Methods for fiber identification of Hawaiian barkcloth

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Introduction

Barkcloth is a fabric made by beating fibers from the inner bark of certain trees and shrubs. In the South Pacific, barkcloth (**tapa**) traditionally carries great social and functional importance. While most Polynesian cultures made tapa primarily from paper mulberry (*Broussonetia papyrifera*) deliberately introduced during migrations from Asia, Hawaiian tapa (**kapa**) was also made from a variety of endemic species. Among these, māmaki kapa (purportedly made from *Pipturus albidus*) was the second most common after wauke kapa (made from *B. papyrifera*). Kapa making in Hawai'i was discontinued by the end of the 19th century, until it saw a resurgence in the late 1970s as an expression of cultural identity. During this period the techniques to make māmaki kapa were lost, and today's kapa artists cannot replicate māmaki kapa with wauke techniques or using the ethnographic record alone. Additionally, māmaki kapa in museum collections tends to be far more deteriorated than wauke kapa of a comparable age for uncertain reasons. Our investigation is thus motivated by identity and conservation concerns.

Objectives

1. Evaluate prior research on Hawaiian kapa fiber identification. Ascertain whether their methods are reproducible.
2. Create an identification key for Hawaiian kapa fibers.
3. Determine whether māmaki kapa is sourced from *Pipturus albidus*.
4. Determine why māmaki kapa deteriorates faster than wauke kapa of a comparable age.

Prior Work

Funk, Evangeline. 1979. *Anatomical Variation of Fibers in Five Genera of Hawaiian Urticaceae and its Significance to Ethnobotany.* Unpublished Master Thesis in Botanical Sciences. University of Hawai'i.

Pang, Benton. 1992. *The Identification of Plant Fibers in Hawaiian Kapa: From Ethnology to Botany.* Unpublished Master Thesis in Botanical Sciences. University of Hawai'i.

Scharff, Annemette. 1996. *Māmaki Tapa: Identification & Deterioration.* Unpublished Master Thesis. School of Conservation, Royal Danish Academy of Fine Arts. Copenhagen, Denmark.

Florian, Mary-Lou. 2012. *An anatomical approach to the identification of five Hawaiian plant species that were used in Hawaiian tapa cloth.* Unpublished report. National Museum of Natural History.

Methods & Concerns

Manufacturing, DNA Analysis, Experimental Methods

Using **DNA analysis** and **barcoding** techniques, we have not been able to identify historical tapa. Specimens used were found to be too degraded for such analysis. Not only was the tapa worn, used in furnishings, and generally subjected to the elements, but the very techniques of manufacture thoroughly disrupt the integrity of the inner bark. For Hawaiian kapa, these include the following:

- **Retting** (fermenting) in fresh or salt water for up to a month
- **Beating** in several sessions lasting up to five days in total
- **Baking** in an earth oven, mixed with fern juices (purported for māmaki)
- **Drying** and **bleaching** (often in direct sunlight for several days)
- **Decoration:** dyeing, painting, rubbing with oils, submerging in mud

This all results in a chaotic microscopic structure. Our objective is to glean order out of this chaos. Towards that end, it is necessary to examine not only vouchers of intact inner bark, but also vouchers of tapa that was beaten from known fiber sources. Scholars and artists from indigenous communities have visited the NMNH and created tapa with us, which we then used for our investigation. Comparing vouchers from different stages of the manufacturing process aids in tracing the tapa back to its plant source.

Fig. 1. Tongan woman removing the inner bark of a paper mulberry tree. Photo by Adrienne L. Kaeppler.

Fig. 2. Moana Eisele, Community Scholar from Hawai'i. Anthropology Conservation Laboratory, Smithsonian Institution, 2012.

Measurements of Fibers

Pang (1992) measured fiber diameter and cell wall thickness. Unfortunately, this method has too many practical problems to be viable:

- Individual fibers vary greatly in size, thus requiring a large sample, which may raise ethical concerns.
- Ranges of measurements from different species show significant overlap.
- Fiber shape (cross-section) and fiber twist must be taken into consideration.
- Hydration of the fibers can cause fluctuations in size.
- Fibers do not lie flat within tapa. Thickness of the material becomes an issue at this scale, affecting fiber depth and angle of incline. Solutions include destructive maceration to flatten out the sample or 3D SEM techniques to account for perspective.

Pang noted that fiber dimensions vary in nature according to the plant's geographical area of origin. (Soil moisture and nutrition, elevation, and wind stress can affect fiber formation.) He also determined that there were significant differences in fiber size along different areas of the stem (*B. papyrifera*).

Similarly, Funk (1979) measured fiber length, fiber diameter, and lumen diameter. Fiber length is an unusable characteristic. Beater marks break fibers, and it is ethically inadvisable to obtain samples of tapa that are large enough to measure a statistically significant number of intact fibers.

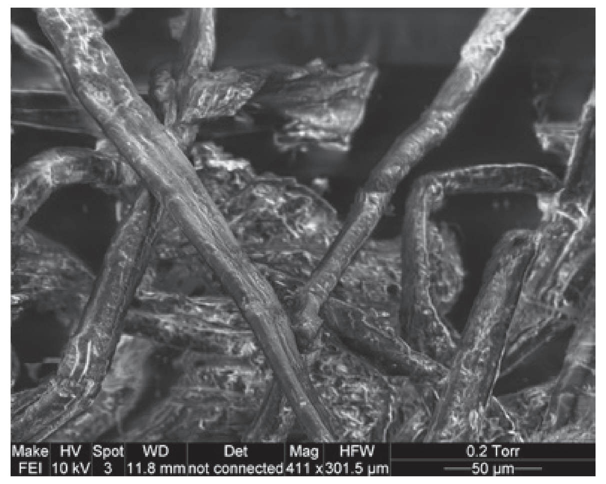

Fig. 3. Fibers from a typical (purported) māmaki kapa at edge of beater mark. Note the overall disorganization and the twisted and angled fibers.

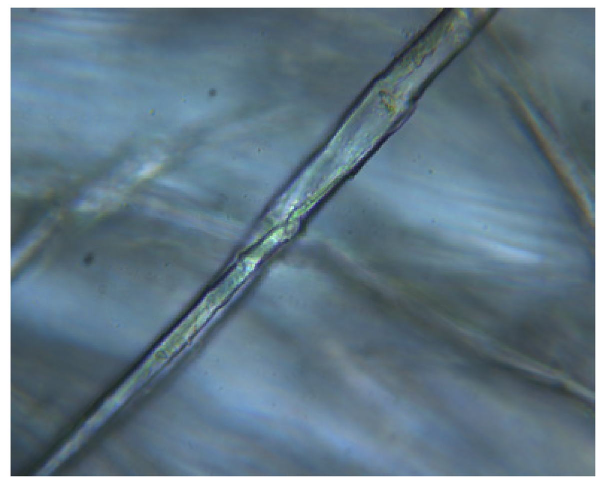

Fig. 4. Although it is often easier to flatten out fibers on a slide for light microscopy than on a stub for SEM, it becomes more difficult to ascertain how fibers twist, which will affect measurements. (*B. papyrifera*, 400x).

Morphological Characteristics of Fibers

All authors relied on morphological characteristics to some extent.

- Presence or absence of a fiber sheath (transparent envelope or cuticle)
- Lumen visibility (cavity inside fiber)
- Cross markings, enations, and dislocations
- Shape of fiber ends (rarely present intact)
- General fiber cell shape

Our research found these to be more useful than fiber measurements, but this approach has its own problems:

- Authors sometimes use the same term to refer to different characteristics
- Manufacturing damage to tapa fibers distorts or destroys characteristics
- Not all fibers display characteristics associated with a species
- Fibers can display characteristics not expected from their species

For example, fiber sheaths are strongly associated with *B. papyrifera* (wauke). These are easily destroyed during manufacturing. Inexperienced light microscopy users can confuse focal blur with fiber sheaths. Additionally, our research has found fiber sheaths in *Artocarpus altilis* (breadfruit) vouchers.

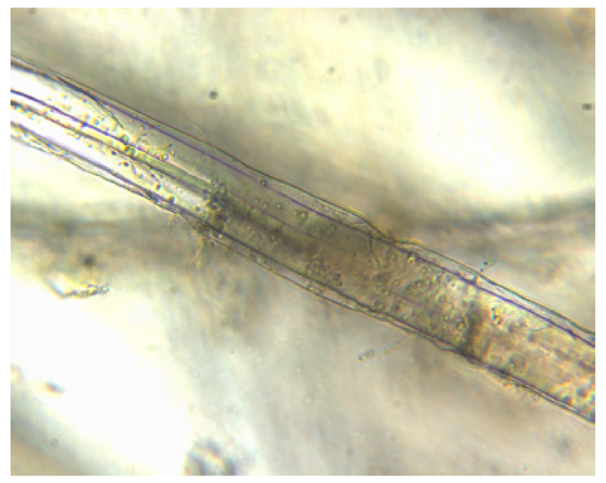

Fig. 5. *Artocarpus altilis* fiber sheath.

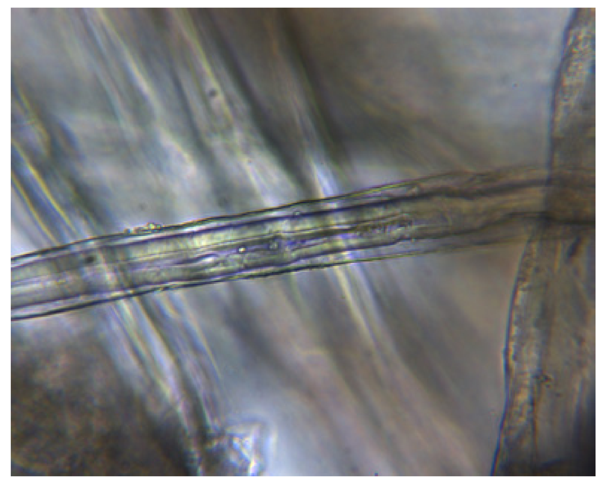

Fig. 6. *Broussonetia papyrifera* fiber sheath.

Associated Features

This approach has been largely unexplored before Florian's research. This is where we focused our recent investigation. Expanding the focus from fibers to associated features embedded in the macerated phloem tissue offers a greater basis for anatomical analysis. Our aim is to find features that are (1) unique to a certain species or (2) absent from a certain species. We also note features that might be attributed to manufacturing method rather than the plant species. This approach also allows us to explore evidence of pest-related deterioration. Examples of associated features:

- **Identification:** sieve tube elements, parenchyma, druses, and starch
- **Manufacture:** paints, oils, adhesives, and evidence of immersion in mud
- **Pests:** molds, beetles, and bacteria

The major problem with this approach is that it is difficult to separate associated features introduced through manufacture from features that are inherent to the plant from which the fibers were sourced. Contamination from tissue left on the beater or anvil can also occur, both in the production of tapa voucher specimens as well as in the historical context. Part of our research dealt with how to overcome this hurdle in identification.

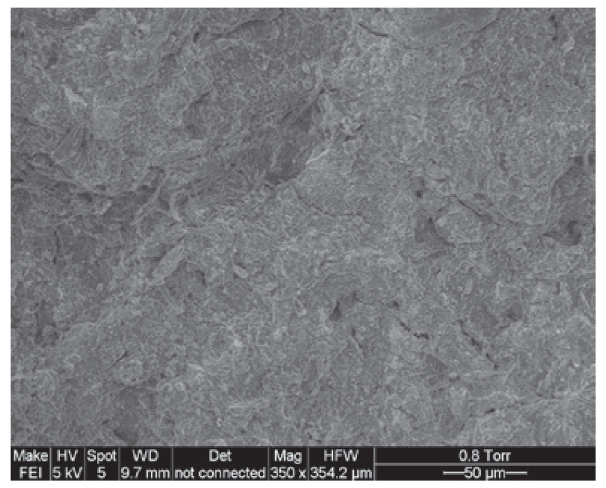

Fig. 7. Tapa surface is impenetrable with SEM. Observations are often limited to watermark areas and the edges of the sample.

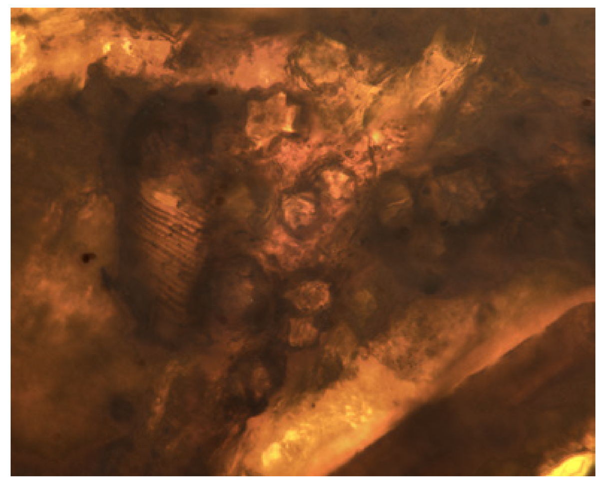

Fig. 8. When augmented with focus stacking and high dynamic range techniques, light microscopy can reveal associated features in the darkest of tapas without need for maceration.

Future Work

We examined 12 tapa voucher samples and 10 unknowns using light microscopy and constructed an identification key. Our results from this investigation are being verified by Mary-Lou Florian. They will be published in due time along with other aspects of the ongoing NMNH Tapa Project.

We are also working to reverse-engineer the process for constructing māmaki kapa, incorporating this microscopic evidence into our efforts.

REU Site, EAR-1062692

Acknowledgements

We would like to thank Mary-Lou Florian, Michele Austin-Dennehy, Sue Lutz, Stanley Yankowski, and the aforementioned authors whose work informed this investigation. Special thanks are due to Elizabeth Cottrell, Gene Hunt, Virginia Power, and the entire National History Research Experiences (NHRE) program, which is generously supported by the National Science Foundation, The Jean and Bill Lane Internship Endowment, and others.