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Abstract

*Banana (*Musa spp. *) plants have long been valued for their many usages, such as for fruit or for cooking purposes. However, a specific species of the banana plant (*Musa textilis*) has been utilized in the Philippines, its native region, to produce strong and durable textiles. Abaca, as it is commonly known in the country, is mainly woven on backstrap and floor looms in village-based communities nationwide. It can then be used to make bags, clothes, sandals, and more. This paper summarizes textile weaving and usage within indigenous groups in the southern island of Mindanao of the Philippines, as well as an analysis of the dyes used for these textiles via photospectrometry. Photospectrometry uses light to analyze various chemical compounds. This method will be used to determine patterns in plant and soil dyes on abaca fiber textiles from Mindanao, the Philippines, within the visible wavelength (350 nm-810 nm). For some indigenous groups, abaca is treated with beeswax (*Cera alba*). Photospectrometry will be used to assess color (also known as chromatophores), natural vs. commercial dyes, luster of waxed vs. unwaxed fiber (hydrocarbons), and other properties. This research can be used to better understand the significance of specific weaving, dyeing, and other techniques on abaca within Filipino culture. The compounds of natural and commercial dyes can also be understood from a chemical standpoint by examining textile dyes and wax through photospectrometry.*

1. Introduction

Southeast Asia is known for its vast and complex techniques of textile production. From silk to cotton, many different types of fibers are utilized for the making of cloth. One that is unique to the region is abaca fiber, which is derived from the *Musa textilis* banana plant. The cultivation of abaca relies upon the utilization of its fiber taken from the "trunk" or petiole of the "banana tree" (Hamilton & Milgram, 2007). Textiles made with abaca can be dyed, especially through natural dyes such as plant leaves, flowers, and even mud. More common textile fibers like cotton are known to use widespread sources of dye, such as the *Indigofera tinctoria* indigo plant, purple dye from *Bolinus brandaris* mollusks, and red dye from the *Dactylopius coccus* insect (Ferreira et. al., 2004). It is not clear if these other dyes have been used in abaca in Mindanao. Color is derived from dyes through the presence of chromatophores, which are cells containing pigment that absorb light at specific wavelengths within the visible spectrum, which ranges from about 380 nanometers to 750 nanometers. The wavelength of absorbance determines the color of the pigment, but over time, these cells tend to oxidize and lose certain organic groups within the molecule, causing the reflected color to change as well. Additionally, wax provides changes to the perceived reflection of the chromatophore, in which waxed textiles not only appear more lustrous, but differ in the amount of light absorbed and reflected. This change comes from the chemical composition of wax, consisting of various chains of hydrocarbons that reflect visible light. The objective of this research is not only to examine how abaca is utilized and dyed in various regions of the Philippines, but also to examine the reflectance of natural versus commercial dyes on various abaca textiles, as well as differences in waxed versus unwaxed textiles within the visible light spectrum.

The dyeing of textiles goes as far back as the production of textiles themselves, with natural dyes being the key source of pigment up until recently. Significance was given to the color of textiles, as the color of clothing would represent levels of status and power. Royalty, such as kings and priests, would set themselves apart from others by wearing colors that portrayed regality, such as purple or red. In addition, colored textiles would provide a means of diversification of individuals within a society, allowing for creativity to flourish and for communities to develop a common goal of producing desirable textiles. Botanical dyes were the most available sources, but small organisms were used as well (Ferreira et. al., 2004). There are several qualities to an ideal dye, in which it not only must have a noticeable pigment, but the color should not fade when the textile is washed, or exposed to sunlight and air. For example, dye from the indigo plant was popular because it was compatible with most natural fibers, and mordants were used as well to ensure that the dye stayed fixed onto the textile. In the Mindanao context, beeswax was sometimes utilized to provide a luster to textiles of various colors. This paper aims to look at the differences in reflectance due to wax and color, and how it provides information about the material of the cloth.

In Southeast Asia, abaca is traditionally utilized for textiles in the Philippines, where it can be woven through many different techniques and dyed through various sources. One of the main regions is the Bicol region, located in the island of Luzon in the Philippines. New DNA analysis shows all abaca plant species originated from the Bicol region, and has since had a large impact on the material culture of the area (Orlex et. al., 2020). The fiber can be used to make anything from rope and handbags to hand-woven fabrics, such as textiles and sandals. The handicraft industry in the area arose from the earlier abundance of abaca, in which the locals took advantage of the durability and versatility of the fiber to create a wide range of products (Owen, 1984). The industry can be described as a type of cottage industry, since the main source of labor comes from work done directly at home, and is mostly present in rural areas. The advantage to a cottage industry is that it binds the community towards a common purpose, especially in an agricultural economy. In this way, weaving is expressive of their identity and a means of providing works of original art, as each piece is different from the other, and can have different symbols woven into various textiles that tell a story. A specific type of hand-woven fabric is sinamay, made through abaca fiber that is stripped from the stem of the plant and is then bleached in the sun, making it white and soft enough to construct a loose tabby weave. This can then be used to make shawls, hats, and gift bags (*Weaving the Islands*, 2022).

