters in length, with wing-shaped petals and a slim white marking at their center. Each bloom lasts only twenty-four hours.[106] Butterfly pea flower owes its striking blue color to anthocyanins, a type of flavonoid with antioxidant properties.[107] The anthocyanins in butterfly pea exist in two forms: flavylium (red) and quinoidal (blue), giving the flowers their characteristic violet hue. Notably, the anthocyanins in butterfly pea flowers are highly heat-stable, making them particularly valuable for culinary and textile applications.[108]

Figure 75. Butterfly Pea. 1840, Flicker. https://www.flickr.com/photos/swallowtailgardenseeds/15098331684/in/photolist-2ffaif4-2ffaijH-Kyk7nN-p1bTZw-QCddeT-4neTht-2k9S22J-poahkr-2k8tfZV.

[105] Gomez and Kalamani, "Butterfly Pea (Clitoria Ternatea)."

[106] Pwee, "Butterfly Pea."

[107] Juswardi et al., "Antocyanin, Antioxidant and Metabolite Content of Butterfly Pea Flower," 354.

[108] Smith, "Butterfly Pea - A Natural Food Coloring."

Process

I first boiled 5.5 g of ground butterfly pea flower in a tea bag with 4 g of potash and 300 ml of water for 18 minutes. Immediately after putting the tea bag into the potash and water solution, the color turned to dark brown, which was strange because when I washed the bowl after grinding the flowers, the water was blue. So it was not because the fiber or color structure got destroyed, but potash seemed to have altered the color.

Fig 76. Ground butterfly pea.

Fig 77. Washing the mortar with water.

Fig 78. Adding the 10 g alum solution immediately caused the color to turn lighter.

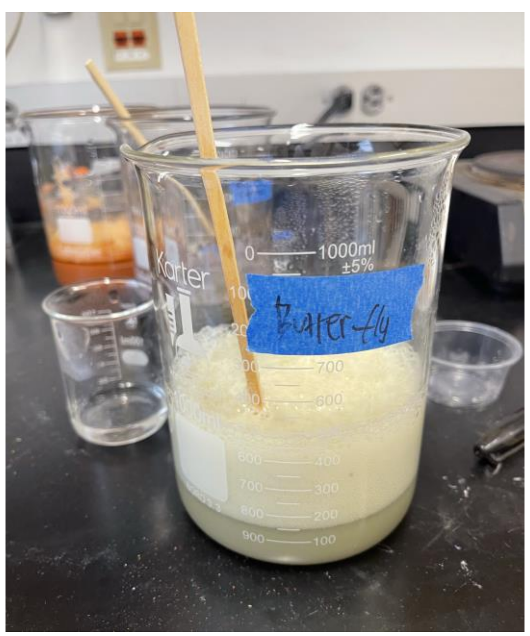

Fig 79. After pouring a portion of the alum solution in, the color turned to a pale green-grey.

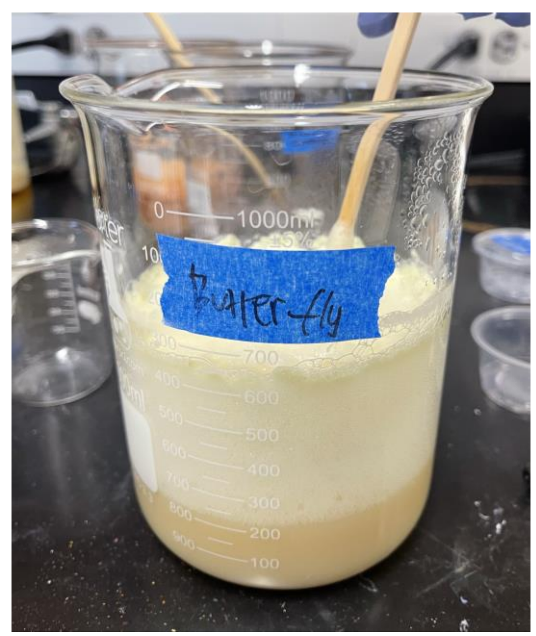

Fig 80. Adding the remaining alum created a pale yellow.

Fig 81. 5.5 g of butterfly pea flower created 2.71 g of pigment.

Second Batch

I was disappointed that I didn't get a blue pigment, so I tried again using the method where I boil the dyestuff in water first, then add the alum and the potash solution into the dyestuff water at the same time. I dissolved 3 g of potash in 20 g of water and 10 g of alum in 40 g of water.

