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Reviewed Article:

Searching for Dubh: Experiments in Black Dyes Pre 15th Century in Ireland and Scotland

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This paper explores sources of black dyes in Ireland and Scotland prior to 1500, in order to better understand the extent to which they were used and the hues that can be produced. I propose that it is possible to obtain true blacks using only natural dyeing techniques. To test this hypothesis, four variations of historically plausible dye methods, and a control, were tested based on the availability of the dyestuffs. Brown Shetland wool was dyed according to possible historical methods, and each variant was subjected to a series of tests to examine

lightfastness and wash fastness. Initially, testing showed a low indigotin content, an organic compound which creates a blue pigment, in the sourced woad, resulting in a poor dye bath and skewed results. The woad-based samples were repeated using a modern method of extracting indigotin from woad due to limitations in sourcing and time. Each dye sample was subjected to a long-term light exposure test utilizing blue wool standard cards for comparison, in addition to two different wash and rub tests. The two samples that were created using woad as a base dye and produced the richest shades of black with the least amount of apparent damage to the fibers. Closer examination showed that the addition of alum resulted in substantial degradation of the fleece and made it difficult to spin. Additionally, all samples proved to be lightfast. Further testing is required of the other plausible recipes collected, in addition to repeat testing using the more historical methods in this experiment. However, this experiment did show that lightfast black colour was possible to produce prior to the import of logwood.

> It is possible to dye a true black without the use of logwood or other imported dyestuff. The Irish and Scottish have several known methods to achieve black textiles. Woad base dyeing with oak galls and iron water on top is very effective and seems to limit some of the corrosive effects of the iron.

Blacks Before Logwood?

In the world of Medieval hobbyists and reenactors, there has long been a debate on the use of the colour black in textiles prior to 1500 AD. Black dyes are often complex and typically require multiple pigments to achieve. Many involve the use of iron water (liquor), water which has been infused with iron ore, which can be damaging to textiles, particularly animal fibers. In antiquity, the most common black dyes used a combination of iron and tannins, such as oak galls (Liles, 1990, p.184). Due to cultural understanding of the colour, some argue that true blacks were not easily obtainable without the use of an imported hardwood, called logwood. However, in Ireland and Scotland, there is a longstanding tradition of dyeing black using locally obtained materials. I seek to explore sources of black dyes in Ireland and Scotland prior to 1500, in order to better understand the extent to which they were used and the hues that can be produced. I firmly believe that true blacks are possible to achieve using only natural dyeing techniques.

During the 16th century a tree, called logwood or *Haematoxylum campechianum*, was brought to Europe by the Spanish. When introduced, this hardwood from the Americas made it possible to easily obtain glossy black textiles in many fibers. Logwood is native to Central America and the Caribbean. Its red heartwood produces a chemical called hematoxylin, which is used to produce rich black dyes when combined with iron (CAMEO, 2022). This inexpensive dye revolutionized the textile industry, allowing black dyes to become extremely popular across Europe. Logwood became one of the most common dyestuffs used to create black

dyes. Due to its inexpensiveness, it has the longest commercial use of all natural dyes. (Liles, 1990, p.184)

Linguistic Understanding of Colour

One issue presented when looking at written and oral traditions using colour terms, is that cultures have different understandings of colour that change over time. Every language has its limitations, and every culture has a unique way of understanding and expressing observations of the world around them. Often, vocabulary within a language is impacted by cultural importance and geographical surroundings. In regards to colour naming, a great deal of research has been done examining languages across the world and comparing their terms and understanding of colours. According to a study by Twomey, et al. (2021, p.1), colour terms are fairly consistent in pattern and understanding across the world. It is of interest to note that hues and shades are sometimes not distinguished in the same way cross culturally. For example, prior to the 15th century, most European languages did not have a word for the colour orange. It was referred to as red or yellow-red (Mellor, 2023). Prior to the invention of synthetic colours, most colour terms were derived from nature. Heather Pulliam (2012, p.1), in her essay on Medieval colour concepts, notes that although humans see millions of colours and hues, most English-speaking peoples use ten to twenty terms on a daily basis.

In a modern context, when shown several shades on the gray, brown, and black spectrum, people may disagree as to what actually constitutes a black colour. Some only consider the absolute darkest shades without any visible evidence of individual colour as black, while others may include charcoal, dark gray, blue-black, reddish, or brownish black. A general search on the colour 'black' yields a spectrum of hues, showing that in a modern context, restricted to the English language, there are in fact several shades considered to be black.

Colour Concepts in Ancient Ireland and Scotland

Throughout known history, the Irish were understood to be extremely skilled dyers and able to produce a wide range of colours. Colourful clothing was a cultural preference for many centuries. Wide ranges of blue, green, red, orange, yellow, gray, brown, purple and black were all possible to obtain using local materials. (Joyce, 1906, p.389,466) The Scottish have also been known historically for their extensive dyeing abilities (Joyce, 1906, p.469). The Gaelic language has an extensive vocabulary for colour terms, and clearly differentiates between brown, gray, and black. It is speculative on whether or not the grays and browns included very dark hues, or if those would have been considered black.

Evidence for Early Dye Practices in Ireland and Scotland

Prior to the year 1500, localized dyes were often used. In Scotland and Ireland, dyeing as a household level practice continued into the 19th century. Recipes and techniques were often

guarded by women and largely unknown to men (Joyce, 1906, p.466). At a glance, there appears to be limited written evidence regarding early medieval, and more ancient dyeing practices in Ireland and Scotland. Without more modern techniques of extracting dye traces in textiles, researchers have had to rely on oral traditions and folk practices, in addition to folk tales and more obscure literary references.

Primary Sources for Black Dyes Prior to 1500

There are several written references to black dyes within Ireland and Scotland as well as in continental Europe. Codes of laws, household inventory or merchant records, manuscripts and books all can provide insight into dyeing practices. Listed below are a small fraction of documents discussing dyes or actual black garments.

Ancient Laws of Ireland-Senchus Mòr

According to a set of ancient Irish laws, called the *Senchus Mòr,* "Black and yellowish and gray clothes are to be worn by the sons of the Feini grades; and old clothes by the sons of *ogaire* chiefs..." (Hancock and O'Mahoney, 1869 cited in Dunlevy, 1989) Feini grades were a lower-class group of freemen, often those who worked the land. Black clothes being a designated colour indicates that it was commonplace enough to be used by those lower in social class.

Household Inventories

Household inventories provide insight into the items owned and worn by people. In *Dress in Ireland,* Mairead Dunlevy (1989, p.29) mentions two lists of household items from the late 1300s, which contain black clothing. A landowner lists several houppelandes, or voluminous gowns, that are owned in russet, blue, black, and red, while a farmer from Balrothery owned a wardrobe with black and blue gowns, a red hood and white jacket.

Manuscripts and Books

A German manuscript, called the Innsbruck Manuscript from 1330, details several dye recipes. It states that one should "Take green nutshells [walnut] and grind them together and let them rot for seven days in a [stoneware] pot and therewith make a black dye" (Trans. Leed, 2008). This recipe is relevant as it provides a recipe using materials available to the Irish and Scottish.

Extent Remains (Historical Textiles)

One can also look to textiles still in existence for evidence supporting the use of black dyes. *The Final Attack on Jerusalem,* a tapestry dating to 1480, from Hainaut, Belgium, contains black areas with two visibly different sections of black threads. The more degraded threads seem to be part of the original tapestry, while the others, part of an 18th century restoration. Based on chemical analysis, the original threads were dyed with a tannin-based dye such as gall nut, alder bark, or sumac. (Degano, et al., 2011, p.5839, 5845)

In a grave at Arrington, Cambs, circa A.D. 130-160 black yarn was found. Based on chemical analysis, it seems to contain indigotin from woad and madder or bedstraw (Wild, 2002, p.7). Due to the presence of woad in black yarn, it shows that it was used as part of the dye process.

In excavations in London, black textiles from the 14th century have also been discovered. The black textiles found seem to use tannin dyes, as well as pigmented wool overdyed with madder. Evidence of woad and tannin are often difficult to detect through chemical analysis due to degradation of woad and the presence of naturally occurring tannins taken in during burial (Crowfoot, et al., 2001, p.201).

Secondary Sources for Black Dyes Prior to 1500

In addition to primary written documents, one can examine written stories and oral traditions. Stories and folk tales often contain descriptions of clothing and daily practices. These details provide valuable insight into dyeing practices and the clothing worn. In Mairead Dunlevy's *Dress in Ireland: A History* (1989, p.25), she discusses descriptions of dress in the *Vision of Mac Conglinn*e, a satire from the 11-12th century, stating "...when Cathal Mac Finguine went to a place where he was provided with only 'small bread and broken nuts' he dressed in a dun-coloured cloak".

Traditional Dye Recipes and Books From Later Periods

Dye recipes and books from later periods can also be sources of information. If the techniques and materials used were available to the Irish and Scottish at an earlier date, it is probable that they had knowledge of the methods. *The Dyer's Handbook: Memoirs of an 18th Century Master Colourist* (Cardon, 2016) discusses several dye recipes used commercially.