1.1. Indigenous groups who produce abaca ikat cloth

Certain indigenous groups in the Philippines produce unique textiles from abaca. One such group are the T'boli, native to the South Cotabato province on the island of Mindanao. The T'boli are farmers whose homelands are within the highlands of Mindanao, but they also turn to foraging forest produce for food as well (Casal, 1978; Joshua Project, 2023). Aligned with the material culture of the Philippines, the T'boli have some of the most colorful textiles and costumes, which they utilize for ceremonies and pass down through generations. Weavers use natural materials to reflect the belief that the natural environment is sacred, as individual aspects of nature could contain a spirit that connects the mortal world to the spiritual world. This is why the T'boli are often referred to as "dreamweavers," who weave a specific textile from abaca called *t'nalak* (Hernani et. al., 2021). T'nalak contains images originating from dreams, and is mainly dyed with black, brown, and red dyes through a technique called ikat. Ikat is a combined dyeing and weaving technique that involves dyeing specific threads with a waterproof material before submerging into a dye bath. The areas bound with the waterproof material are not dyed, and allows for selective dyeing of specific thread through several rounds of dye baths before weaving. This is also known as a tie-dye resist technique, and ikat can be separated into warp, weft, or double ikats. Warp ikats consist of vertical color changes in the cloth, whereas weft ikat is identified by horizontal changes in color. Double ikat is the most complicated technique because it consists of both horizontal and vertical color transitions, and appears the same on both sides of the fabric, although the T'boli and other groups in Mindanao only practice warp ikat (Fotheringham, 2019). This method is performed by skilled weavers, and the fiber must be perfectly dyed. One source of black dye for the T'boli is *Diospyros nitida* (Quizon & Magpayo-Bagajo, 2021), a species of trees commonly found within Southeast Asia with broad leaves from which the dye can be extracted. Red dye is procured from the roots of *Morinda citrifolia*, a type of mulberry plant that has a wide range of medicinal uses. Black and red dye can be extracted by crushing up the leaves and roots, respectively. Natural dyes are good resources for the dyeing of textiles because they are widely accessible and adhere well to the fiber. Abaca textiles made by the T'boli are able to last due to both the durability of the abaca fiber and the lasting pigment of the natural dyes.

Another indigenous group that makes use of abaca textiles are the Mandaya, located in the mountain ranges on the island of Mindanao in areas such as Davao Oriental, Mount Kampalili, and many more. The history of the Mandaya has been broadly linked to theories of the peopling of the Philippines by American anthropologists during colonial times. Since then, they have had conflicts with other indigenous groups, and been the target for colonization by Spaniards. Like the T'boli, the Mandaya have traditionally practiced indigenous religions prior to conversion, consistently retelling stories of the sun, moon, and stars, and how the interactions between nature gave rise to humans (Cole, 1913). This relates to the Mandaya's oral traditions of passing down myths over generations, which then transmits values of the community and pieces of their history as well (Yengoyan, 1985). Upon contact with the Spaniards, several members converted to Christianity and decided to settle into villages, but many retained the traditional faith. Like the T'boli, the Mandaya are farmers, who practice a specific type of farming called swidden agriculture. This method involves cyclic farming, in which there are periods of clearing the fields by slashing or burning the forest, thereby allowing a period for new crops to thrive. Recently, the Mandaya have had enough of a surplus of abaca fiber to sell as a cash crop, and historically have been known to exchange ikat cloth with Agusan Manobo neighbors (Quizon & Magpayo-Bagajo, 2021). The Mandaya are known for their ikat patterns in abaca, especially with highly revered crocodile motifs. The Mandaya also use *D. nitida* and *M. citrifolia* as natural dyes, similar to the T'boli, but it is also believed that they use mud as a natural source of black dye as well (Quizon & Magpayo-Bagajo, 2021). This technique is used to make a textile called *dagmay*, in which abaca yarn is dyed with tannin and then soaked into iron-rich mud for days, allowing enough time for the mud to penetrate and adhere to the yarn (Garcia, 2019). The fiber is then woven into patterns that reflect Mandaya folklore, and can be used to create skirts for women, as well as blankets. In this way, the Mandaya tie their belief system on the interactions between the natural environment and humans into the textiles they weave.

Another indigenous group are the Bagobo, who reside in the mountainous ranges on the west coast of the Davao Gulf, and are one of the biggest indigenous tribes in Mindanao. Historically, there is not much mention of this tribe, but there are several origin stories from the Bagobo themselves. For one, tribal historians relayed how the origins of the human race began from the children of a man and his wife, Toglai and Toglibon, who later on died and became spirits in the sky (Cole, 1913). This depicts why the Bagobo revere spirits, and have stayed fast to their beliefs for generations, as not every tree or every river contain a spirit, but spirits can inhabit specific trees or specific bodies of water (Benedict, 1916). The Bagobo, similar to the other tribes of the Philippines, practiced indigenous religions prior to conversion. It is also possible that they have largely been influenced by other cultures diffusing into the region as well. For example, the Bagobo believe in nine heavens, with a god to rule over each of them, and several of the deities resemble Hindu gods (Benedict, 1916). This goes to show that the indigenous tribes are not completely isolated from the lowland, and in fact, have shared ideas and beliefs quite frequently. They practice agriculture, as well as hunt and fish, with rice being the chief crop grown in clearings on the sides of the mountain. The cultivation of rice is tied to the religious practices of the group (Benedict, 1916), and sacrifices are often made throughout daily life. Several ceremonies are held to honor spirits, and textiles are highly valued, especially for ceremonial purposes. *M. textilis* is dyed and woven into several garments, which is then embroidered with beads and other accessories (Cole, 1913). Like the other indigenous tribes, the Bagobo community in Davao del Sur utilize *M. citrifolia* and *D. nitida*, as well as other natural sources, to dye their textiles red and black, along with the typical ikat technique (Quizon & Magpayo-Bagajo, 2021). The weaving of the fiber is also indicative of gender and status. Clothes displaying the highest status are constructed into three panel tube skirts with some of the more difficult ikat patterns (Quizon, 1998), which is one of the textiles being observed for this study. For the Bagobo, beautiful abaca garments are regarded as their defining pride and joy (Hamilton & Milgram, 2007). In these ways, the Bagobo prize the textiles that they wear, and their clothes represent their connection to their culture and way of life.

2. Materials and Method

2.1. Photospectrometry samples

The textiles used for this study include various pieces from the Philippines that were loaned to the teaching collection of the Seton Hall Anthropological Material Culture Research Lab. The first is an unwaxed, undyed piece of fabric made from sinamay, commonly used in the Bicol region. The second is a waxed, ikat patterned, and cut piece from the T'boli made with red and black natural dyes. The third is an unwaxed loom-length (or uncut) textile made by the Mandaya with natural dyes also with an ikat pattern. The fourth is a waxed striped skirt made by the Bagobo that incorporates commercially sourced dye. The fifth and final textile is a Bagobo mother (*ine*) and child (*bata*) three-panel skirt that was waxed and made with natural dyes. All pieces date from the late 20th century to the early 2000's.

2.2. Equipment

The equipment used for the study consists of an Ocean Insight ST-VIS minispectrophotometer with 25 µm micron slit, along with a 20 Watt FHSA tungsten halogen lamp light source. An Ocean Insight reflection probe was utilized as well, with a diameter of 400 µm and length of 2 meters, and an RPH-1 reflection probe holder. A WS-1 diffuse reflectance standard was used, along with an OceanView spectroscopy software.

2.3. Method

The method involved placing the reflectance probe into the reflectance probe holder at a 90° an-

