Advances in conservation of Māori textiles; analysis and identification

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Abstract

A number of new methods and technologies for investigating Māori textiles have emerged from ten years of research in the Department of Applied Sciences - Clothing and Textile Sciences, University of Otago, Dunedin, New Zealand. Research projects undertaken include development of numerous identification methods for textile plants endemic to New Zealand (bright field microscopy, Scanning Electron Microscopy (SEM), Micro-Computed tomography (micro-CT), Polarised Light Microscopy (PLM)); exploration and improvement of safe display parameters for naturally-dyed Māori textiles (artificial light-ageing, micro-fading); and testing the efficacy of consolidants recommended for remedial conservation treatment of black-dyed muka (fibre) from harakeke (New Zealand flax, *Phormium tenax*). Of note is the collaborative and interdisciplinary nature of the work undertaken (research partnerships with iwi (Māori tribal grouping), customary weaving practitioners, New Zealand museums, conservation laboratories and other University departments), in addition to the adaptation of international standard textile testing methods to better reflect the artefact types of interest (for instance testing of fibre aggregates rather than woven European fabrics). Research outcomes are of relevance to practitioners and artists as well as those caring for Māori taonga, and have added to knowledge about both Māori textiles, and plants and dyes used in Māori textiles production.

Key words: Māori textiles, plant material identification, test methods, analysis, consultation, interdisciplinary, textiles conservation

Introduction

The Department of Applied Sciences – Clothing and Textiles Sciences (University of Otago, Dunedin, New Zealand) has been undertaking research of relevance to the cultural sector for over ten years, with a specific focus on increasing understanding of the properties, structure and ageing characteristics of textile materials endemic to New Zealand. Clothing and Textiles Sciences offers degree programmes accredited by the Textile Institute (UK) (BSc, BAppSc, postgraduate diploma, masters, PhD), which fall into two broad research themes; physical aspects of textiles (fibres, yarns, fabrics (types, production); mechanical and physical properties; human/environment interactions including human performance and safety) as well as social (economic, historical, cultural aspects of dress and textiles; material culture; fashion trade). Research of relevance to the cultural sector involves interdisciplinary and collaborative study, that incorporating both broad Departmental research themes. Three main ongoing research areas in regards to Māori textiles can be identified; 1. textile plant materials identification (brightfield microscopy, Scanning Electron Microscopy (SEM), Micro-Computed Tomography (micro-CT) and Polarised Light Microscopy (PLM), 2. conservation and preservation of Māori textiles (light ageing behaviour of naturally-dyed New Zealand textile plant materials for establishment of 'safe' display parameters; testing efficacy of consolidants for deteriorating tannate-dyed Māori textiles) and 3. examination and analysis of pre-European Māori textiles (which lies outside the scope of this paper). All research foci are *interdisciplinary* (undertaken in collaboration with Departments of Anthropology and Archaeology, Botany and Chemistry, University of Otago), *collaborative* (research partners include cultural institutions such as Te Papa Tongarewa National Museum of New Zealand, Tamaki Paenga Hira Auckland War Memorial Museum, Canterbury Museum and Otago Museum, as well as customary weaving practitioners), and *consultative* (mechanisms include the University of Otago Research Consultation with Māori policy, in addition to community relationships established in each cultural institution in New Zealand). Applied Sciences is in a unique position in regards to doing research in the cultural sector, situated within an academic context whereby applying science to answering questions in the real world and melding science with culture is considered desirable. The major goal of researchers working in this area is to bring together stakeholders, whether from communities of practice or care, with scientists working in academia. While New Zealand museums tend to be under-resourced in regards to access to scientific expertise and analytical equipment, New Zealand universities have both the relevant tools and the personnel to undertake research of importance and benefit to the cultural sector.

Research framework; ethics and consultation

Generally speaking a consultative research framework for the work undertaken at Clothing and Textile Sciences is provided by constituents such as conservators, practitioners who engage in customary weaving practice, and those who are custodians of Māori cultural material. Research questions generally develop out of longstanding relationships with these constituents, and are guided by desires for greater knowledge about Māori textiles and their preservation from a number of different, yet interrelated, perspectives.

It is important to note that study of Māori textiles take places in a bicultural context established by the Treaty of Waitangi (1840; Māori and the British Crown). Specific protocols and processes are enacted in New Zealand museums to ensure that appropriate access to, and research of, Māori artefacts occurs, in accordance with the special rights and responsibilities of Māori in accordance with the Treaty. The University of Otago has specific requirements for those engaging in any research of interest or relevance to Māori, in line with its Treaty obligations (see http://www.otago.ac.nz/research/maoriconsultation/).

The Treaty of Waitangi is considered the founding document of the modern New Zealand state, and frames New Zealand as a bicultural nation (Durie, 1993). Biculturalism can be defined as 'a context where two founding cultures are entitled to make decisions about their own lives for mutual co-existence' (Joseph, 2000). In the New Zealand context, the Treaty of Waitangi positions Māori and Pakeha (New Zealanders of British descent) as the two founding cultures in a national partnership, with equal rights to existence and governance (Tamarapa, 1996). Article II of the Treaty of Waitangi specifically provides Māori with authority over their lands and taonga ('all dimensions of a tribal group's estate, material and non-material' (Kawharu, 1989). This bicultural environment, and recognition of the Treaty of Waitangi, implies an acknowledgement of the particular relationship and responsibilities that Māori have towards taonga, and that taonga have special intangible and spiritual values that are best understood by Māori. At the University of Otago, the principle of biculturalism is recognised principally through the Memorandum of Understanding (MOU) between Ngāi Tahu (iwi whose tribal boundary (rohe) covers most of the South Island of New Zealand) and the University, together with the associated Policy for Research Consultation with Māori. The Policy for Research Consultation with Māori was designed to provide a process through which all research undertaken at the University of Otago could be assessed by the Ngāi Tahu Research Consultation Committee to determine whether it was of interest, or relevance to Māori. Aside from consultation set out in relevant policies at the University of Otago, each cultural institution whose collections are accessed for research have their own specific consultation process. For example, at Otago Museum all matters associated with Māori cultural material are assessed by their Māori Advisory Committee (MAC), composed of local representatives. Consultation does not only take place with Māori. Other relevant parties (botanists, archaeologists, museum staff, Department of Conservation staff) are consulted and informed about activities associated with research. Another important aspect of consultation and research on Māori textiles is the agreement to provide any information gained back to constituents associated with projects; research dissemination can take the form of hui, conferences, university seminars and public talks, as well as more standard forms of academic dissemination such as peer-reviewed publications.

Textile plant materials identification

He Rārangi Whakaaturanga O Ngā Taonga Rākau /Atlas of Plant Material and Fibres from New Zealand and the Pacific

New Zealand and international museums have extensive holdings of Māori textiles, most of them made from unidentified plant materials. It is generally accepted that identifying plants that have been used to make artefacts is difficult. The first step in positive identification of plant materials is that they display the diagnostic features that have previously been identified using known reference material. While reference databases or libraries of the major commercial fibres are well established, this is not often the case for those that are not in common useage. An objects conservator, Heike Winkelbauer (formerly Auckland War Memorial Museum, now Academy of Fine Arts, Vienna), alerted academic staff to the absence of any such criteria for evaluation of plants used for artefacts in New Zealand collections. To remedy this situation a reference database of plant materials and fibres used in the Pacific and New Zealand was developed, published and made available online by Cruthers and Carr (2007) (Carr and Cruthers, 2007). The *He Rārangi Whakaaturanga O Ngā Taonga Rākau /Atlas of Plant Material and Fibres from New Zealand and the Pacific* lists thirteen plants commonly used for the production of textiles in the region determined through consultation with stakeholders such as the Department of Conservation, Landcare Research–Manaaki Whenua, Te Roopu Raranga Whatu O Aotearoa, and museums. Reference images of each plant, as well as micrographs of transverse sections showing identified key diagnostic features, leaf surfaces (micrographs obtained using SEM) and measurements of ultimate fibres (individual fibre cells, the unit beyond which subdivision of the fibre is no longer possible; Carr and Cruthers, 2007) are provided for the purposes of identification. Additionally Carr, Cruthers, Girvan and Scheele (2009) have listed the diagnostic features of the thirteen plants identified during the compilation of the *He Rārangi Whakaaturanga O Ngā Taonga Rākau* including descriptions of the shape, appearance and distribution of fibre bundles, the epidermis and vascular tissue for each species (Carr et al., 2009). Ultimate fibre dimensions and the existence of wax crystals on the leaf surface of some species have also been noted. *He Rārangi Whakaaturanga O Ngā Taonga Rākau* therefore provides the first key step in identifying plants used to produce artefacts in New Zealand and in the Pacific.

However in practice, the use of this reference database to identify plant material found in artefacts is problematic. Artefact production usually requires processing of plants (e.g. retting, cooking, harvesting, drying, heating). While a botanist will use all parts of a plant for species level identification, artefacts are usually made from only one part of a plant, and then considerably altered from its original form due to the processes used to turn it into an artefact. Reference images and diagnostic features identified on *He Rārangi Whakaaturanga O Ngā Taonga Rākau* were obtained from contemporary, minimally-processed plant specimens (leaves stripped, but not softened; fibres removed from leaf, not pounded or boiled) and were therefore not representative of the processing of fibre or leaf in customary Māori textiles production. While **ultimate fibre** measurements were recorded in the Atlas, **fibre aggregates** (ultimate fibres and associated plant tissue, together forming fibre bundles (Lowe and Smith, 2012, Smith et al., 2013, Smith et al., 2011) are used for construction of Māori artefacts, therefore these measurements cannot be applied to 'fibre' typically found in artefacts. This means that available reference material is not directly comparable with samples of plants derived from artefacts.

Another confounding factor for New Zealand plant identification is that all leaf and fibre bearing plants in common useage are monocytelydons (e.g. harakeke, New Zealand flax, *Phormium tenax*, J. R. Forst & G. Forst; tī kōuka, cabbage tree, *Cordyline australis*, (Forst.f.) Endl; kiekie, *Freycinetia banksii*, A. Cunn); their physical similarity compounding the inherent difficulty of aged plant identification (Carr et al., 2008, Smith et al., 2013, Lowe and Smith, 2012). Leaves have very similar anatomical features, such as the size, shape and arrangement of vascular tissue and the appearance of mesophyll and epidermis making it difficult to discern among them (Figure 1). Additionally the anatomical similarity of these plants is further complicated by the fact that specimens from artefacts usually only contain fragments of the full leaf section, making already similar 'diagnostic' features even more difficult to discern. In the context of cultural materials conservation the challenges of identification of materials are then compounded by the desirability of use of non-destructive analytical methods where possible.

Micro-computed tomography (Micro-CT)

Micro-CT was explored as a plant identification method as a result of the difficulties in identifying aged plant material from artefacts in comparison with available reference material. The use of micro-computed tomography in textile identification was suggested by the work of O'Connor and Brooks (O'Connor and Brooks, 2007, O'Connor et al., 2008), and the existence of necessary equipment and an experienced operator (Andrew McNaughton) at the University of Otago.

Tomography uses X-rays to image an object in sections, and is most widely used in medicine as computed axial tomography (CAT) or computed tomography (CT) scanning. Section data (which provide a view of internal structures) are collected by an X-ray source and detector that move around the object, and are then reconstructed creating a three-dimensional model (Pearsall, 1998). Micro-CT scanning produces models with higher detection (1 μm) and resolution (2-3 μm) than CT scanners, and is used on small specimens (maximum diameter range typically 70mm). As micro-CT is a non-invasive and non-destructive technique that can generate an image of the internal structure of an object, it has a wide range of applications. The conservation literature reported the use of CT scanning to identify complex multi-media artefacts, particularly from archaeological contexts (Sasov, 1998, Stelzner et al., 2010) and noted the potential of micro-CT for examination of finer aspects of textiles, and noted the potential of micro-CT for examination of finer aspects of textiles (e.g. individual yarns and fibres, O'Connor and Brooks, 2007, O'Connor et al., 2008). Previous studies indicated micro-CT images may have similar spatial resolution and detail to optical micrographs (O'Connor et al., 2008), therefore the micro-CT technique was assessed as a means for identifying plant materials in New Zealand artefacts.

Firstly it was established that images gained from micro-CT displayed the morphological features visible in reference transverse sections of the textile plants for identifying harakeke, tī kōuka, and kiekie. Micro-CT then presented an easy way to see internal diagnostic features of leaf without the difficulties associated with preparing transverse sections from desiccated and embrittled specimens. However the issue of visually discriminating key diagnostic features using small, fragmented, and damaged specimens, derived from plants that had been heavily processed still had to be accounted for. Visual diagnostic characteristics previously identified for each species underscored the similarity of tī kōuka and harakeke, and also that visual identification was problematic given the high natural variability of plants. Therefore measurable, objective characteristics of each plant species were determined, rather than relying on visual differences as diagnostic. A suite of key diagnostic features that were appropriate to plant material found in artefacts (measureable, rather than purely visual; specific to particular plant tissue, rather than needing a whole cross section) was determined by examining previously published transverse sections of each species (Figure 2) (Smith et al., 2013). Firstly measures of identified features were obtained (e.g. upper and lower mesophyll thickness; vascular bundle length, using Image J (Rasband, 2008)) and in some cases ratios were calculated (such as length to width of upper or lower fibre bundles). Descriptive statistics (mean, standard deviation, minimum and maximum) were calculated for each species by pooling data across specimens. Differences in the size and shapes of features among the species were then analysed using statistical tests available in the software package SPSS (SPSS Inc, 2007). Data plots of measured ratios enabled determination of significantly different features among artefacts, or in other words key diagnostic features based on measurement, rather than visual similarity or difference. However identified visual characteristics were still useful in combination with these measurable characteristics. An identification key was therefore developed that provided a set of dichotomous (yes/no) decisions in a hierarchical process, based on both visual and measurable characteristics from reference transverse sections and micro-CT images (Smith et al., 2013).

When micro-CT was tested on specimens from museum artefacts (specimens ranging in length from 1-25 mm, width 0.5-3 mm; from Auckland War Memorial Museum Tamaki Paenga Hira, Canterbury Museum and the National Museum of New Zealand Te Papa Tongarewa; for detail of artefacts see Table 3; Smith et al. 2013) just over 50% of plants represented by specimens were identified. Interestingly some institutional identifications of plant species used were proved incorrect. Micro-CT images of leaf specimens from artefacts also looked completely different when compared to transverse sections of contemporary reference material; fragmented, disorderly and confusing (Figure 3). Moving away from subjective identification criteria such as appearance however, to quantifiable features, enabled the identification of species sometimes from very small, even apparently negligible amounts of plant tissue. The key for identification combined visual recognition and measurements of these diagnostic features to identify species through a process of elimination (Smith et al., 2013). Provided that sufficient diagnostic features were present and measurable (in particular, both upper and lower fibre bundles in harakeke and tī kōuka), the key could be used to discriminate among the three species, despite visual similarities. However success in identification depended entirely on the leaf tissue that was available (e.g. kiekie characterised from the existence of an oval vascular bundle with clearly identified central lumen). A fragment of the same size of epidermis however, was not sufficiently different to be considered diagnostic to one species. Micro-CT undoubtedly presented some ways forward for identification, especially in regards to developing measurable, rather than subjective, characteristics of New Zealand plant species. However damage caused by plant material processing and a concomitant lack of sufficient information left in specimens from artefacts to identify them, meant that researchers at Applied Science continued to search for a minimally invasive yet more accurate means of identifying the plants contained in artefacts.

Polarised Light Microscopy (PLM)

The next method explored for identification of textile plant materials from New Zealand involved the application of Polarised Light Microscopy (PLM). Despite widespread use of PLM for fibre identification elsewhere (Goodway, 1987, McCrone, 1994), and important developments in using PLM for plant fibre identification in textile artefacts of great antiquity (Bergfjord and Holst, 2010, Bergfjord et al., 2010, Kvavadze et al., 2009) the characteristics of New Zealand plant fibres under PLM were unknown.

The leaves of plant species used in Māori textiles (harakeke *Phormium tenax*, wharariki *Phormium cookianum*, tī kōuka *Cordyline australis*, ti ngahere *Cordyline banksii* , tī toi *Cordyline* *indivisa* and kiekie *Freycinetia banksii*), are sometimes processed to extract the fibrous tissue as long strands of fibre aggregate. Once processed in this way, the fibre from different species looks very similar to the naked eye, making it difficult to identify the species from which the fibre was sourced. It is also difficult to differentiate between fibre extracted from New Zealand plant species from that of other plant species, such as European flax *Linum usitissium*. However, the individual fibre cells in each fibre aggregate can have species specific characteristics, which when viewed with a polarising microscope reveal diagnostic features (e.g. morphology, calcium oxalate and/or carbonate crystals type, fibrillar orientation, birefringence, refractive index).

A fragment of fibre aggregate consists of many thousands of fibre cells, enabling small lengths of fibre aggregate (e.g. a single strand less than 10mm long) to be used for fibre identification. The preparation of microscope specimens comprises a simple but destructive maceration technique involving sodium hypochlorite. The polarising microscope is used to assess a range of morphological and optical features of the fibre cells, including shape (cell length and width, aspect ratio, regularity along length, tip shape), cell features (pits, nodes, dislocations, cross markings, lumen), associated crystals (presence/absence, shape, configuration) and optical behaviour under polarised light (sign of elongation, microfibril twist via modified Herzog test, parallel and perpendicular refractive indices) (Luniak, 1953). Species identification relies on systematically noting the combination of all features listed, as no single feature is unique to a species.

Obvious and reliable differences were observed using polarised light microscopy among the fibre cells from different genera (i.e. *Linum, Phormium, Cordyline* and *Freycinetia),* with more subtle differences observed within genera (i.e. *Phormium* sp. - harakeke, wharariki; *Cordyline* - tī kōuka, ti ngahere, tī toi). The following examples illustrate how different combinations of cell features can be used to identify species. Fibre cells from *Linum* and *Phormium* have a far higher aspect ratio (mostly due to a far greater cell length) than cells from the other genera and both lack pits in the cell walls, but are otherwise morphologically similar. However, the microfibril twists are opposite (*Linum* S-twist, *Phormium* Z-twist), and the parallel refractive index of *Linum* (1.585-1.595) is higher than *Phormium* (1.535-1.569), enabling these genera to be easily distinguished. *Freycinetia* fibre cell are also easily identified from other plant genera due to a number diagnostic features including cell wall pits, abundant cubic and/or raphide crystalsand inconclusive Herzog results (Figure 4). Some fibre cell features were not useful for distinguishing among New Zealand species, namely sign of elongation (all positive) and refractive indices (due to high within species variability, and overlapping perpendicular and parallel refractive indices between species). Additionally, fibre cell characteristics were not influenced by differences among individual leaves, or plants within a species, provenance (i.e. growing location of the source plant), customary dyes or ageing. Most importantly for those working with specimens from artefacts, customary processing from leaf to fibre does not affect the ability to identify species. Applying PLM to the same specimens previously assessed by micro-CT (Smith et al., 2013) also improved species identification from 50% to 98%. The extremely small specimen size required, and the ability for cells to be unaffected by processing used in the conversion of plants to textiles, as well as the availability of PLM equipment in most museums, makes this method likely of interest to those interested in plant identification in artefacts from the Pacific.

Conservation and preservation of Māori textiles

Research in Applied Sciences falls into two main categories in regards to preservation of Māori textiles; examining the light ageing behaviour of naturally-dyed New Zealand textile plant material for establishment of 'safe' display parameters, and testing the efficacy of consolidants for deteriorating tannate-dyed Māori textiles.

Light ageing behaviour of naturally-dyed harakeke fibres

Requests from conservators from Te Papa Tongarewa National Museum of New Zealand for empirical evidence of safe levels of display for Māori textiles prompted this research project. While international guidelines existed for display of light sensitive materials, such as dyed plant fibres (Ashley-Smith et al., 2002, Derbyshire and Ashley-Smith, 1999, Ford and Smith, 2010), no assessment had been made of the specific light-ageing characteristics of naturally-dyed New Zealand plant fibres. Therefore this research project collected light-ageing data specific to New Zealand cultural materials, rather than relying on existing general guidelines. There were several novel features of this experimental work. Previous research had focussed on paru-dyed (mud dyed, black coloured) muka as Māori textiles constructed from them had been observed for decades to have parlous physical integrity, a cause for considerable concern among conservators and weaving practitioners (Te Kanawa et al., 2008). Previous research by others had demonstrated loss of tensile strength a change of hue in paru-dyed muka caused by accelerated thermal and chemical ageing research (Daniels, 1999), and provided some understanding of the chemical pathways of these changes (Daniels, 1999, Te Kanawa et al., 2008). However, the relationships among colour change, molecular structure and tensile properties when subjected to accelerated light ageing that simulated museum conditions (UV filtered light, temperature and relative humidity controlled) were unknown, particularly for muka dyed with colours other than paru.

Although colour change is one aspect of judging artefact condition, associated physical or chemical change effects exhibition, conservation treatment and storage, and is often thought to accompany colour change. Tensile testing of aged fibre specimens was used to assess changes in strength (tenacity), flexibility (modulus), extensibility (strain) and brittleness (strain to rupture, energy to rupture). Although tensile properties of non-aged, non-dyed muka had been documented (Lowe et al., 2010), and some information was available for tensile strength of paru-dyed muka sampled from artefacts (Daniels 1999), the effects of ageing on tensile properties of muka was not well documented. Identification of plant fibres and the effects of accelerated ageing had been assessed using vibrational spectroscopic techniques to discern changes at the molecular level by others (Edwards et al., 1997, Garside and Wyeth, 2006, Edwards et al., 2006). However, no such spectroscopic data was available for New Zealand plant fibres and dyes. Therefore using multiple experimental approaches, the influence of light exposure and traditional dye treatments on muka properties was examined. Firstly dyed and non-dyed muka were exposed to accelerated light ageing to develop knowledge of rates of colour change for each respective dye condition. Physical and chemical changes to non-dyed and dyed muka were explored in relation to tensile properties and molecular structure. In the process techniques for assessing colour change of inherently variable plant fibres were developed. In this way light fastness (visual assessment and microfading), mechanical (tensile testing) and chemical (ATR-IR spectroscopy) tests were used to develop specific knowledge of safe display parameters for non-, paru (black) and tanekaha-dyed (red-brown) muka. An additional benefit was the ability to compare results from more traditional methods of artificial light ageing (Blue Wool standards) with microfading data.

While the specific results of this experimental work will be published soon (Lowe, Smith, Fraser, Paterson, Ford, Gordon, Hanton, Ngarimu-Cameron, Daroux, forthcoming) there are several aspects of the research that are noteworthy. Firstly traditionally–dyed black and brown muka is more stable to exposure to light than previously thought, and that when colour change is first observable (1JNF) for any of the dye conditions, there is no evidence of concomitant physical or chemical deterioration. It is hoped by the researchers that by using multiple approaches to address concerns about the effects of display on textiles both broadens museum practitioner's understanding of deterioration mechanisms and provides confidence that all aspects of deterioration are being addressed, thereby enabling greater confidence in determining display parameters. Additionally, congruence of datasets gained by the two artificial ageing methods (traditional light ageing and microfading) both increased researcher confidence about making recommendations to museums based on artificial light ageing data and furthered knowledge about new techniques (micro-fading for establishing light stability when on display).

Also of interest is the development of testing regimes and methods that accounted for the inherent variability of plant fibres. To account for known variability in harakeke properties (Lowe et al, 2010), muka was extracted from six leaves taken from three harakeke bushes of a single cultivar. While other conservation science researchers often use a small number of replicates; here a large number of specimens were tested to assess tensile properties in relation to light exposure (i.e. strands of muka; a total of 2160 fibre aggregates, with n = 8 fibres per combination of bush (n = 3) x leaf (n = 6) x dye type (n = 3 - none, tanekaha, paru) x fade level (n = 5 - none, 0.4, 1.2, 3.6, 10 Mlux hours)). Individual dyed and light aged muka strands were tested, using a proven technique developed at the Department of Applied Sciences (Lowe et al., 2010; (Carr et al., 2005) for testing the tensile properties of single muka strands of very small dimensions (e.g. 233 mm, 0.0055g), with test specimens reflecting the standard composition of many Māori textile artefacts, as opposed to European woven fabrics. Statistical analyses, computed in R v. 3.1.0 (Team, 2014) and which accounted for the variability within and among individual plants, were used to assess the influence of dye colour and fading. Use of rigourous experimental and analytical methods, designed to account for the specific aspects of textiles made from endemic New Zealand plants, as well as the use of appropriate descriptive statistics combine to develop good practice in conservation science research.

Testing the efficacy of consolidants for deteriorating tannate-dyed Māori textiles

Analytically robust approaches were also applied to testing the efficacy of a consolidant proposed for use on deteriorating black dyed Māori textiles. Iron-tannate dyes are problematic for textiles as they often cause fibre embrittlement, increased acidity and loss of fibre strength (Daniels, 1996, Daniels, 1998, Te Kanawa et al. 2008). Additionally, metal ions in the iron-tannate dye complex may accelerate acid hydrolysis and oxidation (Wilson et al., 2012), which may be further exacerbated by the degradation of tannic acid over time (Krekel, 1999). Iron-tannate dyes have been used on a variety of cultural materials, and their potentially negative impact on both cellulosic and proteinaceous substrates has long been recognised. Generally speaking, the dyes are produced by combining a plant polyphenol (tannate; which can be derived from a diverse range of sources), with iron salts (also derived from diverse sources) to create a dye complex resulting in the colour black (Hofenk de Graaff et al., 2004). Of the three main dye colours traditionally used in Māori textiles, iron-tannate dyes used to produce black coloured fibre were the most common (Te Kanawa, 2001), and are still in widespread use. The tannin component of the dye comes from either the bark of hinau (*Elaeocarpus dentatus*) or a combination of manuka (*Leptospermum scoparium*) and kanuka (*Kunzea ericoides*). The production of black-dyed Māori textiles is a two stage process. The first involves immersion of the prepared fibre in a bath of the polyphenol (either hinau or manuka/kanuka). After soaking, removal of fibre from the bath and drying, the fibre is then placed in a solution of iron-rich mud, or paru, which is a mordant providing the source of iron ions, resulting in black colouration. Aside from the plant phenol source having an impact on the stability of the resulting black dye (hydrolysable vs. condensed tannins), it is thought that the specific paru used (and therefore abundance of iron (III) ions, and consequently unbound iron (II) ions remaining after the dye complex is formed) may also have an effect on the properties of the resulting dye.

In relation to Māori textiles, most commonly cited examples of deterioration are the detachment of decorative tassels from kākahu and weakening of yarn elements in piupiu (Daniels, 1996, Daniels, 1998), though other Māori artefacts comprised of paru-dyed fibre are also subject to the effects of iron-tannate dyes, for example paru-dyed areas of tāniko borders on cloaks can fail (Tamarapa, 2011). In severe cases, iron-tannate dyed fibres may become highly fragmented or disintegrate completely (Wilson, 2012).

While previous international and national research had explored the deterioration mechanisms of tannate dyed textiles, and made suggestions about how deterioration might be appropriately mitigated, there was a lack of consistency and clarity in both the research carried out, and the resulting recommendations made to conservators caring for deteriorating collections. In 2001 Rangi Te Kanawa, a textile conservator from Te Papa Tongarewa, had proposed a consolidation treatment using sodium alginate for treatment of deteriorated paru-dyed Māori textiles. Therefore the objective of an investigation in Applied Sciences (undertaken in collaboration with Rangi te Kanawa and Te Papa Tongarewa, and funded by the Auckland War Memorial Museum) was to understand the effects of sodium alginate consolidant on the properties of artificially-aged muka dyed with paru, and make recommendations for those in cultural institutions working with deteriorating paru-dyed Māori textiles. Experimental work investigated the properties (colour, tensile, pH) of paru-dyed muka consolidated with sodium alginate, and the effects of light ageing on these properties. Sodium alginate was applied at three different concentrations (0.25, 0.5 and 1 % w/v in water, plus non-consolidated control) to paru-dyed muka (dyes were combinations of two tannin types) and two paru types (sourced from different geographic locations) both before and after accelerated light ageing (two methods of accelerated light ageing were used: textile industry standard (0 – 10 MLux hours) and microfading (0 – 1 Mlux hours); to a total of 800 fibres (with n= 20 fibres (1 fibre from n=20 bushes) per combination of dye (n=5) x consolidant (n=4) x fading (n=2 - none and 10 Mluxhours)). Colour change, tensile strength and pH of consolidated and non-consolidated muka was then measured. Results of this research project, completed in November 2016, will be reported soon.

Both the test and experimental methods used, and the collaborative nature of the research work, reflect the continuing aims of Applied Sciences in regards to this research area: to provide practical guidelines and advice to custodians of Māori textile artefacts based on good science, and to do so in ways the specific needs and composition of New Zealand artefacts. Iron-tannate dyes are not created equal, due to both the variability in tannin source plant (e.g. hinau, manuka or kanuka) and the potential natural variability of the iron-containing paru mud used as a mordant. Whilst several studies testing the efficacy of conservation treatments for iron-tannate dyed artefacts have attempted to reduce the variability in the dyeing process by creating a model substance to replicate the iron-containing mud (e.g. Smith and Te Kanawa, 2008, Wilson et al., 2012) the research project carried out by Applied Sciences made a conscious decision to use actual paru collected from New Zealand sources; firstly to provide a more accurate representation of Māori textile artefacts, and secondly to elucidate the potential effects of paru source on the stability of dyed muka. Test specimens (single traditionally-harvested, processed and dyed muka strands) used by Applied Sciences also reflect the artefacts for which consolidants are being created for. Elsewhere manufactured woven textiles have been developed for testing consolidant efficacy on iron-tannate dyed textiles, which may offer easier conformation to standard test methods for testing of textiles, though have limited relevance to Māori textile artefacts. In these ways, the experimental method of the Applied Sciences research project reflected the unique characteristics and preservation concerns relating to paru-dyed textiles made from harakeke.

Conclusion

Research of relevance to the cultural sector with a focus on conservation of Māori textiles and developing a greater understanding of textile plants endemic to New Zealand has been carried out by researchers at Applied Sciences – Clothing and Textile Sciences over the last decade. During this time advances have been made in regards to plant material identification (minimally invasive, maximum information gained) enabling accurate identification of aged, processed plant material in artefacts, as well as in preservation of Māori textiles made from naturally-dyed and non-dyed muka (establishment of light ageing behaviour and display parameters; examination of efficacy of sodium alginate consolidants). Standard test and experimental methods for testing textiles have been adapted to more accurately reflect the composition and structure of Māori textiles as well as account for the natural variability of plant fibres, whilst maintaining scientific rigour. The principal goal of researchers at Applied Sciences, Clothing and Textile Sciences is to undertake work of relevance to the cultural sector to enhance knowledge about Māori textiles by engaging with those whose focal concern is their ongoing preservation.

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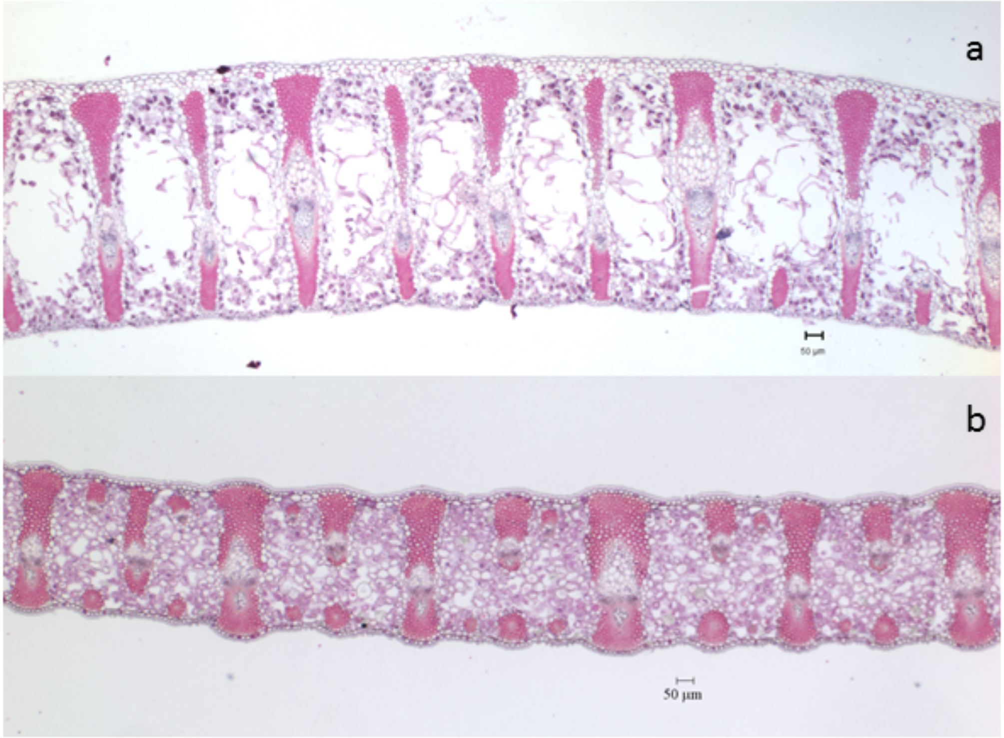

Figure 1. Reference transverse section of a) harakeke - New Zealand flax, *Phormium tenax*, and b) cabbage tree, *Cordyline australis*, J.R. Forst & G. Forst; showing visual similarities

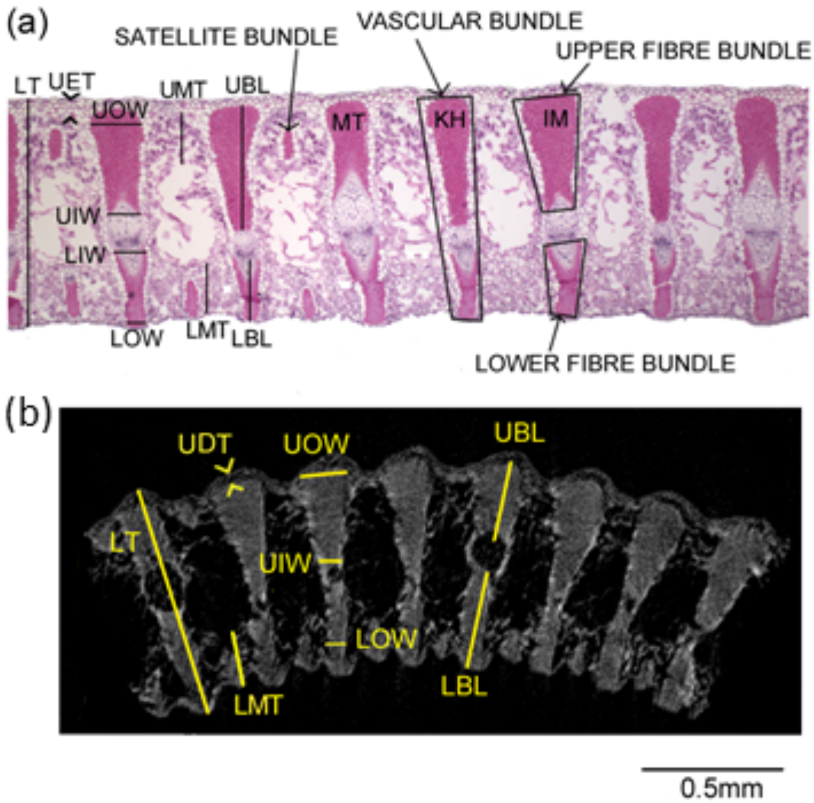

Figure 2. Micro-CT images (a) and transverse sections (b) of harakeke (New Zealand flax) *Phormium tenax*, showing measurable characteristics

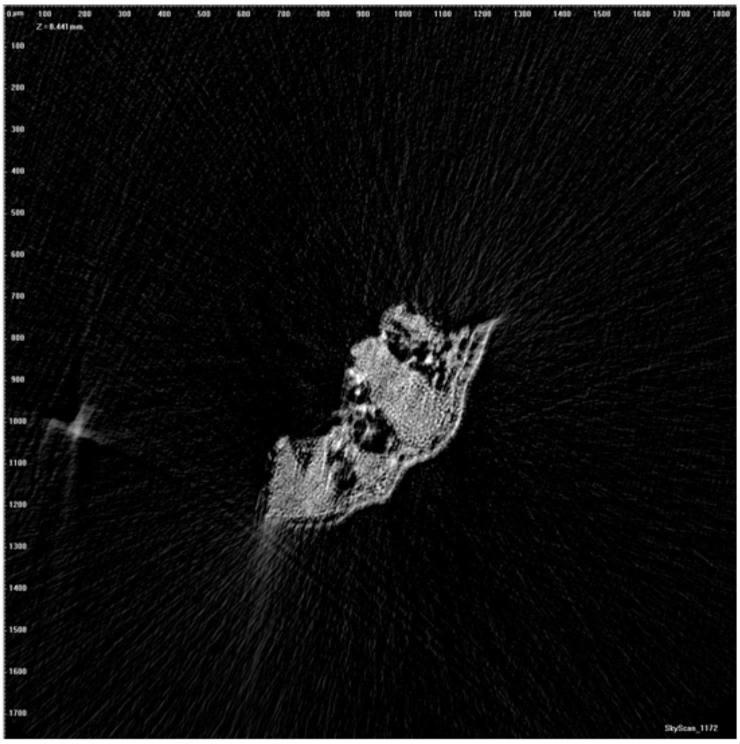

Figure 3. Example of disordered cross-section from specimen taken from artefact

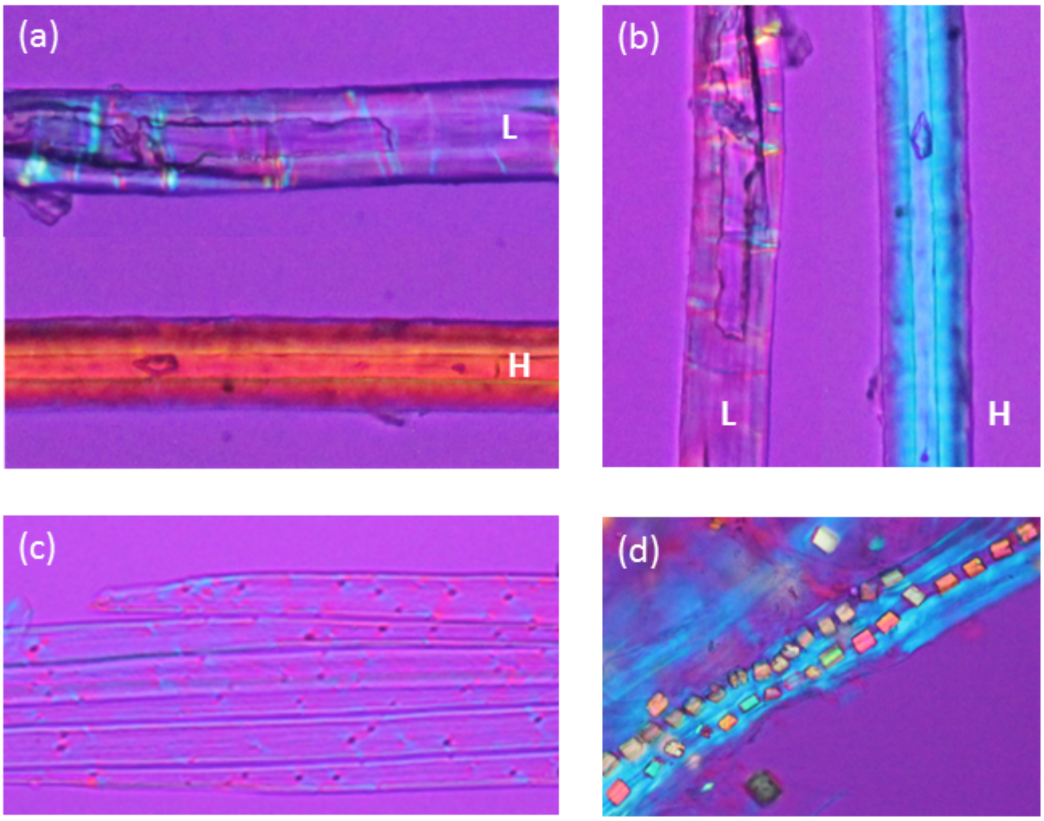

Figure 4. Polarised light microscopy of ultimate fibre cells; demonstrating (a-b) differences in Herzog test between flax *Linum usitissium* (L) and harakeke (H) *Phormium tenax*; and c) cell pitting and cubic calcium oxylate crystals characteristic of kiekie *Freycinetia banksii.*