It states: In order to give a deep black colour to an undyed woollen cloth, ancient dyers would first dye it into as deep a blue as possible, one of these nearly black blues that are obtained from repeated dippings in indigo vats and on which is built the extraordinary prestige of indigo in all civilisations. Mediaeval European dyers of fine broadcloth would then mordant it with alum and tartar and top-dye it with madder, thus producing the very prestigious black called brunette, brunet, bruneta in their respective languages" (Cardon 2016, pp.139-140).

Traditional Dyeing Techniques of Ireland and Scotland

More contemporary dyeing practices can gain insight into older practices. Up until the 1930s, many people within Ireland and Scotland continued to dye with local natural dyes and traditional practices. Oftentimes, these dye recipes were passed down throughout generations. In the folklore archives at University College Dublin, several interviews are recorded. In one interview a teacher states: "Long ago the women used to dye the wool black and make cloth out of it. They used to get airgead lóchra (meadowsweet). This is white flower

that grows plentifully along hedges... When it was well boiled, they strained off the water and put it back into the pot again. They put the wool into and also a substance called 'bog ink'...This gave a good black colour to the water and a lasting dye to the wool..." (Bean Uí Ghiobáin, 1938). Bog ink refers to bog mud which naturally contains high iron content and would provide a similar effect to post mordanting with iron water.

According to Maureen Kerr (2023) in South Uist, in the Western Isles of Scotland, her grandmother used to use the roots of the yellow flag iris to create a rich black dye. She was also told by several older women in the area that they would wait until the plants reached ten inches in height and were in full bloom before harvesting. The top part of the plant and flower was used to dye as well as the roots. The roots, when combined with alum, created a dark bluish-gray. When combined with iron, they created black dye (Kerr, 2023).

Lands of Plenty: Natural Resources Available Prior to 1500

Ireland and Scotland are filled with a vast array of local plant and mineral resources that can be used in the process of dyeing textiles. For millennia, the Gaelic peoples have honed techniques and skills associated with dyeing. Many of these plants are still available in the landscape, providing opportunities to experiment with them, and to attempt to replicate past dyeing practices.

Mordants

Mordants are substances added before or after dyeing to help the dye become more permanent and wash fast. Mordants are typically salts or metals that help dyestuffs chemically fix to fibers. (Liles, 1990, p.211) There are many options for mordants available in Ireland and Scotland, and amongst them are *(*SCA Celtic Resources, 2014*)*:

- Aluminum Sulfate obtained from urine, wood ash, oak galls or burnt seaweed
- Copperus (ferrous sulfate) - From Iron Ore or bog mud
- Copper- often from use of copper pots
- Fir Club Moss in place of Alum
- Tannins: Oak galls, Walnut Shells, Alder Bark

Dyestuffs

Dyestuffs refer to substances from which dyes can be extracted. They can be of plant, animal, or chemical origin. Dyestuff can be used in combination with each other or with mordants to alter the colour and to make the dyes more permanent. Within Ireland and Scotland, many plants are used for dyeing. Some of which include:

- Oak Galls- ground

- Woad - leaves broken down in a fermentation vat
- Yellow Flag Iris- roots, flowers and leaves
- Meadowsweet - whole plant
- Madder- roots
- Water Lily- roots
- Boiled Furze bark (SCA Celtic Resources, 2014)

Plausible Ways of Dyeing Black

Based on the resources available and evidence for their use, there are many methods that can, and have been used to achieve strong black dyes. Adding aluminum sulfate as a compound, or from urine to the recipes can alter the colour and improve fastness. Listed below are a few of the many ways in which black hues were historically produced on wool:

- Iron water and Oak Galls (Liles, 1990)
- Iron water and Oak Galls with Woad as over or under dye (Cardon, 2016; Ortega Saez and Cattersel, 2022)
- Yellow Flag Iris roots and iron water or bog mud (Kerr, 2023; Snapdragon Life)
- Meadowsweet (whole plant) pre-mordanted with bog mud or iron water (Edmonston, 1844 cited in Fraser, 1983; Bean Uí Ghiobáin, 1938)
- Woad overdyed with madder, gall nuts, and/or weld (Liles, 1990; Degano, et al., 2011; Cardon, 2016; Ortega Saez and Cattersel, 2022)
- Woad dyed and alum post mordant with madder overdye (Kirby, 2022)
- Rotted green walnut shells (Innsbruck Manuscript as presented by Drea Leed, 2008)
- Walnut shells and iron (Hägg, 1984 cited in Priest-Dorman, 1999)
- Boiled furze bark (Lucas, 1958)
- Waterlily roots with iron, pre-mordanted with alum (Fraser, 1983, p.117; Grierson, et al., 1985)

Materials and Methodology

The entire experiment was conducted over the course of nine months. It was done in its preliminary stages in the summer of 2023, and concluded in the spring of 2024. After the initial series of tests was conducted in the summer of 2023, new woad vats were made and new samples were dyed and tested (See Table 1).

Date	Activity
May 2023	Began prepping dyestuffs
June 2023	Initial Dyeing completed

September 2023	First round of testing completed
October 2023	Woad Vat #2 began
December 2023	Woad Vat #3 prepped, and second round of dyeing completed
January through February 2024	Extended tests were performed

TABLE 1. CHRONOLOGY OF THE EXPERIMENT.

The recipes ultimately chosen to experiment with were due to the prevalence of evidence for their use historically, as well as the availability of the materials. I opted for a dark-coloured fleece from Shetland sheep to begin with, as dyeing it black would be easier than on a light colour. Shetland sheep are an ancient breed and very similar to the sheep available throughout much of Irish and Scottish history. References in the *Senchus Mór* mention that black was often worn more by lower class people (Hancock and O'Mahoney, 1869 cited in Dunlevy, 1989). Lighter coloured fleece was likely reserved for more colourful and favorable dyes, and the darker would have been in less demand and more likely to be used by the common person.

I chose four variations, in addition to a control. Approximately 7.09 g of fleece was used for each variation. A commonality in all methods is the use of iron in the form of iron water or from preparation in an iron pot. Future experiments will pay closer attention to the composition of the iron source used in the experiment and note how it compares to the historical sources. Many recipes also call for a tannin, such as oak galls, walnut, or oak bark. It is possible that yellow flag iris roots, in addition to meadowsweet flowers may have been used more frequently in Scotland, due to the long-standing use into the early 20th century, however I was unable to obtain them.

Recipes

Control: Oak Galls and Iron Water

1. Oak Galls and Iron Water with a Woad Overdye
2. Oak Galls, Alum and Iron water with Woad Overdye
3. Alum Mordant with Woad Dye, Post Mordanted with Oak Galls and Iron Water
4. Woad Dye and Post Mordanted with Oak Galls and Iron Water

A two variable wash test will be performed to check for wash fastness using castile and lye-based soaps. Lye-based soaps would have been some of the most prevalent soaps used prior to 1500, however imported castile soaps were available (Routh, et al., 1996). A long scale light exposure test using Blue Scales (Textile Fading Cards), from Talas Online, will also be carried out over the course of 70 days, instead of the traditional 90-day exposure, due to unanticipated time constraints. Blue Scale cards are used to run standardized tests on textiles for weathering and lightfastness. All variations and the control will be compared to a modern

synthetically dyed black textile for visual reference. Two samples of white linen will be dyed to demonstrate the strength of the dyestuffs and the colour achieved independently. At the time of the experiment, I was unable to obtain light coloured fleece. Linen does dye differently than fleece, and that will be taken into account, and only used as a reference to test the general strength of the dyes. One linen swatch will be dyed with woad, and the other with oak galls and iron water.

Preparation of Dyestuffs and Mordants

Many dyes require several days or weeks to prepare and must be planned accordingly. The dyeing process begins with preparing the shared ingredients required for the dye recipes. Iron water takes at least one week, while the entire process involved in a woad vat takes, on average, two weeks but can take longer. Oak galls are much quicker to ready and can be done on the day of dyeing. One must also make sure that the substance being dyed is properly prepped to be able to take on dyes. In the case of wool, it is most frequently dyed as raw fleece (See Figure 1). Fleece must be properly cleaned of debris and oils.

Iron Water

Iron water is a solution of water and vinegar infused with iron oxide, in the form of rusted iron objects. I chose to start with steel wool pads as they have a large surface area and are easily obtainable. In the past, old, rusted nails or shavings of iron ore would most likely have been used.

1. I began by unrolling four wool pads.
2. They were doused with rubbing alcohol and lit on fire to burn off any protective coating. It is important not to use steel wool scrubbies, as they are coated in a material that prevents rust from accumulating (See Figure 2).
3. Next, I coated the steel wool with common white vinegar and salt and allowed it to sit in the sun for a few hours.
4. After visible rust began to form, they were cut into pieces
5. The steel wool was then placed into quart jars, filling ¾ full, and covered with a combination of a two-to-one ratio of water and white vinegar. Caution was taken to not overfill the jar as the chemical reaction does cause it to initially bubble up.
6. I allowed them to sit for about two weeks, stirring twice daily. The solution became very dark with a lot of sediment. Containers can be covered loosely if at risk of being contaminated. Sediment will begin to form on the bottom of the jar by the end of day two (See Figure 3).
7. To use, sieve particles and pour into a non-reactive container such as a plastic bucket, stainless steel, or iron pot. In this case, a plastic bucket was used.