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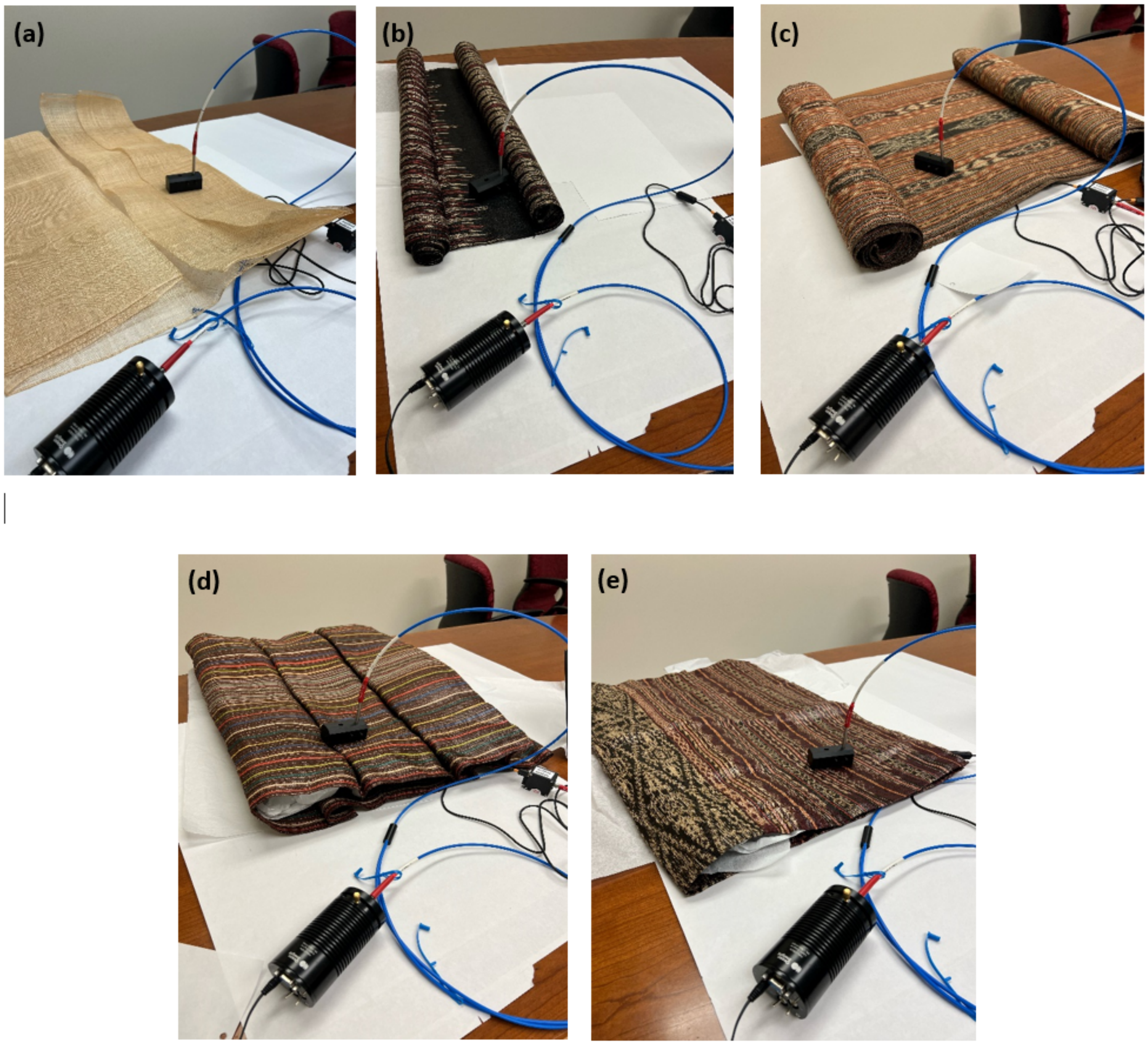

Figure 1. (a) Image of spectrophotometric method for analysis of sinamay; (b) Spectrophotometric method for analysis of T'boli cut piece; (c) Spectrophotometric method for analysis of Mandaya textile; (d) Spectrophotometric method for analysis of Bagobo striped skirt; (e) Spectrophotometric method for analysis of Bagobo mother (ine) and child (bata) three-panel skirt

gle directly on top of the textile being observed, as seen above. In order to improve specificity of the dyed thread analyzed, a piece of paper was used with a hole cut out the same size as the reflectance probe, allowing the probe to only measure the reflectance of dyes of one color. The lights were turned off as well to also improve specificity to the reflectance of the dye. The OceanView software was used with the method of color reflectance, with the automatic processing setting at "% reflectance." The spectrum from 400 nanometers to 800 nanometers within the visible wavelength was measured against % reflectance, with the automatic integration time set to 66 milliseconds, 20 scans to average, and a boxcar width of 5.

3. Results and Discussion

For this study, specific sections of the same color on various textile were observed, with a photospectrometer measuring the % reflectance of those colors. The dominant wavelength of each color was procured as well, which gives information towards the color's hue. Analyzing the dominant wavelength can also measure the accuracy of the photospectrometer by comparing the experimental value to the true value for that color. The dominant wavelengths for undyed fibers presenting as beige are accurate, since beige normally has a wavelength less than 600 nm. The wavelengths of the black dyes were not included, since black absorbs all light and reflects none: therefore, it does not transmit a wavelength. The red dyes were not very similar in values for dominant wavelength, and not quite as accurate, since red has a dominant wavelength of around 700 nm. In addition, blue and red are on opposite ends of the visible light spectrum, but the table shows that the red fiber for the three-panel skirt produced a wavelength similar to the one for the blue thread. This could be due to the fact that there are various hues to red, which could all yield separate wavelengths, producing an outlier. Furthermore, the experimental value for the wavelength of orange is accurate, since it normally yields a wavelength less than 600 nm. The wavelengths for the two different brown dyes are precise, as well as accurate. The actual dominant wavelength for yellow is around 570-580 nm, which the experimental value matches. The wavelength of green ranges up to 570 nm, and the value procured from this study is around that range (Volchko, 2018). Lastly, the dominant wavelength of blue is around 490 nm, and the experimental value was around the actual value. Additionally, the Bagobo two-panel striped skirt included commercial dye, which makes it more likely for the dominant wavelengths of these colors to match the true value, as they were synthetically produced. As most of the dominant wavelengths for each color were similar to the accurate values, it can be determined that the photospectrometer is an accurate instrument to measure reflectance.

Sinamay Tabby Weave (Unwaxed)	
Undyed Fiber (Beige)	578.8 nm
T'boli Ikat Cut Piece (Waxed)	
Undyed Fiber	581.8 nm
Red	623.4 nm
Mandaya Uncut Ikat (Unwaxed)	
Undyed Fiber	581.0 nm
Orange	598.7 nm
Brown	595.5 nm
Bagobo Two-Panel Striped Skirt (Waxed)	
Brown	599.1 nm
Yellow	583.0 nm
Green	584.1 nm
Blue	506.0 nm
Bagobo Three-Panel Striped Skirt (Waxed)	
Red	512.1 nm
Undyed Fiber	587.5 nm

Figure 2. Color of observed fiber per textile, along with the reported measurement of dominant wavelength (in nanometers).

In Figure 3, the reflectance curves of red dyes from two different textiles were compared. Both curves start off at the same reflectance at less than 10%, and then stay stagnant for a couple hundred nanometers before curving upwards. At 800 nm, the reflectance from the red dye from the Bagobo three panel skirt ends at 57%, while the red dye from the T'boli ends at 44%. As mentioned before, the different hues of red dye could explain the differences in the reflectance curves between the two. However, both dyes display the same

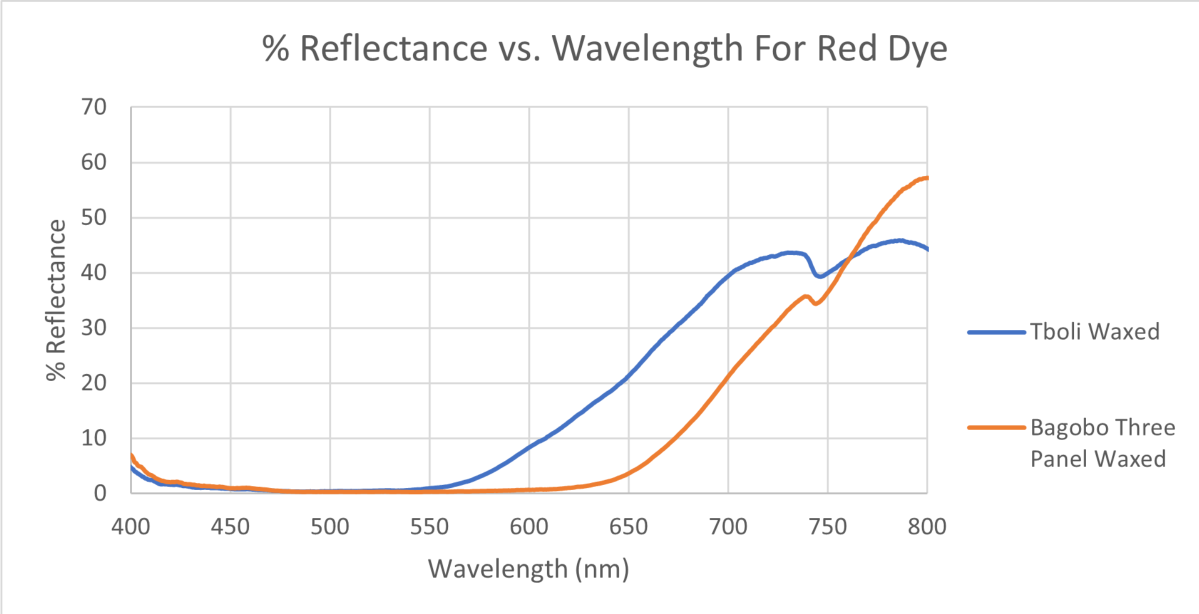

Figure 3. Reflectance Curves for Red Dye from Waxed Textiles.

spectral pattern, in which they curve upwards and reach an inflection point, and then dip downwards before curving back up again. This could provide evidence towards the accuracy of the photospectrometer in observing the same color, especially since both textiles are waxed, as this removes a confounding variable. The red dyes that were observed for this study were also quite bright, and since the beeswax adds additional light, the high reflectance values would make sense. Both the Bagobo three panel and the T'boli textile were made from natural dyes, but the ways that the sources of the red dye *Morinda citrifolia* were utilized could vary based on their availability within the region. Although they live within the same island, the T'boli are located more towards the south, and thereby could have variations in how one botanical source for red dye was used while the Bagobo may have another.