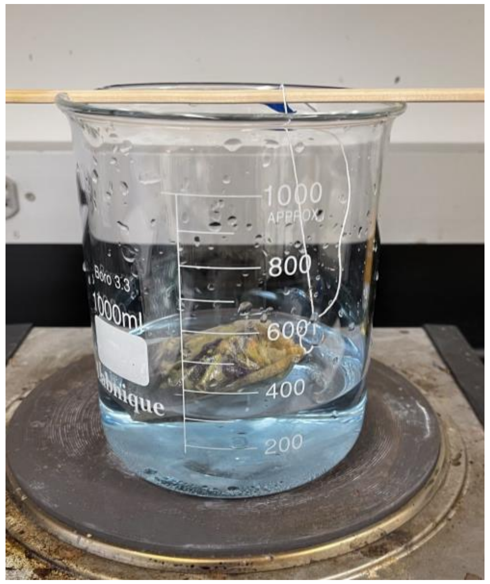

Fig 82. I put 4.5 g of whole butterfly pea flower in a teabag and boiled it in 300 ml of water for 18 minutes.

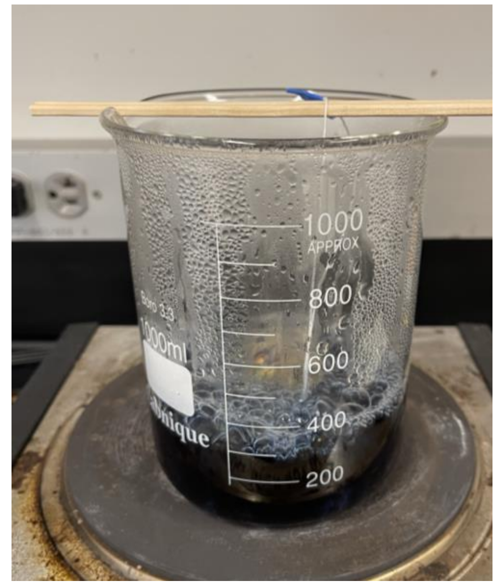

Fig 83. The solution was a dark purplish blue after the boil.

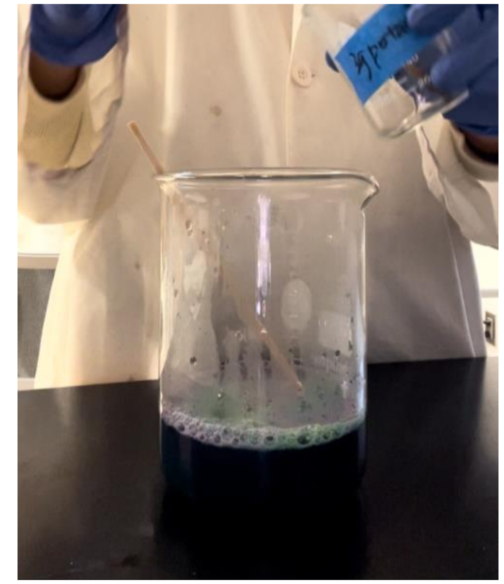

Fig 84. I put some alum in first, which did not change the color, but when I added the 3 g potash solution, the color turned to turquoise (only mild bubbling at first).

Fig 85. Bubbling intensified as I stirred the solution. There was more bubbling than hibiscus but not as much as average pigments like madder roots.

Fig 86. Alum created pinkish purple bubbles.

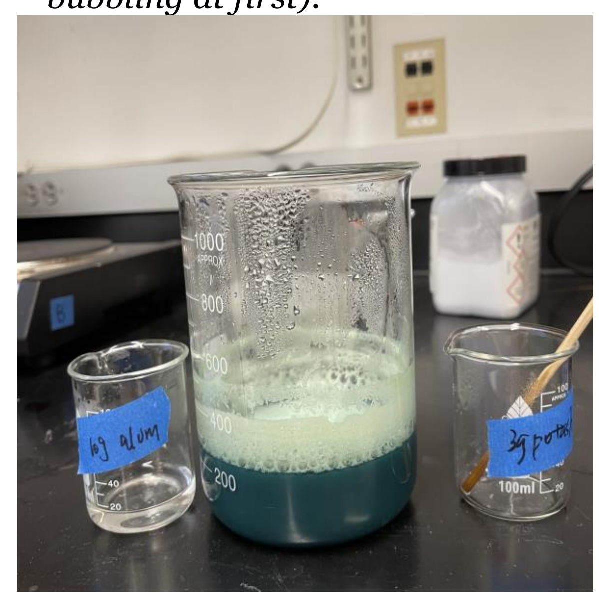

Fig 87. I ended up using 3 g of potash and 5 g of alum.