This method enables a lot of iron to be extracted from new material in a short period of time. By firing the steel wool, any coating is removed, allowing for more oxidization. The solution of vinegar, water and salt poured over and sunned for a few hours rapidly rusts the wool (Freeman Marsh, personal communication, 17 June 2023[1]; Sew Historically, 2015).

Woad Fermentation Vat

A woad fermentation vat consists of woad (*Isatis Tinctoria*) leaves that have been boiled or couched, a method of preservation, and then fermented in a solution, historically stale urine, but can also be a solution with madder, bran, and soda ash, alum, or salt (Liles, 1990, pp.83-84). Two different historical methods were tried before it was determined, via the method of dehydration of Woad Vat #2, that the woad itself did not have much extractable indigotin. The woad used had been preserved with a freeze dry method, which in theory, is supposed to be usable for dyeing; however, in this case, it was not (See Figure 4) (See appendix 1 for additional information on the method used and results). The first method which was subjected to additional testing, is detailed below, in addition to the modern method used for the retest. A modern method using extracted indigotin powder from woad and Thiourea dioxide, or thiox, was used in the interest of time, and due to sourcing problems of historically adequate woad.

Vat 1 Methodology

(Liles, 1990, p.82; Stasinska, 2020; Freeman Marsh, personal communication, 17 June 2023)

1. A gallon of urine was collected and put into a glass jug. I left it to sit covered, in a ventilated area for three to five days, until the colour and smell clearly changed. Placing it outside on a hot day greatly reduces the time needed.
2. Five ounces of dried and crushed woad leaves were measured out and put to soak with a small amount of water overnight to rehydrate in a plastic container.
3. I transferred the woad into a loose weave synthetic netting and tied it into a bundle with string. The remaining liquid and woad bundle were placed into a large stainless steel pot.
4. I covered it with a lid and kept it in a warm place. Ideally temperatures should not exceed 60 degrees Celscius, and should not go under about 40. The pH level needs to be maintained between eight and ten. The very high temperatures, and bright sun in southern Texas created the perfect temperature for the vat to ferment. Most days ranged from a low of 27 degrees to a high of 46, with high humidity and additional heat index. Traditionally, a woad vat would have been set near a lit fire to keep warm. However, with temperatures well over 40 degrees each day, I did not think fire would be needed. However, it is likely the temperature was too low for the woad to ferment as well as it needed to.

5. The vat was stirred gently twice daily. The bundle of woad was squeezed and massaged under the liquid using gloves to help extract the dye. I tried to be careful not to introduce oxygen into the solution in the vat.
6. In theory, the vat is ready when there is a layer of blue scum and the colour of the liquid has turned yellow-green. Traditional sig vats (urine fermentation vats) can take up to three weeks to be ready for dyeing, but will need at least two weeks without the addition of ingredients to speed up fermentation. The material used for the vat could impact the composition and chemistry within the vat. For example, copper, aluminum and cast-iron pots would leak some trace metal into the vat. Most dyers I consulted with prefer to work with stainless steel or cast iron when dealing with woad.

Woad Vat #3 Methodology

In the interest of time, and due to difficulty sourcing additional fresh or couched woad, I opted to use a modern method. In place of the traditional fresh or couched woad, I used extracted indigotin from the woad in a powdered form (See appendix 1 for more information). The modern method allows a vat to be prepared in a matter of hours as opposed to weeks. The method used to create the vat is described below using recipes based on those in *The Art and Craft of Natural Dyeing* (Liles, 1990), Teresinha Roberts (2006), in addition to the personal experience of experienced dyer, Wendy Freeman Marsh.

1. I prepped the fleece for dyeing by soaking ½ pound of scoured fleece in a solution of warm water, sprinkled with thiourea dioxide for two hours.
2. To rehydrate the woad powder, 20 g of woad powder was mixed with 30 g of warm water (48.9 degrees Celsius).
3. A solution with 300 ml of very hot water and 14 g of washing soda in the form of sodium carbonate was also prepared. The solution was allowed to cool to 48.9 degrees Celsius.
4. The woad paste was then added to the washing soda solution and stirred gently. The paste was left to rest for 30 minutes.
5. Approximately five gallons of tap water was heated to 54.4 degrees Celsius.
6. ⅛ teaspoon of sodium hydroxide (lye) was added to the water and stirred until dissolved.
7. The woad solution was added to the vat by slowly submerging it into the large pot.
8. One teaspoon of thiourea dioxide (thiox) was sprinkled over the vat.
9. Vat was left to rest at 54.4 degrees Celsius for two hours. The vat is ready when the solution turns light yellow-green and has blue frothy bubbles on top.

Oak Galls

Oak galls are created when insects burrow into the outer layers of bark on oak trees creating round ball-like growths on branches. The growths contain high concentrations of tannin

which produce brown dye hues. Some species contain more tannins and are considered better for dyeing. Aleppo oak galls are the most often sold for dye purposes (Ellis, 2018). The species native to Ireland include *Quercus petraea,* known as sessile oak and *Quercus robur,* commonly called Pedunculate Oak (Let's Go Ireland). In Scotland, Pedunculate Oaks are common (Forestry and Land Scotland).

In order to prepare oak galls for dyeing (Liles, 1990, p.19):

1. Oak galls need to be removed of remaining bugs or nests, crushed and powdered. I purchased oak galls that were already in powdered form.
2. The tannin powder was dissolved in a small amount of warm water. For one pound of fleece, it is recommended to use about 1.6 oz of extracted tannin powder.
3. The dissolved mixture was added to four to six gallons of hot water that was approximately 130-170 degrees Fahrenheit.

Alum Bath

Alum, or potassium aluminum sulfate is used to mordant fibers prior to dyeing, it can sometimes be used as a post mordant. (Liles, 1990, pp.18-19) Alum is native to the region and has thus been likely used since very early times (Joyce, 1906, p.466). Historically, clubmoss has been used to obtain aluminum for dyeing as it naturally contains the element in greater quantities. Clubmoss has little effect on the overall colour, however, it does make dyes more permanent (Sweetnam, 2020). While clubmoss was unavailable to me, the chemical derived from clubmoss was readily available. As an alternative, I used potassium aluminum sulfate for my alum bath.

1. To set up an alum bath, I took one ounce of potassium aluminum sulfate and dissolved it in a small amount of water at 175 degrees Fahrenheit.
2. I then stirred until fully dissolved and let it cool to room temperature.
3. The alum mixture was poured into a pot suitable for heating, with enough water to cover the fleece (approximately one gallon).
4. I brought the mixture to a simmer and turned off the burner. The fleece was then added to the mixture and left to rest for 17 hours.

Preparing Fleece

Fleece has historically been dyed as unspun fleece. It is easier for the dye to impart more consistent hues into the fibers. In order for dyes to stick to and embed in the fleece properly, the natural oils present need to be removed, via a process called scouring. Lanolin is extremely water repellent, which helps to insulate sheep from harsh wet conditions, but it will also prevent dyes from seeping into the fibers. Traditionally, fleece was scoured using urine and/or lye base soaps and hot water (Liles, 1990, p.17). Prior to dyeing my fleece, using the

above dyestuffs and mordants, it needed to be scoured. To scour the fleece (Liles, 1990, p.17; Kerr, 2023):

1. I removed any larger particles of dirt and debris that remained. Then the fibers were straightened and loosed by hand combing and removing pieces that are matted.
2. A bucket was filled with hot water, a small amount of dish soap, and washing soda.
3. I placed the fleece in the bucket and submerged it to soak overnight.
4. The liquid was then drained and rinsed thoroughly with warm water, being careful not to agitate the fleece.
5. It was left on a towel to dry flat.
6. Conclusions

Urine- The Not So Secret Special Ingredient

There are many folk stories regarding the use of urine in traditional dyeing practices. It has historically been used as a fixative to help dyes stick to the textile, and to aid in the breakdown of certain dyestuffs, such as woad and indigo. It has been thought that young boys, pregnant women, diabetics, and drunkards often provide the best urine. Arguably, this is due to additional sugar and grains in the urine in the case of diabetics and alcoholics. For young boys and pregnant women, there may be additional nutrients present and higher levels of urea (Liles, 1990, p.81). Liles also suggests increasing intake of water-soluble vitamins such as b, c, and other minerals, in addition to increasing protein consumption, several days prior to and during the period of collection (Liles, 1990, p.81).

There are many differences in diet between my modern high salt and protein diet and that of the average Scottish or Irish person before the industrial revolution. I do not consume alcohol, however Europeans during the Medieval and earlier periods often drank diluted alcohol as a way to combat bacteria in drinking water. I do, however, drink large amounts of water, typically around two liters or more daily. Wheat and rice are eaten in greater quantities, whereas oats were the primary grain for much of Ireland and Scotland. I also consume a larger amount of meat-based proteins than the people of the past did. These differences likely cause the urine to be somewhat different in the bacteria present, nutrients, level of urea, and its concentration. It is likely that differences in the urine could affect the speed at which it ferments and reduces the woad.

Dyeing the Fleece

To begin dyeing, I measured out 63.8 g of the freshly scoured and dried fleece. This was then separated into five piles of 7.09 g of fleece to be used in each variation. The samples tested using the woad in Vat #3, contained 113.4 g of fleece in each, to allow enough for the lightfastness test and for spinning prior the wash tests. All tools needed, such as gloves, sieves, tongs and stirring sticks were gathered. As much of my dyeing, with the exception of

the woad, was done in the kitchen, food items were carefully separated from areas of possible contamination, and the necessary dye baths were set up. Plastic bags were labeled with each variant recipe and used to keep the treated wools separate after being dried.

Control Recipe: Oak Galls and Iron Water

Once the oak gall bath has been prepared and cooled, 7.09 g of scoured fleece and washed white linen were added to the solution. The samples soaked for over 24 hours to absorb the greatest amount of tannins into the fibers. After removing the fibers from the oak gall bath, I rinsed them thoroughly with warm water and gently squeezed out the water. The fleece was separated and straightened somewhat before being placed with the linen into a bucket of strained iron water. I left the fibers in the iron water for a single 30-minute dip. After removing them, they were again rinsed in warm water, separated, straightened and placed to dry flat. On first appearance, the fleece was substantially darker and did indeed look black. The fleece, when dried, is a dark brownish-black (See Figure 9), the linen (See Figure 10), however, is jet black. A noticeable change in the texture of the fleece was also observed. It felt much dryer and coarser than prior to dyeing.

Oak Galls and Iron Water with a Woad Overdye

For this recipe, 7.09 g of scoured fleece were treated in the same method as the control and left to dry flat. The fibers appeared as black as the control. Next, they were soaked in a mixture of approximately 355 ml of equal parts warm water and urine for one hour prior to entering Woad Vat #1. The fibers were left to sit in Woad Vat #1 for 12 hours undisturbed. A test strip of white linen (See Figure 11) was also placed in the vat, so that I would be able to clearly see the strength of the dye. The fibers were gently removed and strained into another bucket to avoid introducing extra oxygen into the vat. Although there was a slight colour change on the test linen, the dye still seemed too weak. I opted to add 10 g more of woad that had been soaked in a warm solution of water, urine and the drips from squeezing out the fleece from the dye bath for one hour. The fleece and linen were then returned to the woad vat for an additional two hours.

The test linen did become darker and very light blue-green in colour, indicating that the vat is working however still fairly weak. The fleece was left to oxidize for one hour prior to rinsing in a vinegar and warm water solution and laid to dry flat. Once the fibers dried, the fleece (See Figure 12) was very black in colour, however a small amount of colour rinsed out during the rinsing process. It is of interest to note that the blue colour in the linen completely faded in sunlight in a matter of hours.

Oak Galls, Alum and Iron water with Woad Overdye

After 7.09 g of scoured fleece soaked in the oak gall bath for 24 hours, it was placed into a bath of alum solution prepared in the method previously detailed. The fibers were removed

after a 17-hour soak, rinsed thoroughly but gently in warm water and left to dry flat. When the fibers were completely dry, they were submerged in an iron water bath for 30 minutes. Again, the fleece was rinsed thoroughly with warm water and laid to dry flat. The Alum seemed to impede the absorption of the iron, and the batch appeared less dark than the control (See Figure 13).

The fleece was then soaked in approximately 175 ml each of warm filtered water and urine for an hour, before being placed into Woad Vat #1. The fleece was loosely placed into a mesh pouch and submerged in the dye bath for 12 hours. I removed the fibers, strained, and squeezed them out over another bucket and laid them to rest for one hour, before returning them to the vat for a second four-hour dip. After the second dip the fibers were rested and then rinsed with a mixture of 355 ml containing warm water and a small amount of white vinegar, and left to dry flat. When dry, the fleece was a very dark brownish black.

Alum Mordanted with Woad Dye and Post Mordanted with Oak Galls and Iron Water

The scoured fleece was submerged in the alum vat and left for 17 hours. The fibers were removed, rinsed in warm water, and spread out to dry flat. Prior to being dipped in Woad Vat #1, the fleece was soaked in a mixture of warm water and urine for one hour. The fleece was put into a mesh pouch and placed into the woad vat for a12-hour dip. The fleece was removed and rested in the same manner as the previous batches, then returned to the vat for a second dip of four hours. Upon removal from the vat, the fibers were rested and rinsed in the warmer water and vinegar solution and air dried. The fleece did not appear to have changed much in colour.

Oak galls were then dissolved in warm water and a tannin bath was prepared using the method described in Section 5.1.3. The fleece was added to this bath and left to soak for 24 hours before removing and rinsing well with warm water. The fibers were then submerged in an iron water bath for thirty minutes, removed, rinsed with warm water, separated and left to dry flat. After drying, this textile was the darkest black and substantially softer than most others.

Sample Retest with Woad Vat #3

This variant (See Figure 14) was retested using the contents of Woad Vat #3. Initial tests showed that it was one of two variants with excellent results, warranting a retest with a better woad vat. After consulting with several other dyers, the retested sample was first dyed with woad, and then alum mordanted, because an alum pre-mordant could impede the indigotin in the woad from bonding properly. I opted to dilute the iron water solution 1-1 with filtered water as it was more concentrated than in the first test. Additionally, 113.4 g of fleece was used this time, as I planned to spin most of the sample for wash tests.

In the retest, a shorter dip duration was used, in addition to more dips, to allow the color to build more. Extended period dips did not help build up the color as well as a larger number of short dips. The fleece was distinctly blued after an initial dip of 15 minutes, and two subsequent five-minute dips in Woad Vat #3. The blue was most apparent on the lighter-coloured tips of the fleece, which for future tests will be removed to provide consistent colour. A test strip of unbleached linen turned robin's egg blue in colour. The dye was not worked into the fleece as well as it could have been during submersions and was not rinsed in between dips after the 15-minute exposures. It is probable that the colour could have been darker if these methods were applied, and or if there was a higher concentration of extracted woad used in the vat.

An alum mordant was applied in the same method as used previously, followed by a tannin bath in oak galls, and post mordanted with the iron water solution for thirty minutes. The sample was rinsed three times in warm water and then swirled through a vinegar and water soak to help set the dye. The fleece remained very black and soft when dried, however, the fibers did seem somewhat more brittle than the undyed fleece (See Figure 15).

Woad Dye and Post Mordanted with Oak Galls and Iron Water

For the last variation, 7.09 g of scoured fleece was placed into the bath of warm water and urine for one hour, prior to being placed in the woad vat in a mesh pouch. The fibers were left in the vat for 12 hours, before being removed and laid to rest. After resting for one hour, the fleece was returned to the woad vat for the second four-hour dip. The samples were left to air dry flat after rinsing thoroughly with warm water and white vinegar. The chocolate brown fleece did not appear to change in colour at this point.

The dried fleece was then submerged in the tannin bath for 24 hours, before being rinsed and soaked in the iron water bath for 30 minutes. I removed the fibers, rinsed, straightened and left them to dry. When dried, this sample (See Figure 16) was extremely dark black, and remained quite soft.

Woad Vat #3 Retest

This variant was also subjected to retesting. A 113.4 g sample of scoured fleece was dyed in the woad vat in the same manner as the previous variant (See Section 5.4.4a). No alum treatment was applied to this sample, and it was over dyed with first a 24-hour oak gall bath, and finally, a 30-minute dip in the diluted iron water solution. The fleece remained jet black and soft throughout the rinsing and drying process.

Testing and Results

Appearance Prior to Washing

Prior to washing the control, the samples overdyed with oak galls and then iron water were indeed a deep black in colour, while the other samples still had a brownish hue to them. The control sample, oak galls, iron water with woad overdye, and the oak galls, alum, iron water and woad samples were more of a very dark brown that appeared black under certain lightings, however they were distinctly more brown than the other samples taken. The retested samples using Woad Vat #3 were a deep black without a brown hue. It seems that the use of urine also adds a level of protection to the fibers and ability to bond with pigments that is not achieved with thiox alone. This theory would require additional testing to substantiate.

Wash Fastness Test

In order to test the wash fastness of the fibers tested, two thirds of each of the original samples were hand washed individually with castile soap and warm water. Castile soap, made from plant-based oils, was available from around 800 CE (Routh, et al., 1996), however as an imported item it would be quite expensive. The average home laundress would have likely used combinations of stale urine and lye, made from hardwood ash, to wash and remove stains from clothing. (Rawcliffe, 2009, pp.153-154) After stitching a wool garment they were often spot washed and sprayed with alcohol based solutions containing fragranced extracts and oils. Full washing, particularly of outer garments was probably done seasonally or only as needed.

Although wool is washed less frequently than linen or silk, it is important that freshly dyed textiles are washed to remove any residual chemicals or unfixed dyes. I filled a bucket with warm water and a little Bronner's lavender scented castile soap. Due to the smells lingering in the textiles, it is possible that herbs and flowers could be added to help remove unwanted odors. Using very little agitation to avoid felting the fibers, I swished and worked the soapy water into all the fibers, and left them to soak for thirty minutes. The bucket was drained, fibers squeezed out and then refilled with warm water. The fleece was swished around in the rinse water before it was dumped out and the fibers were run under running water for a few seconds. After washing, the fibers were spread out on labeled cardboard and placed in the sun to dry (See Figure 17).

Minimal fading resulted from the wash process. Two variants, both overdyed with oak galls and iron water, remained extremely jet black after washing, while the others were more of a dark brownish-black. Both samples overdyed with oak galls and iron water were softer than the other samples. The linen dyed remarkably black and stayed as such after washing. I did not expect a bleached white linen sample to accept the dyes so well. Washing the woad dyed linen showed the weakness of the dye. The small amount of colour in the textile seemed to run out, resulting in an off-white linen with a grayish hue.

Woad Vat #3 Retest Samples

The retested samples were subjected to more in-depth wash testing. Each sample was divided into three equal sections after being spun and plied (See Figure 18 and Section 6.2.2 for details on this process). One section was washed using warm water and castile soap in the same method as used in Section 6.2. The second section was washed with warm water, grated lye soap, and white vinegar, while the third was left as an unwashed control. Lye based soaps were used more frequently throughout history due to their inexpensive nature and efficacy. Castile soaps are generally more gentle, however, would have been more expensive and less accessible to the average consumer.

The samples that were washed in castile soap had minimal fading and remained fairly similar in texture to their unwashed counterparts. The sample treated with alum did unravel somewhat in the wash process, while the other had little change in the twist of the fibers. The castile soap proved quite gentle and caused no visible damage to the fibers.

The lye wash was prepared with four to six cups of warm water, a tablespoon of grated lye based soap with lavender added, and a tablespoon of white vinegar. Both samples to be tested were gently washed in the solution, squeezed out, and then rinsed in four to six cups of plain tap water. An additional rinse was required under running water, as soap residue did remain in the fibers after the initial rinse. A small amount of fading was apparent after washing in both samples. The alum treated sample was substantially unraveled and fuzzy. (See Figures 19 and 20)

Combing and Spinning Retest Samples

I opted to have the fleece samples spun and plied in order to allow for a more efficient wash test. Spinning is not a skill I am not proficient in, so I requested a more experienced spinner[2] to aid me. Prior to spinning, the samples were combed using single tooth combs in a method similar to what would have been used throughout Ireland and the British Isles. Combing fibers straightens them, and allows them to be spun more easily into strong worsted yarn/thread. After both samples were spun, the yarn from the woad, oak galls and iron water sample, was rewetted and left to hang extended with small pattern weights in order to set the spin and keep it from unraveling with future use and processing. The sample with alum added spun so poorly and had so much breakage already, I felt that setting the spin was not going to make much difference.

The sample of fleece treated with alum experienced a lot of fiber loss during the combing process, equating to approximately 75% of the original sample. Alum did seem to make the colour more fast, in that less dye rubbed off onto the hands of the comber and spinners. Spinning was extremely difficult, and the fibers kept breaking. Although the fibers seemed to be horrible for spinning and weaving, they were extremely soft and fluffy, and according to my spinner, seemed ideal for felting.

The sample that was not treated with alum combed out more easily, only resulting in about 25% wastage. The fibers spun easier and did not break. This variant is much better for weaving and created a great deal of yarn. There was some rubbing off of pigment onto the fingers of the spinner, much like one sees when dealing with new dark wash jeans. The dye easily washed off the hands, and did not result in a visible change in the hue of the fibers. (See Figure 21)

Lightfastness Exposure Test

Dyes often fade after being exposed to sunlight for long periods of time. A modern method used to test commercial textiles for lightfastness is called the blue wool standard scale test (Materials Technology Limited). This test compares fading on textiles over a 90-day period, with a blue wool swatch card, demonstrating eight degrees of fading. The exposed card and samples are compared to an unexposed card to determine the lightfastness of the textile. Due to time constraints, a 70-day blue wool standard lightfastness test was conducted, in place of the typical 90-day test.

Initial Tests

During the first series of testing in July, I did not have the time to do a long exposure test. However, in an effort to do a preliminary test, I divided the rinsed fibers in half and exposed one half of each variant to direct sunlight for durations of three and seven hours. The samples in the three-hour exposure were covered with two layers of brown packing paper and weighed down after the time frame elapsed. The exposed fleece was compared to the unexposed portions for each recipe. Very little fading was observed for any of the samples. (See Figure 22)

Long Term Lightfastness Test

In order to test the lightfastness, all samples to be tested were divided into two. One part of each was attached to a large board and labeled. The samples were covered loosely in a clear vinyl cover to keep rain off the textiles, and prevent moisture from building up under the protective layer. I chose the cheapest vinyl plastic I could obtain in hopes that it would not prevent UVA and UVB rays from reaching the fibers, but still provide them with some protection from the elements (See Figure 23). The board was left outside in partial sun, under an awning, for 70 days. Due to unforeseen time constraints, which resulted from issues with the woad vats, I was unable to perform the typical 90-day test.

The exposed samples were brought inside on the evening of the 70th day for examination. Unexposed samples of each variant were attached to the board and then compared (See Figure 24). Using the blue wool standard cards, I compared the amount of fading in each sample with the card scale. The samples proved adequately lightfast for textiles (See Table 2). Apparel items should have a lightfastness score of at least four for modern commercial usage

(Materials Technology, Ltd). With the exception of the woad only on linen and the woad with alum sample from Woad Vat #3, all samples scored a four or five on the blue standard scale. This score implies that some amount of fading will occur over time but will remain bright for a significant amount of time with proper wash care. The exposures indicate that the use of oak galls and iron water with woad creates a more lightfast pigment than woad alone.

Sample	Blue Scale Rating	Light Fastness	Scale of Blue Blackness (lightest to darkest)
Bleached Linen- Oak Galls and Iron Water	4	Fair (Impermanent)	5
Bleached Linen- Woad	2	Poor (Fugitive)	NA
Unhleached Line- Woad	3	Poor (Fugitive)	NA
Wool- Oak Galls and iron Water	4	Fair (Impermanent)	4
Wool- Woad, Oak Galls and lron Water (Vat I)	5	Fair (impermanent)	6 Darkest (Very Black)
Wool-Alum, Woad, Oak Galls and Iron Water (Vat 1)	4	Fair (impermanent)	3
Wool- Woad., Oak Galls and iron Water (Vat 3)	5	Fair (impermanent)	2
Wool- Woad, Alum, Oak Galls and Iron Water (Vat 3)	3	Poor (Fugitive)	1 Lightest (Distinctly Dark Brownish Black)

TABLE 2. LIGHTFASTNESS TEST RESULTS

Margins of Error and Probable Causes

I had several issues with my first two woad vats. It was ultimately determined by dehydrating Woad Vat #2 for two weeks (See Appendix 1), that there were negligible amounts of extracted indigotin in the vat. Thus, I concluded that it was not possible to extract much pigment from that particular batch of woad. It is probable that the urine was either too concentrated or not enough, and that too much oxygen was introduced into the first vat while stirring and massaging out the woad bundle. It is also possible that urine was not stale enough to begin with and had not built up enough ammonia. I further suspect that too many oats were introduced into Vat #2 in an attempt to speed up fermentation (See Appendix 1) and accelerated the rate of fermentation too quickly, which resulted in a very weak dye bath.

Woad Vat #3 had much better results as it used already extracted pigment from woad, ensuring that there was at least some in my vat. Given the increased amount of fleece used in the vat, it would have been better to use greater amounts of the powdered woad, as the indigotin content in the vat was quickly spent. A larger amount of extracted woad powder

would have allowed for more concentrated and more frequent dips, likely resulting in darker blue hues.

As almost four months passed between making my iron water and using it in the first batch, I suspect that the iron content in the retested samples were significantly different. I hypothesized that there would be a much higher iron content and opted to dilute it in a 1:1 ratio. Given that the final result was slightly more brown, I suspect it may have been diluted too much. I do know that there would be a maximum amount of extracted iron from the steel wool, but I had not thought to research a great deal into the ways in which to ascertain the maximum amount that could have been extracted. Future experiments using iron need to take into account the actual iron content used.

It is possible to dye a true black without the use of logwood or other imported dyestuff. The Irish and Scottish have several known methods to achieve black textiles. Woad base dyeing with oak galls and iron water on top is very effective and seems to limit some of the corrosive effects of the iron. In France, during the later 15th and 16th centuries, a ban was placed on iron-tannin dyes for wool, with the exception of those first dyed in indigo or woad as it limits the amount of iron needed in the process (Kirby, 2022). Locally sourced natural mordants and dyes, such as yellow flag iris and meadowsweet were used to create black into the 20th century, demonstrating their longevity in use, and the cultural preference towards the results.

More research is needed into the scale of recipes available, their wash and lightfastness, and overall durability. In the future, I would like to experiment more with other dyestuffs capable of producing black, particularly yellow flag iris and meadowsweet. Both plants were used in Ireland and Scotland by home dyers into the 20th century. Recreating several different recipes and testing them on multiple textiles would provide a wider scope of what is possible, and probable historically. Fabric produced from the dyed fibers could be made into garments and subjected to more in-depth wash, lightfast, and durability tests. Very little research has been done regarding earlier period textiles in Ireland and Scotland and warrants a great deal more study.

1 Wendy Freeman Marsh is known in the Society for Creative Anachronism, as Mistress Willoc Mac Muiredaig, who is known for her extensive experience in natural dyeing. Mistress Willoc provided detailed information regarding methodology and troubleshooting throughout the project.

2 Magnifica Biatrichi Malatesta Canzionari di Palermo, as she is known in the Society for Creative Anachronism, has expertise in spinning and weaving. She assisted with the spinning and plying of the samples.

Keywords dyeing
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Appendix 1

Woe is My Woad Vat

Several weeks into this project I learned that fermentation woad vats are some of the most difficult dyeing methods. I was informed that I picked an extremely tricky project for my first foray into the world of natural dyeing. I utilized the experience of two experienced natural dyers, did extensive research, and hoped for the best.

Inevitably, many things still went wrong. I had increasing difficulty getting a working woad vat in order. I spent nearly three months, and tried two different historical methods for creating a woad fermentation with almost no success.

Troubleshooting Woad Vat #1

I initially underestimated the amount of time needed to prepare the vat for dyeing. After a week and a half of waiting, I began to run short on time. In order to speed up the process, I fed the vat a pureed mixture of two tablespoons of quick oats, mixed with 59 ml of boiling water, 118 ml of fresh urine, and 1.23 ml of washing soda. The total pH of the mixture was 11. The mixture was added to the woad vat and gently stirred, in hopes of speeding up the process of fermentation and reduction.

Fermentation vats were fed as needed in similar methods throughout the Middle Ages and prior. Recipes often call for the addition of bran or madder (Liles, 1990, p.84; Stasinska, 2020). Bran contains fructose which helps aid the fermentation process required to successfully reduce woad into extracted and soluble white indigo (Liles, 1990, pp.79-81). Quick oats also have a fructose coating and are very similar in chemical make up to oat bran. As quick oats were readily available to me, I opted to use them in place of oat bran.

After adding the oat mixture, I let the vat continue to ferment for four more days. By day 15, the vat was very yellow in colour and the smell had become much more fermented, similar to kombucha. I conducted a 15-minute test dip on bleached white linen. Although a small amount of pigment seemed to impart on the cloth, the vat was far too weak.

The process was still taking longer than it should have, so I added an additional puree of one teaspoon of oats mixed with 59 ml water, 59 ml of fresh urine, and 2.46 ml of washing soda on day 16. The pH remained a steady 10. On day 16, after additional oats had been added the day before, and more woad was added in the morning, the smell began to become sour and the colour of the vat became brown. At this point, I was out of time, and needed to dye whether or not the vat was ready.

The day after dyeing with the woad vat, the sour smell became more pungent, but the less so the following day, with visible film forming on top of the solution. I hoped that by topping off the vat with more urine, the vat could be salvaged and used in the future. Unfortunately after another week of troubleshooting, the woad vat was beyond my scope of understanding to repair.

The time constraints afforded to me did not allow the vat to ferment for more than 16 days. In future, urine collections will be from the first urine of the day and left to stale for at least one week. I would also plan to allow a minimum of three weeks for the vat to reduce and ferment. More care should have been taken to avoid introducing oxygen into the vat and a detailed record of the temperature in the vat should have been kept.

Vat #2 Methodology and Findings

In October, a second woad vat was started using the remaining freeze-dried woad purchased for Woad Vat #1. During this test, I opted to use a different common historical method using bran and madder roots to help aid fermentation and reduction. Madder and bran were frequently used in woad fermentation vats (Liles, 1990; Hartle, et al., 2015).

1. Approximately 1.89 l of urine was collected and fermented in an airtight jar for five days prior to preparing the dye vat.
2. 28.4 g of freeze dried woad was rehydrated in enough water of 48.9 degrees Celsius to completely cover the woad. The woad was loosely contained within a synthetic cloth sachet for four hours.
3. The woad and water mixture was poured into a gallon sized glass jar, along with the 1.89 l of fermented urine. The solution was left to sit, covered in the sun for a day.
4. Approximately three gallons of water was boiled and cooled to 71 degrees Celsius. Washing soda in the amount of 28.4 g was added and stirred to dissolve.
5. After cooling water to 57.2 degrees Celsius, 28.4 g of dried and crushed madder roots with 14.2 g of wheat bran were placed in a sachet, added to the water and stirred.
6. The woad solution in the glass jar was slowly added to the madder and bran infused water in a 18.9 l plastic bucket. The initial pH was 11.
7. The bucket was placed inside a 30.3 l steel pot with cut grass and leaves for insulation surrounding it, and placed with the lid on, in the sun.
8. The pH and temperature of the vat were logged daily to ensure that the pH remained between nine and 10, and that temperatures above 26.7 degrees Celsius were maintained. The sachets of woad and madder were gently massaged under the surface of the vat daily. (Liles, 1990, p.91)

After five days, significant bubbles and scum formed in the vat and the sachets were halfway reduced. The pH lowered to 8.5, so 4.9 g of slaked lime was gently stirred in to minimize surface disturbances. The pH immediately increased to 10. On day six, the pH lowered to nine, and the woad was three quarters reduced. Bubbles and scum remained and the colour in the vat began to lighten from reddish to more yellow. The woad was completely reduced by day nine. The vat had a thin layer of blue scum and was a greenish yellow underneath. A 15-minute test dip on unbleached linen was performed after soaking the linen in warm, fresh urine for one hour. Little to no change in colour was noted. An additional 15-minute dip resulted in very little change.

The vat began to darken on the 10th day, so 15 g of baking soda was added to 14.8 ml of water and gently incorporated into the vat. The pH raised from nine to 10. By morning, some scum had returned and the bluish green colour of the vat had lightened slightly. The vat was gently stirred from the bottom and left to rest for a day.

External temperatures began to drop the evening of the 12th day, so the vat was brought indoors. Temperatures in the vat dropped to 21 degrees Celsius by the following morning and the pH was again nine. The colour had turned back to blue and I observed that the vat may have been dead.

It is possible to revive dead vats, so I had hoped all was not lost. The following morning, a self-heating cat mat was placed under the pot, towels wrapped around it, and on top. I gently raised the temperature of the vat from 18 to 37.8 degrees Celsius by submerging glass jars of boiling water in it (See Figure 25). I whisked the vat vigorously until froth formed, before adding 40 oz of fermented room temperature urine (See Figure 26). The vat was whisked again for 30 seconds. I returned the hot water bottles to the vat to help maintain the temperature, put the lid on and draped a light blanket over the top, and left it to rest until morning.

A final test dip was conducted the following day before it was suggested that there was not enough extractable pigment in the woad itself. The test dip showed no colour change. In order to dehydrate the vat, it was poured into four shallow pans, and left in a sunny area of a covered patio for two weeks. If there was substantial extracted indigo in the vat, a blue crystalline substance should have been found in the dried pans. Only reddish powder from the madder remained (See Figure 27).

What's Wrong with my Woad?

Confused by the absence of extracted pigment, I contacted the seller of the woad used. I was informed that it had been processed using a freeze dry method, which produced decent results for her. She was not aware of anyone having issues dyeing with the woad from that batch. I was aware that I had not found any sources for the use of dried woad in dyeing and

began to research more. I learned that in drying woad, it makes extracting pigment almost impossible. I suspected that freeze drying would have impacted the woad similarly.

According to a study done by Oberthur, et al. (2004) drying woad completely alters the metabolic leaf pattern. The study showed that "the bands of indigo precursors [in dried woad] had almost completely disappeared without a marked increase in indigo and indirubin (data not shown). Shock-frozen leaves contained only little isatan B (Rf 0.76) and indican (Rf 0.71) (Oberthur, et al., 2004, p.176). This means that the compounds in the woad needed to extract blue colour are in fact, destroyed completely by drying and greatly reduced when freeze dried. I propose that the seller had not dyed with woad alone, but had also used indigo in her vats. By adding indigo, she would have increased the compounds needed to extract blue dye. The woad used for both Woad Vat #1 and #2 was not suitable for textile dyeing on its own, despite being marketed for that use.

Woad Vat #3

It quickly became apparent that I needed a new source of woad suitable for dyeing. Due to woad being out of season, there was a shortage of availability. I utilized searches in the United States, Ireland, Scotland and England with little, to no luck in finding fermented or couched woad balls. I chose to look for extracted woad powder as an alternative to historical methods. I needed to run the experiment on samples that were actually blued with woad pigment. Extracted pigment proved easier to obtain and was promptly purchased. The fleece dyed with this vat was visibly blued, and unbleached linen turned light robin's egg blue in colour, indicating the success of the vat.

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FIG 1. RAW FLEECE FOR PROCESSING. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 2. STEEL WOOL HARDWARE GRADE PADS ALONGSIDE STEEL WOOL SCRUB BALLS. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 3. IRON WATER JARS WITH STEEL WOOL STILL INSIDE. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 4. DRIED AND CRUSHED WOAD LEAVES. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 5. DAY 15’S WOAD VAT CONTENTS. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

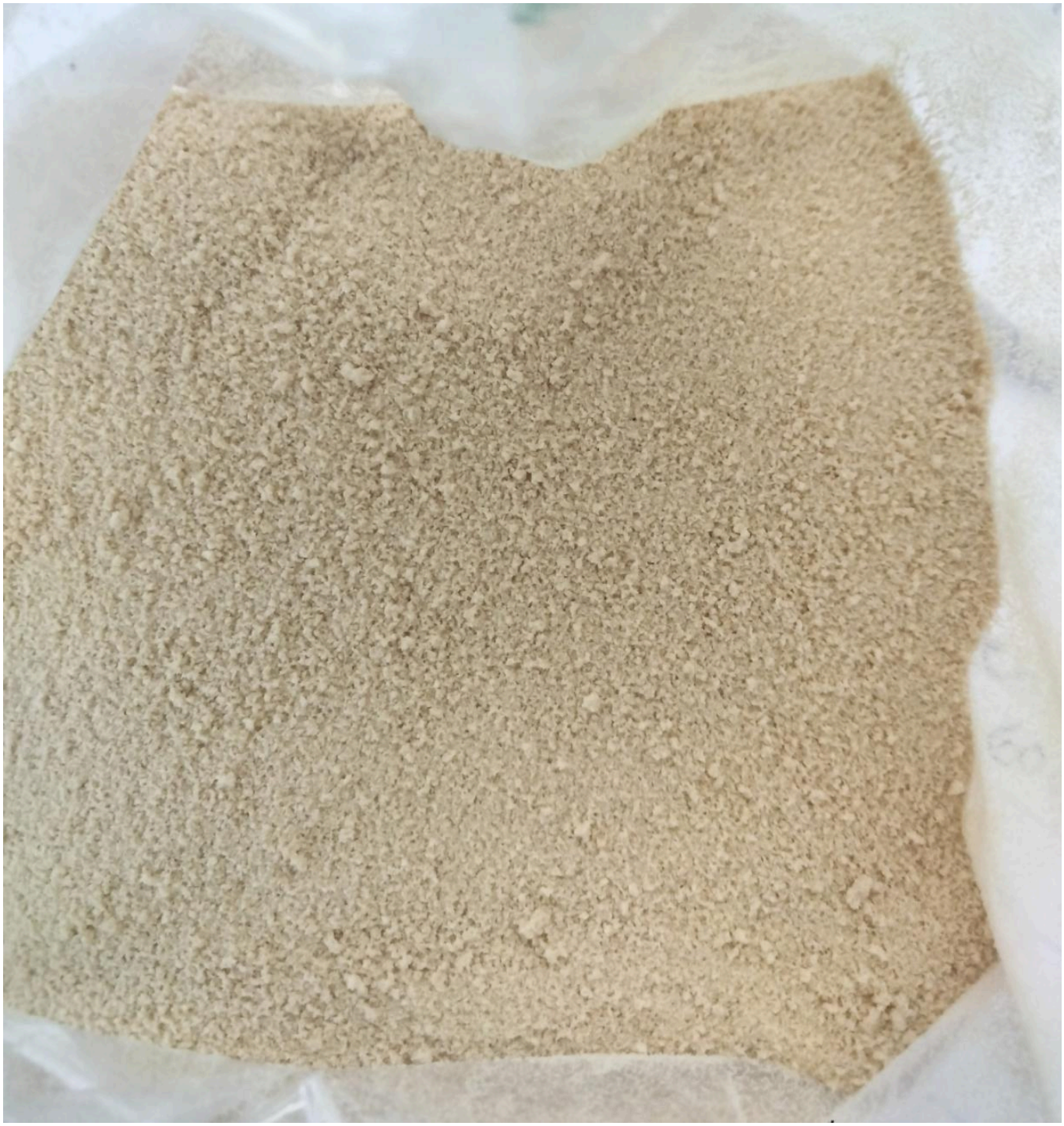

FIG 6. POWDERED OAK GALLS. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 7. FLEECE BEING SCOURED. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 8. FRESHLY SCOURED FLEECE DRYING. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 9. OAK GALL AND IRON WATER DYED FLEECE. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

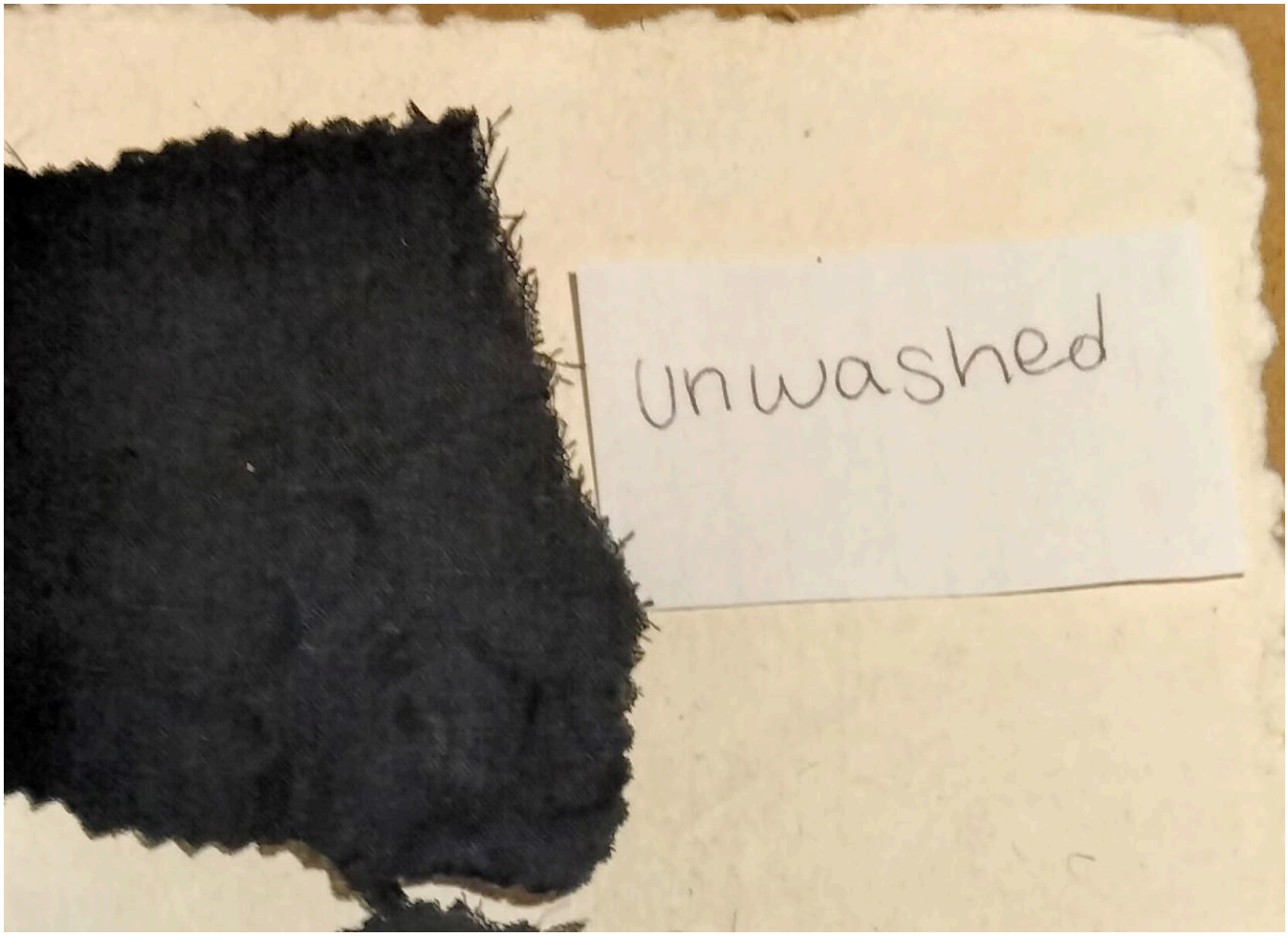

FIG 10. BLEACHED WHITE LINEN DYED WITH OAK GALLS AND IRON WATER. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 11. LINEN AFTER 12 HOUR WOAD DIP AND SECONDARY TWO HOUR DIP. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 12. OAK GALLS AND IRON WATER WITH WOAD OVERDYE. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 13. OAK GALLS, ALUM, IRON WATER AND WOAD OVERDYE. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 14. OXIDIZING SAMPLES OF FLEECE AND UNBLEACHED LINEN FROM WOAD VAT #3. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

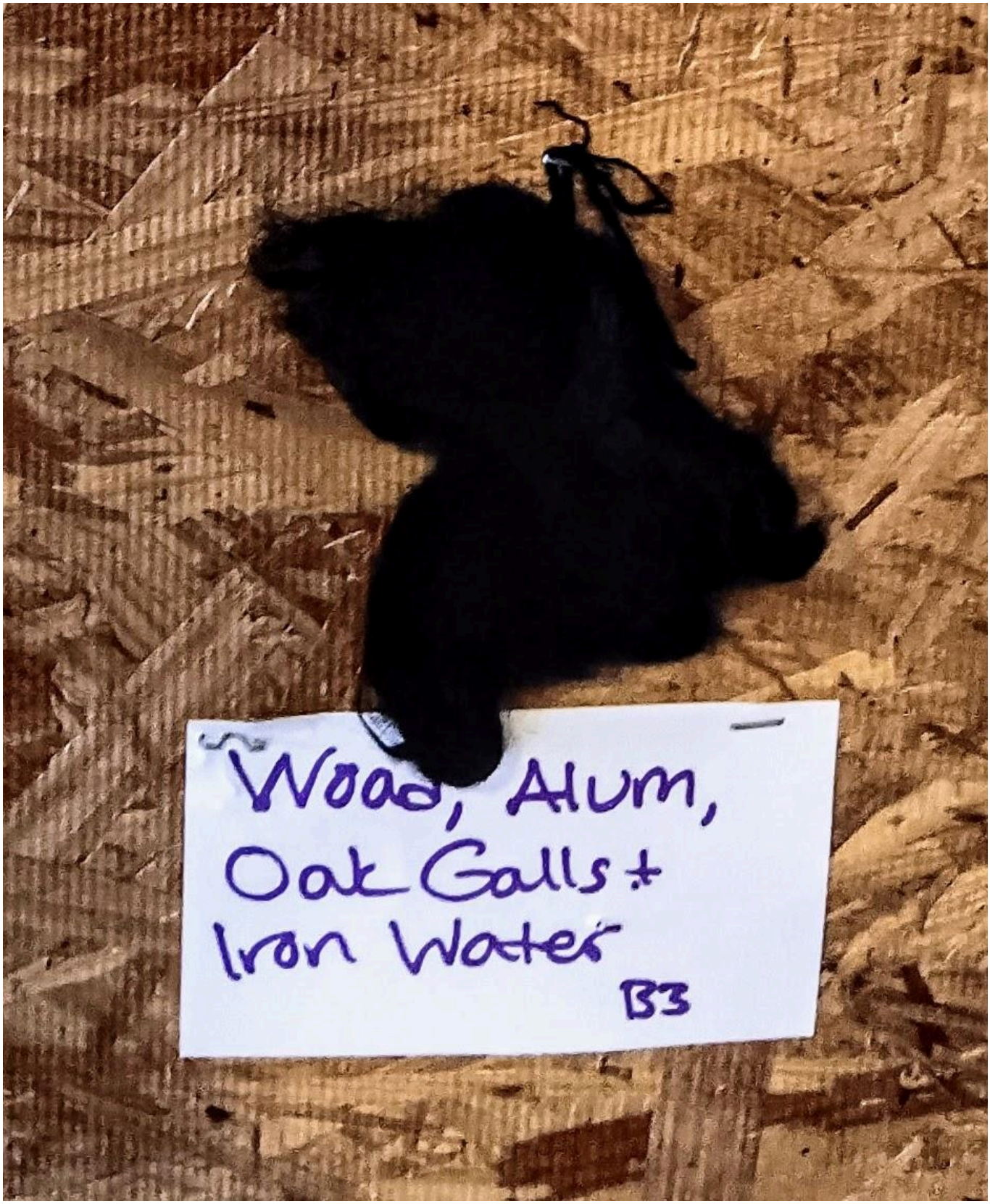

FIG 15. WOAD VAT #3, ALUM, OAK GALLS AND IRON WATER SAMPLE. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 16. WOAD VAT #3, OAK GALLS AND IRON WATER. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 17. AMPLES FOR PRELIMINARY LIGHTFASTNESS TEST PRIOR TO EXPOSURE. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

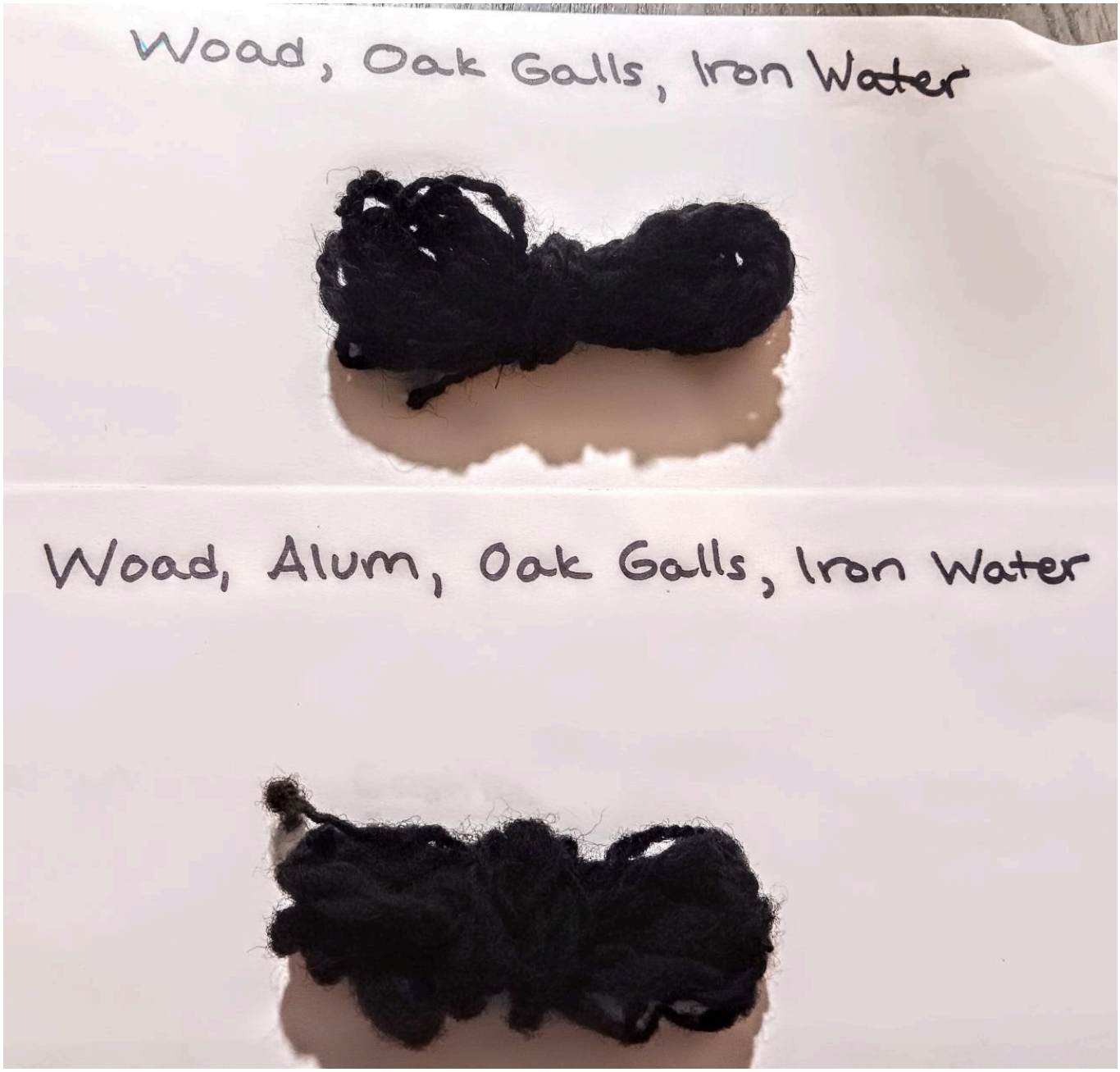

FIG 18. UNWASHED SAMPLES. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 19. WASH SAMPLES. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 20. WASH SAMPLES TREATED WITH ALUM. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 21. WASTAGE FROM COMBING PROCESS. LEFT: WOAD, OAK GALLS AND IRON WATER; RIGHT: WOAD, ALUM, OAK GALLS, AND IRON WATER. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 22. SIDE BY SIDE COMPARISON OF SAMPLES. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 23. EXPOSURE BOARD SAMPLES PRIOR TO EXPOSURE. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 24. EXPOSURE TEST RESULTS. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 25. ATTEMPT TO REHEAT AND REVIVE WOAD VAT #2. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 26. FORTH IN VAT AFTER WHISKING. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.

FIG 27. CONTENTS OF WOAD VAT #2 AFTER DEHYDRATING. PHOTO BY ASHLEY STILLWELL-HASAN, 2023.