Figure 4 displays the reflectance curves for black dye from the Mandaya ikat unwaxed textile, as well as the T'boli waxed textile and the Bagobo three panel waxed skirt. These results are drastically different from the curves for the red dye. For one, the reflectance values are less than 10%, which is accurate because black dye absorbs all light. Theoretically, these values should be at 0%, but it can be difficult to come across true black dye, especially through natural sources. In addition, there is a clear difference in the reflectance curves for the Bagobo and T'boli textile compared to the Mandaya textile. While the textiles for the T'boli and the Bagobo display a similar spectral pattern, in which the reflectance values stay close to 0% and only curve to 3% at the end of the spectrum, the Mandaya black dye has a completely different signature. The Mandaya textile curves downward before reaching an inflection point, and curves upwards to reach a maximum reflectance of 8%, which is much higher than the other curves for black dye. It then curves downwards before reaching another inflection point, and curves up again. This difference in the reflectance curves could be attributed to the fact that the Bagobo and the T'boli textiles are waxed. However, wax typically raises the reflectance values of dye, as shown with the red dye, so it would not be accurate to assume that the addition of the wax could be attributed to a lower percent reflectance. Another explanation could be from the sources of the dye

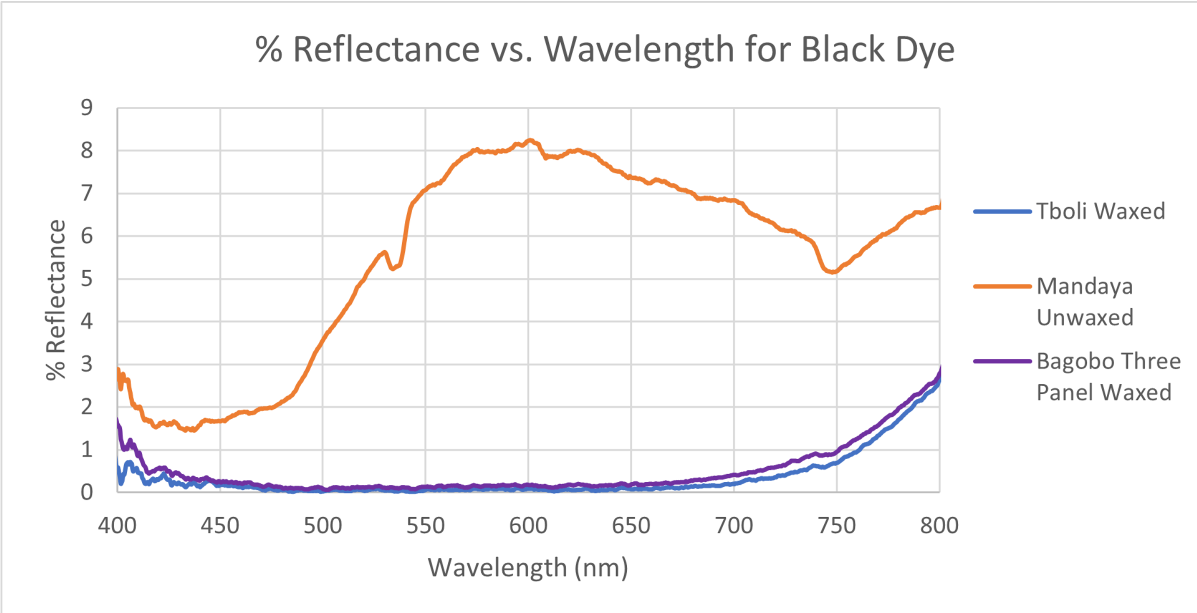

Figure 4. Reflectance Curves for Black Dye from Waxed and Unwaxed Textiles.

themselves. Although the dyes all come from natural sources, the black dye for the Mandaya textile is the only one that is suspected of being sourced from mud. If true, the iron in the mud could be reflecting light within the visible wavelength spectrum, causing the black dye from the Mandaya textile to portray higher reflectance values than the other black dyes. However, with the data given in Figure 4, a correlation can only be made between the possible sources of the dye and the reflectance curve. In addition, since the T'boli and the Bagobo textiles had very similar spectral patterns, the readings are consistent with the ethnographically reported source for black, *Diospyros nitida*, for both the T'boli and the Bagobo.

Figure 5 portrays the reflectance curves for the undyed fiber from the T'boli waxed textile, the Mandaya unwaxed textile, the Bagobo three panel mother (ine) and child (bata) skirt, and the unwaxed sinamay. The first noticeable aspect of the curves involves the shape, as it differs greatly from all the others. For all four textiles, the reflectance curves of the abaca fiber dip down and then inflect upwards, until all reach a maximum reflectance of 100%. In this way, the spectral signature remains the same for all undyed fibers presenting as beige. The high reflectance is accurate, since beige is very similar to white, and reflects more light than it absorbs. The addition of the wax could contribute to the high reflectance value. The sinamay textile stands out due to the reflectance curve reaching 100% reflectance the earliest in terms of wavelength. However, there is not much of a difference in the spectral signature of the Mandaya unwaxed textile versus the other waxed textiles, which provides further evidence to the difference of the black dye compared to the others. The wax could also prevent oxidation of the chromatophores within the abaca fiber, thereby protecting the pigment of the textile for longer.

Lastly, the reflectance curves for the commercial dyes present in the Bagobo striped skirt were examined. As seen in Figure 6, compared to the curves from the natural dyes, these reflectance curves appear "cleaner," or with a lot less noise than the others. Since commercial dyes are synthetically produced, there is a lower likelihood of these dyes containing materials other than those contributing to the portrayal of a specific pigment.

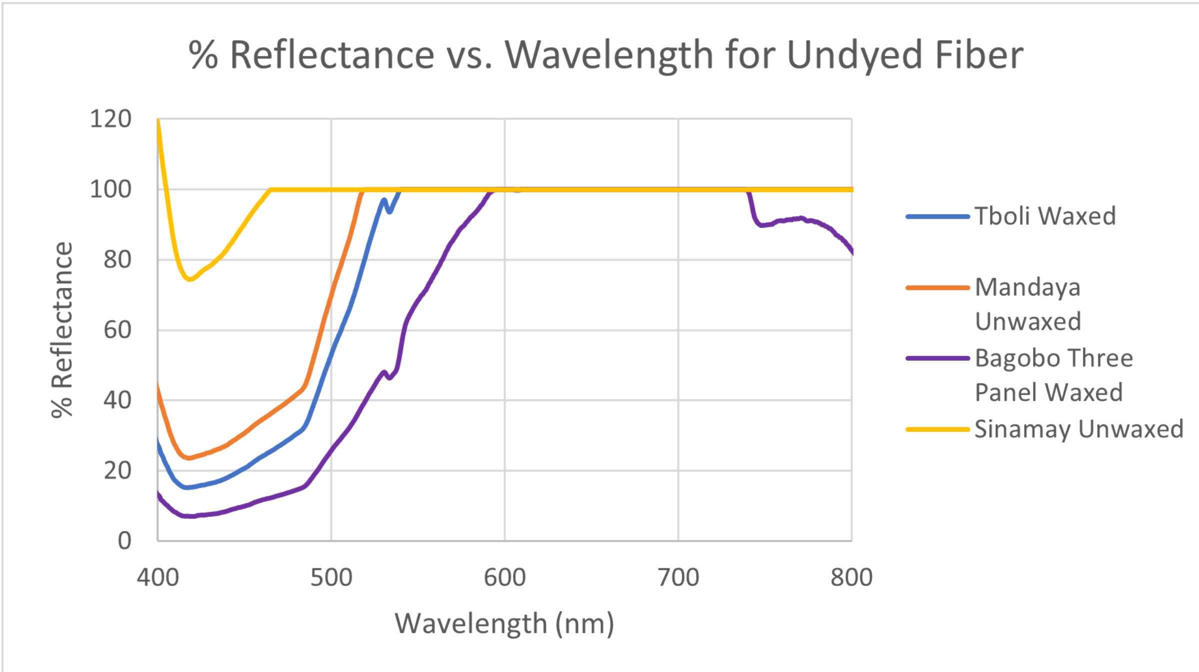

Figure 5. Reflectance Curves for Undyed Fiber from Waxed and Unwaxed Textiles.

Natural dyes, however, have more of an uncertainty to the makeup of the natural sources, since there is no precise method of being able to tell what else could be present within the source that could affect the reflectance of the dye. There are many advantages to using synthetic dyes over natural dyes. For example, a larger amount of natural dye is needed to achieve the same pigment as synthetic dye, and the availability of natural dyes can vary based on temperature and season. However, some advantages to using natural dyes is their biodegradable nature, making them more environmentally friendly than synthetic dyes (Sutra, 2020). In addition, the lighter dyes seem to reach 100% reflectance before all the others, as seen by the yellow and green dyes, and is accurate; the yellow and green dyes also display similar spectral signatures. The blue dye, which is darker, tends to reach 100% reflectance later in the spectrum. This textile was also waxed, which could also contribute to higher values for reflectance.

4. Conclusion

The weaving and dying of abaca textiles (*Musa textilis*) are important aspects of Filipino indigenous culture. Many groups, like the T'boli, Mandaya, and the Bagobo, all share similarities in the integration of textiles within their belief systems, and portray motifs that symbolize various aspects of their culture. These indigenous groups also dye their textiles with similar plants, like *Diospyros nitida* and *Morinda citrifolia*, and portray similar patterning techniques, such as ikat. By gathering information on the background of these textiles, photospectrometric analysis was able to be performed on five separate ethnographic textiles from various regions in the Philippines, including ones made by the indigenous tribes themselves. From this research, the photospectrometer was deemed accurate through the measurements of the dominant wavelengths of each color in comparison to the true values. Additionally, the reflectance curves of various red, black, and undyed fiber were compared, along with curves

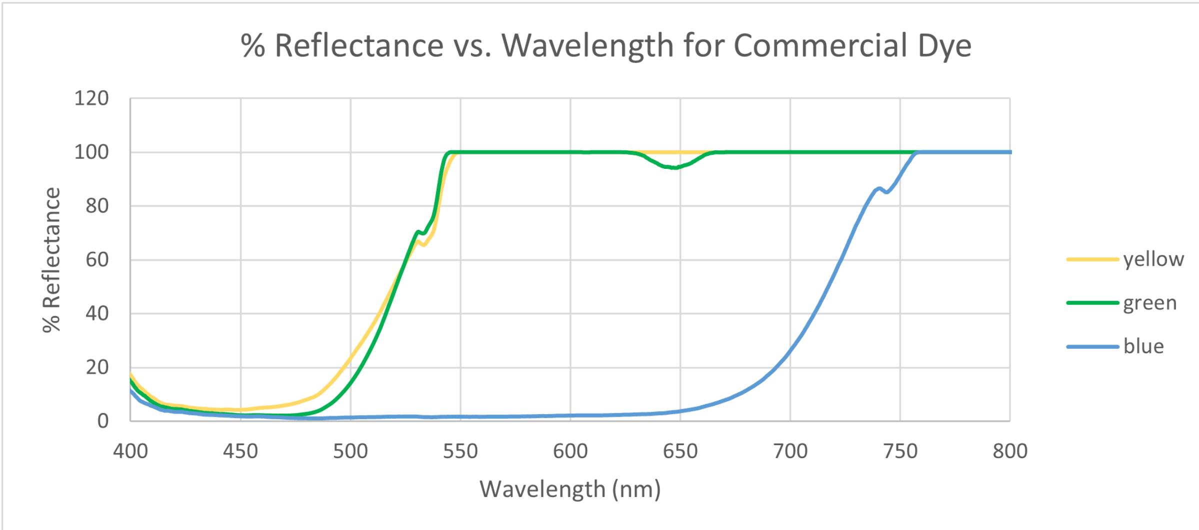

Figure 6. Reflectance Curves for Commercial Dyes from Bagobo Two-Panel Striped Skirt.

for commercial dyes, and it was noted that the textiles with wax had higher reflectances than the ones without. Furthermore, each color was shown to have a spectral signature, and the waxed versus unwaxed textiles could be analyzed to give proof towards the cultural origin of the textile. For instance, the Mandaya do not wax their textiles while the Bagobo and the T'boli are more likely to. The origin of the dye could also be speculated with the differences in the reflectance curve, as shown with the Mandaya black dye compared to the black dye used by the T'boli and the Bagobo. Future work could include analyzing the dyes within the ultraviolet or the infrared spectrum in order to come to a definitive conclusion about the materials within the dye, as well as an analysis of beeswax by itself as a standard of comparison to beeswax on textiles. The differences in the reflectance curves between the commercial and the natural dyes were also observed, in which the commercial dye curves displayed less noise and higher reflectance. The merit of using photospectrometry techniques combined with ethnographic data in the study of textiles has been demonstrated by pointing to future areas of investigation of this indigenous art form. All in all, textiles serve an important means of documenting, preserving, and celebrating Filipino culture across and within groups throughout time, and the dyes used emphasize the diversity and creativity within each and every piece.

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