Fig 88. The pH was around 8.

Final Product

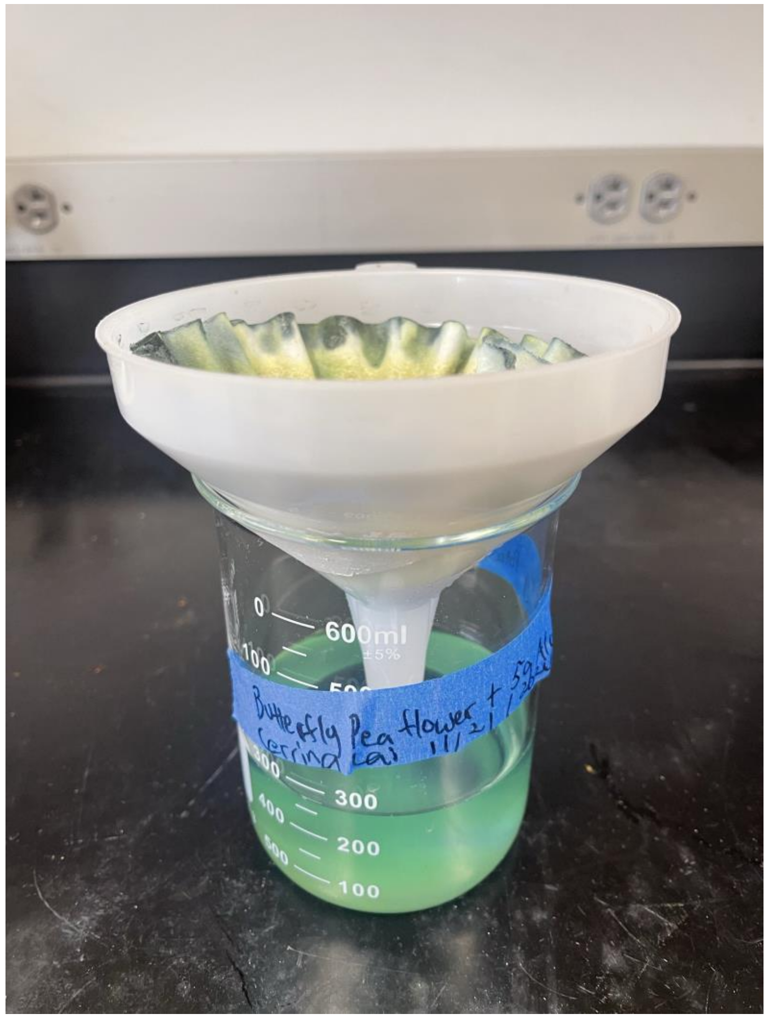

Fig 89. Washed the pigment.


Fig 90. 4.5 g of butterfly pea flower created 1.49 g of pigment. The color became a warmer and lighter green compared to the dyestuff solution.

Final Pigments

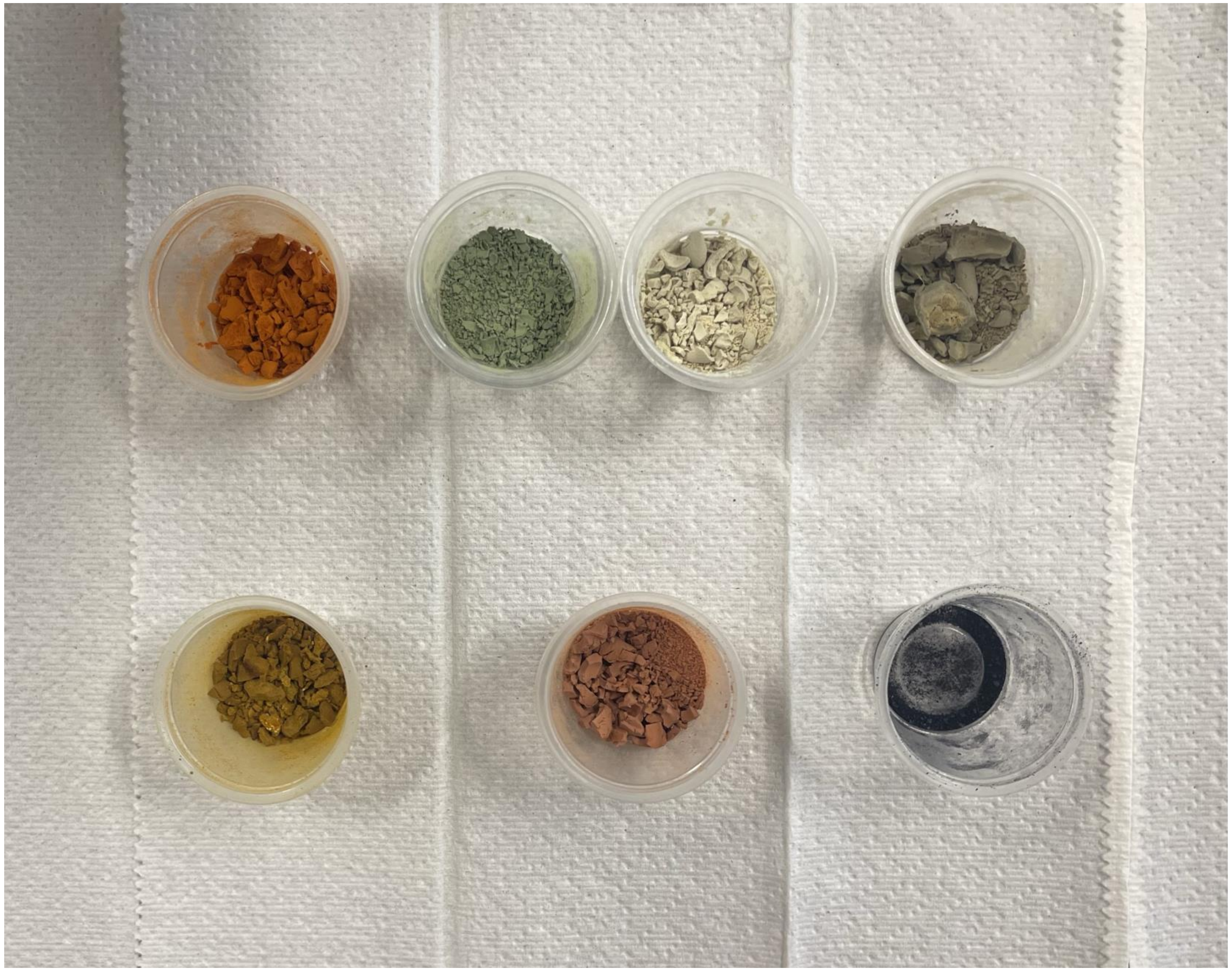

Fig 91. Top: saffron, butterfly pea second batch, butterfly pea first batch, woad.
Bottom: marigold, madder root, hibiscus third batch.

Paint Making

I combined the pigments with 2 types of binder—gum arabic and egg yolk—to make paint. Gum arabic was transparent while egg yolk added a yellow tint to the color.

Gum arabic

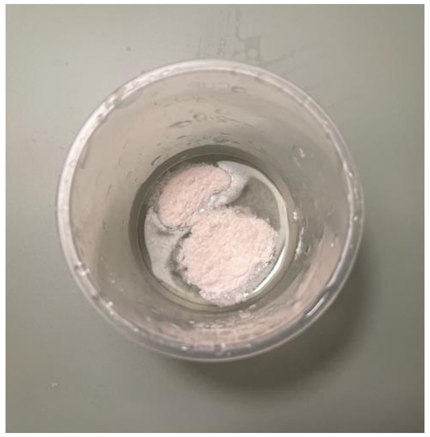

Fig 92. Dissolved gum arabic in water using 10:1 ratio (water:gum arabic).

Fig 93. Combined the pigment with the solution using a muller.

Fig 94. I used a pallet knife to help incorporate everything.

Egg yolk

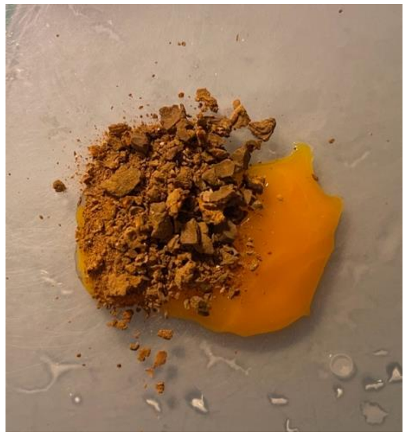

Fig 95. I combined some pigment with egg yolk using 1:2 ratio (pigment:egg yolk)

Fig 96. Mixed them with a muller and a palette knife.

Fig 97. The paint was thicker than gum-arabic paints.

Fig 98. Paint swatches

Painting Process

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