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Introduction

When conservators try to find a specific type of Eastern paper for a certain project, they think about visual specifications, permanence and durability, and, of course, about the price. Unless they are familiar with the language, most conservators have a hard time even remembering the names of Eastern papers. What is more, familiar names of some Japanese papers, *minogami*, or *sekishushi*, no longer assure they are made from 100% Japanese *kōzo*.

It is rare that papermakers themselves directly sell their papers, so naturally most conservators buy papers from vendors. If we do not have information about how the raw materials, preparation and process of papermaking influence the final quality of the paper, we have to depend on what vendors describe as 'archival' or 'good for conservation'.

Understanding artificial ageing tests of Eastern papers

Evaluating conservation quality Eastern papers is a complicated matter. Numerous factors can influence the permanence of the paper, and often those factors are linked together or result from one another. Artificial or accelerated ageing tests have been performed to obtain insights into the properties of the paper and gauge the long-term stability of papers. In present artificial ageing tests, it is still not possible to equate a certain number of artificially aged days with years of natural ageing, especially in the case of handmade paper.

Despite this fact, it remains one of the most valuable methods of understanding which intrinsic properties lead to long-term permanence and durability of paper, by measuring colour stability and strength before and after artificial ageing. In several research tests, Chinese, Korean and Japanese papers were degraded at 80° C to 90° C and 45% to 50% RH for 3 to 4 weeks, or for 16 weeks. Tested papers were evaluated for brightness, tensile strength, pH and DP (degree of polymerization) before and after artificial ageing tests.[1] For example, the pH is an important factor which influences the strength and colour stability of paper. A study showed that, when the pH of paper made from paper mulberry falls below pH 5, the strength decreases and paper yellows at a faster rate.[2]

The author would like to emphasize that these artificial ageing tests have been performed at different temperatures and humidities, and even over different periods of time. The results are intended to compare and evaluate one paper's performance over another under test conditions, rather than to judge the ageing performance of a specific paper in absolute terms, nor to generalize and apply these results to other papers of the same type.

In addition to ageing tests, SEM (Scanning Electron Microscope) images can reveal types of fibre, its distribution, fillers and inorganic ingredients; for example, paper mulberry often contains silica, potassium, aluminium and calcium.[3]

1 Masamitsu Inaba and Ryuichiro Sugishita (Sugisita), 'Permanence of *washi* (Japanese Paper)', in *The Conservation of Far Eastern Art*, ed. John S. Mills et al., preprints for the contributions to the Kyoto Congress, IIC, London (1988), 1–4; Tanya T. Uyeda, Kyoko Saito, Masamitsu Inaba and Akinori Okawa, 'The Effect of Cooking Agents on Japanese Paper', *Restaurator* 20 (1999): 119–25; Masamitsu Inaba et al., 'The Effect of Cooking Agents of *washi* (Part II)', *Restaurator* 23 (2002): 133–44; Minah Song and Jesse Munn, 'Permanence, Durability and Unique Properties of *Hanji*', *The Book and Paper Annual* 23 (2004): 127–36; Fei Wen Tsai and Dianne Van der Reyden, 'Technology, Treatment, and Care of a Chinese Woodblock Print', *The Paper Conservator* 21 (1997): 48–62; M. Brigitte Yeh and Jesse Munn, 'An Evaluation of *xuan* Paper Permanence and Discussion of Historical Chinese Paper', in *Scientific Research on the Pictorial Arts of Asia*, ed. