A foray into fungal dyes

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INTRODUCTION

Natural dyes are known to be sourced from numerous organic substances, from insects to plants. Fungi, organisms of a separate phylum from plants and animals, and lichens which consist of a fungus and a photosynthetic partner have also historically been used for dyeing textiles. These organisms have been briefly explored in dye literature, however the cultural practice, breadth of colors available, and aging properties have been largely unpublished. While several non-destructive characterization tools are available for certain colorants, the identification often requires a reference set for comparison. For fungi and lichen sources, this data currently does not exist. In Washington State in 2022, the International Fungi and Fiber Symposium (IFFS) offered a gathering of fiber and mycology enthusiasts and the opportunity to study dyes from fungi and lichens collected in the United States.

Figure 1: Small dye extraction with diced dried Cortinarius semisanguineous tops and stems soaked and heated (not boiled) in distilled water.

METHODOLOGY - DYE SAMPLES

Dyeing with fungi is a similar process to other natural dyes, with color variations achieved by adjustments to the pH level and the type of the fiber dyed. Methodologies for each fungus may vary slightly, such as hot water versus ammonia dye extraction, and IFFS instructors and books such as *Mushrooms for Dyes, Paper, Pigments, and Myco-Stix* guided the process.

Enough fabric sample bundles were prepared to cover variables including substrate, mordant, and pH. Each bundle consisted of textile swatches chosen to represent substrates commonly found in cultural heritage items: wool, silk, cotton, linen, and one multi-fabric sample with additional modern fibers. Half of the bundles were pre-mordanted with aluminum sulfate (alum) at 15-20% of the dry fabric weight. All samples were dyed during workshops throughout IFFS.

METHODOLOGY - IMAGING

Multimodal imaging was performed using a modified camera and three specific radiation sources. Visible light (VIS), reflected infrared (RIR), visible-induced infrared luminescence (VIL), ultraviolet-induced visible luminescence (UVL) in UVA and UVC wavelengths, and reflected ultraviolet (RUV) images were taken of each sample set, both mordanted and unmordanted. Filters, targets, and post-processing for each mode were used according to guidelines established by the American Institute for Conservation (AIC), UVInnovations, and Cultural Heritage Imaging (CHI) standards.

Figure 2: Cortinarius smithii mushroom, image courtesy of Burke Herbarium

Figure 3: VIS image of Cortinarius smithii and semisanguineous dyed samples (unmordanted set on left, mordanted set on right). Unmordanted (a) Test Fabrics MMF 10A (bands top to bottom: acetate, cotton, nylon, polyester, acrylic, and wool); (b) cotton; (c) linen; (d) silk; (e) wool. Mordanted (f) Test Fabrics MMF 10A (bands as in (a)); (g) cotton; (h) linen; (i) silk; (j) wool.

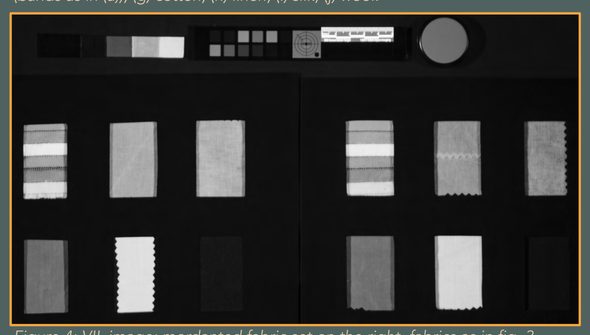

Figure 4: VIL image; mordanted fabric set on the right, fabrics as in fig. 3.

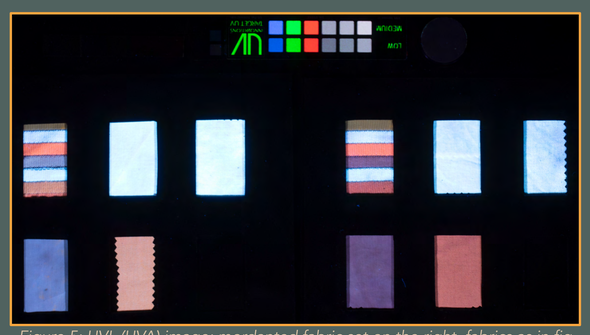

Figure 5: UVL (UVA) image; mordanted fabric set on the right, fabrics as in fig. 3.

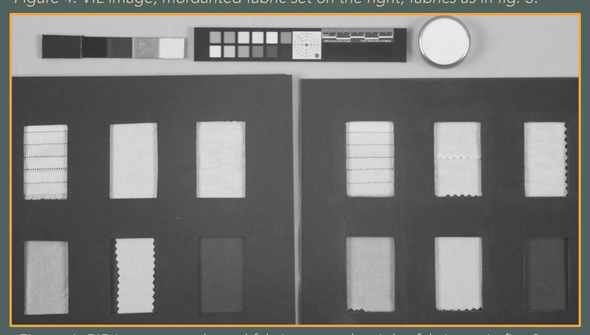

Figure 6: RIR image; mordanted fabric set on the right, fabrics as in fig. 3.

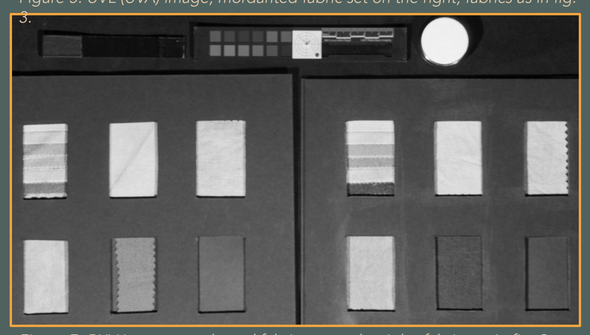

Figure 7: RUV image; mordanted fabric set on the right, fabrics as in fig. 3.

METHODOLOGY – AGING and COLORIMETRY

49 samples were mounted and aged from natural sun exposure following ASTM D 5398 – 97 standard. L*a*b* color measurements were taken before and after light aging using a Datacolor ColorReader. Measurements were taken in triplicate and averaged. Delta E was calculated using these averaged numbers. After light aging, the samples were imaged under normal light and ultra-violet radiation.

OBSERVATIONS and DISCUSSION

IMAGING

Multi-modal imaging allowed for direct comparisons between substrates, mordants, and dyes. Characterization of color under multiple modes of photography is possible, with some lichen and mushroom dye sources fluorescing strongly, such as Letharia Vulpina and Phaeolus Schweinitzii. In general, proteinaceous substrates (wool, silk, and nylon) yield a richer color in VIS and more pronounced visible luminescence in UVL. Mushrooms from the Cortinarius genus (which has known chromophores in the Anthraquinone family) typically showed luminescence across species. Samples mordanted with alum generally showed a heightened luminescence under UVL. In some cases, comparing mordanted and unmordanted samples showed luminescence was due to the alum mordant. Those samples with luminescence under both UVA and UVC were those with a slightly acidic (4) or basic (9) pH.

RIR imaging was less illustrative, with little shift in value between dye source, but VIL results showed a wide variation. Both RUV and UVL results showed distinct relationships between the dyes and UV light.

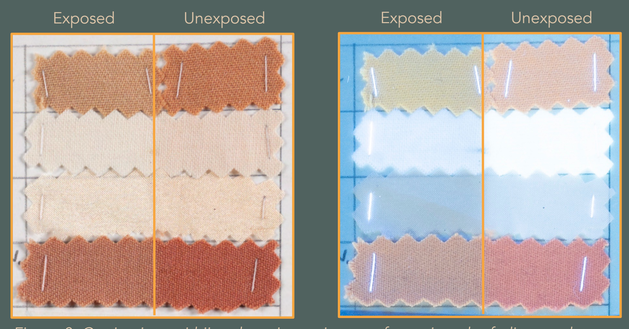

Figure 8: Cortinarius smithii and semisanguineous after aging; the fading can be observed by both a loss of color in VIS (left) and in loss of luminescence in UVL (right).

AGING and COLORIMETRY

After light aging, all samples showed large visible changes (fig. 8). 41 samples were comparable to Blue Wool 2 or 3, six samples were comparable with Blue Wool 4, and two samples were comparable with Blue Wool 5.

25 samples had a Delta E between 10 and 20, 22 samples had a Delta E between 2 and 9.9, and two samples had a Delta E under 2.

With one exception, inclusion of an alum mordant and type of fiber had no affect on longevity. The silk and wool samples dyed with Omphalotus olivascens (fig. 9) benefited from the inclusion of a mordant. These were the most lightfast of the samples, comparable to Blue Wool 5 with a Delta E under 2. In the future, the effectiveness of other mordants on light fastness should be explored.

All samples with visible fluorescence under ultraviolet radiation showed a reduction in that fluorescence after light aging.

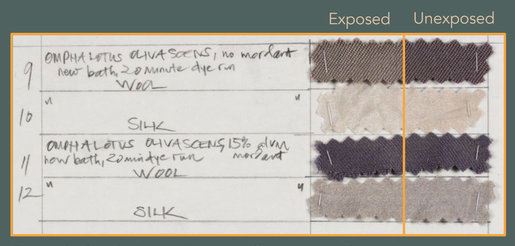

Figure 9: Omphalotus olivacens after aging, VIS; the lower two samples were mordanted with alum and exhibit much less fading than the unmordanted top two samples.

CONCLUSIONS

Results show fungal dyes have a great variation in color depending on fabric substrate, mordant, and pH. Many fungal dyes show notable luminescence, and that luminescence appears light-sensitive. While a resource with these results based on dyed samples may not be fully applicable to collection objects for diagnosis (variations due to age, source, dyeing method, over-dyes, etc.), these images and this data can be useful in continuing efforts to create such a resource to better understand the properties of fungal dyes and their use in cultural heritage.

FUTURE WORK

Plans are in process to conduct High Performance Liquid Chromatography (HPLC) to characterize the chromophores of these dyes and potentially their degradation products. The resulting spectra can act as a reference set to aid future analysis of cultural heritage objects. Additional foraging and dyeing to create a more regionally and methodically diverse sample set is in store for the authors, as is more investigative imaging. A noted difference was seen in the luminescence between ultraviolet wavelength bands. Noting that UVC is considered harmful to organic compounds, the authors are interested in continuing to explore this imaging technique on non-cultural heritage samples to determine its diagnostic potential for fungal dyes.

Figure 10: Samples from the many different dye baths made during IFFS 2022, on wool yarn.

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Figure 11: Dyed samples from a variety of workshops at IFFS 2022.