

**The Effects of Plant Dyes, Watercolours and Acrylic Paints on
the Physical, Chemical and Biological Stability of Japanese
Tissue Paper Used in Paper Conservation**



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February 2015

Thesis submitted in fulfilment of the requirements for the degree of
Doctor of Philosophy, University of Canberra, Australian Capital Territory,
Australia

Abstract

Despite substantial literature on the dyeing of textiles, there is a lack of research about dyeing and colouring Japanese mending papers for paper conservation purposes. In this study, a range of scientific techniques have been applied to improve understanding of the physical, chemical and biological properties of Japanese mending papers after treatment with various dyes and pigments. A variety of toning materials including plant dyes, watercolours, acrylic paints, inks, pastels, gouaches, and colour pencils are commonly used by conservators for paper toning purposes. Plant dyes are often used in artisanal practices including painting, handicrafts, textiles and paper dyeing; however, the chemistry of such colourants and their interaction with Japanese mending papers used in paper conservation has not been studied. The basic premise of this study is that a conservation treatment should not contribute to the physical, chemical or biological degradation of mending papers used for paper conservation purposes and should, ideally, prevent such degradation.

In this study, two Japanese tissue papers (Yukyu-shi and Sekishu Mare) were treated with selected plant dyes, watercolours and acrylic paints. Paper specimens were subject to both moist-heat artificial ageing and accelerated photoageing and colour changes were measured using spectrophotometry and microfading tests (MFTs). Physical experiments (folding endurance, tear resistance) and chemical tests (pH) were used to investigate the paper degradation mechanisms to achieve a better understanding of how paper deteriorates as a result of artificial ageing. The results show that, in general, the papers treated with plant dyes are more acidic than those treated with watercolours and acrylic paints. Almost all of the plant dyes tested in this work showed some degree of fading as measured by spectrophotometry, compared to untreated controls and those samples treated with watercolours and acrylic paints. By contrast, synthetic artists' pigments were relatively stable to colour change. Acrylic paints and watercolours are the most widespread colourants used by paper conservators and their continued use over plant dyes is justified by this study. While their use is undergoing a revival and they are seen to have heritage value as a

traditional product, plant dyes may not be suitable for colour-matching the retouched parts of ancient books and documents because of their propensity for colour change over time.

Dyed papers also displayed less folding and tear resistance after ageing and there was a difference in these properties between Yukyu-shi and Sekishu papers. The untreated Sekishu papers and the Sekishu papers treated with watercolours and acrylic paints exhibited greater tear resistance than the Yukyu-shi papers. The Sekishu and Yukyu-shi papers in untreated form and when treated with acrylic paints, as well as the Yukyu-shi papers treated with plant dyes, demonstrate effective folding endurance after ageing.

A further aim of this thesis was to quantify the growth of *Aspegillus niger* and *Penicillium rubrum* fungal species on Japanese tissue papers with the aid of real time polymerase chain reactions (PCR). This technique amplifies deoxyribonucleic acid (DNA) from the target species which is a proxy for species abundance. Universal PCR primers amplified DNA from both *A. niger* and *P. rubrum* and these species were found to grow preferentially on Yukyu-shi paper, regardless of the treatment. Sekishu papers treated with most plant dyes and chemical colourants were more resistant to fungal growth than similarly treated Yukyu-shi papers.

In summary, this study suggests that for the best long term preservation outcomes for paper materials in archives, libraries, galleries and museums, acrylic artist paints generally perform better in conservation terms than plant dyes and watercolours. This must be balanced against the fact that traditional paper conservation practices may have particular cultural values in some circumstances. Important new insights and opportunities to improve conservation outcomes, and safeguard unique cultural heritage, can be based on the innovative use of an array of scientific techniques that question established canons.

Acknowledgments

I would like to thank all the people who have given me help and guidance during the course of my research studies. In particular, these people include:

Thesis supervisors

- **Dr Tracy Ireland**, Donald Horne Institute for Cultural Heritage, Faculty of Arts & Design, University of Canberra. For proposing a partnership with Forensic Studies for the biological part of the research, providing expertise in conservation ethics and keeping me on track to finish on time.
- **Dr Dennis McNevin**, National Centre for Forensic Studies, Faculty of Education, Science, Technology & Mathematics, University of Canberra. For access to analytical facilities and his assistance with DNA extraction and PCR reaction works.
- **Mr John Greenwood**, Donald Horne Institute for Cultural Heritage, Faculty of Arts & Design, University of Canberra. For conservation advice and introducing me to conservation scientists.

National Centre for Forensic Studies, Faculty of Education, Science, Technology & Mathematics, University of Canberra

- **Dr Michelle Gahan**, National Centre for Forensic Studies, Faculty of Education, Science, Technology & Mathematics, University of Canberra, for training and assistance with DNA extraction and PCR reaction works.
- **Dr Gregory Adcock**, National Centre for Forensic Studies, Faculty of Education, Science, Technology & Mathematics, University of Canberra, for arranging the loan of the climatic chamber.
- **Ms Shirani Katupitiya**, National Centre for Forensic Studies, Faculty of Education, Science, Technology & Mathematics, University of Canberra, for access to analytical facilities.
- **Ms Claire Batum**, Faculty of Education, Science, Technology & Mathematics, University of Canberra, for supplying fungal strains.

All forensic staff who helped me to complete my project.

Faculty of Science, University of Amsterdam

- **Mr Jeffrey Alders**, Masters of Forensic Science candidate, University of Amsterdam, for performing the DNA extraction and PCR reaction works.

National Museum of Australia

- **Mr Bruce Ford**, for performing the microfading tests and providing expertise in the lightfastness properties of dyes and pigments.
- **Ms Nicki Smith**, for arranging access to the microfading instrument.

National Archive of Australia

- **Mr Ian Batterham**, for arranging access to the folding endurance and tear resistance instruments and the loan of the climatic chamber, as well as assistance with disseminating the survey of paper conservation practitioners on the AICCM website.
- **Ms Rajani Rai**, for training on the folding endurance and tear resistance instruments.

Canberra Hospital

- **Ms Helena Beltrami**, of the Microbiology Department of the Canberra Hospital, for supplying fungal strains.

Conservation DistList

- **Mr Walter Henry**, for disseminating the survey of paper conservation practitioners on Conservation DistList Forum.

Network Temático MEEP Forum

- **Ms Valeria Orlandini**, Paper and Photographic conservator, Maryland, USA, for disseminating the survey of paper conservation practitioners on Network Temático MEEP Forum.

American Institute for Conservation, Book and Paper Group (AIC-BPG)

- **Ms Priscilla Anderson**, senior book conservator and AIC-BPG chair, for sharing the survey of paper conservation practitioners with AIC-BPG especially in the U.S.

Mr Neil Urwin, for his kind help in editing the thesis.

Finally, and most importantly, I would like to thank my husband who supported and assisted me in every way. Without his emotional support, I could not have walked this journey so steadily.

Contributions

Report

- Freeman, S & Soleymani, S, ‘*Medieval Palette workshop Report*’, AICCM Newsletter, No. 128, July 2014, Canberra.

Conference presentations

- Soleymani, S, ‘Antifungal properties of dyes and pigments used for toning Japanese tissue papers’, *National Centre for Forensic Studies, Faculty of Education, Science, Technology & Mathematics, University of Canberra*, Canberra, 29 November 2013.
- Soleymani, S, ‘Antifungal properties of dyes and pigments for colouring Japanese tissue papers’, *The Centre for Cultural Materials Conservation, University of Melbourne*, Melbourne, 24 October 2013.
- Soleymani, S, ‘Anti-fungal properties of plant dyes, watercolours and acrylic paints for colouring Japanese tissue papers in paper conservation’. *Australian Institute of Cultural Conservation Materials*, Canberra, 4 October 2013.

Workshop

- Laboratory assistant in Mediaeval Palette Workshop presented by Ms Cheryl Porter, University of Canberra, 12-16 May 2014.

Achievements

- Statement of accomplishment of the Writing in Science course, Stanford University, August-November 2013.
- 3MT (three minute thesis finalist), University of Canberra, 2012.

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Abbreviations

Abbreviation	Definition
A	Adenine
<i>A. niger</i>	<i>Aspergillus niger</i>
APP	<i>Aspergillus</i> and <i>Penicillium</i> primers
AP	Acrylic paints
aq	aqueous
ASP1-ASP3	<i>Aspergillus</i> primers
ASPn	<i>Aspergillus niger</i> primers
a*	redness-greenness
b*	yellowness-blueness
bp	base pairs
BSA	bovine serum albumin
BS	British Standard
BWS	Blue Wool Standard
BWE	Blue Wool Equivalent
BWFSs	Blue wool fading standards
C	Cytosine
°C	degree centigrade
C	catechin
CG	catechin gallate
cm	centimetre
CI	confidence interval
CIE	International Commission on Illumination
Ct	cycle threshold
ΔE	colour change
ΔL^*	lightness change
Δa^*	redness-greenness change
Δb^*	yellowness-blueness change
ΔC	chromaticity change
Δh	hue change
DNA	deoxyribonucleic acid
dNTP	dinucleotide triphosphate
DP	degree of polymerisation
dsDNA	double stranded deoxyribose nucleic acid
DTT	dithiothreitol
dH ₂ O	deionised water
EC	epicatechin
ECG	epicatechin gallate
EGC	epigallocatechin
EGCG	epigallocatechin gallate
E. leaves	Eucalyptus leaves
EDTA	ethylenediaminetetraacetic acid
G	Guanine
g	grams
G	gravity
GC	gallocatechin
g/L	grams per litre

Abbreviation	Definition
g/m ²	grams per square metre
IBM	International Business Machines
IDT	Integrated DNA Technology
ISO	International Standards Organisation
ITS	Internal Transcribed Spacer
K	Kelvin
Kg	kilograms
kPa	Kilopascal
L*	lightness-darkness
Lux	lumens per square metre
Lysis buffer	10mM Tris base, 1mM EDTA, 100mM sodium chloride and 2% Tween 20 with pH 8.0
MΩ.cm	megohm centimetre
MFT	Microfaing test
Mlx	millilux
mg	milligrams
mL	millilitre
mm	millimetre
mM	millimolar
M	molar
Mdiff	Mean difference
mN	millinewton
μM	micromolar
μm	micrometre
u/μL	units per microlitre
μL	microlitre
μg/μL	microgram per microlitre
ng/mL	nanogram per millilitre
ng/μL	nanogram per microlitre
nm	nanometre
NaCl	sodium chloride
PD	Plant dyes
PCR	Polymerase Chain Reaction
PEN	<i>Penicillium</i> primers
pH	Power of Hydrogen
<i>P. rubrum</i>	<i>Penicillium rubrum</i>
qPCR	quantitative polymerase chain reaction
R	Registered
RFU	relative fluorescence unit
RH	relative humidity
RNA	ribonucleic acid
rRNA	ribosomal ribonucleic acid
Rpm	revolutions per minute
SCI	Specular component included
Sekishu	Sekishu Mare
T	Thymine
TAPPI	Technical Association of Pulp and Paper Industry
TE	Tris-EDTA

Abbreviation	Definition
TE buffer	10 mM Tris, 0.1 mM EDTA, pH 8.0
TM	Trademark
T _m	Melting temperature
Tris	2-Amino-2-hydroxymethyl-propane-1,3-diol
UN1	Universal primers
UN2	Universal primers
UV	Ultraviolet
W	watt
WC	Watercolours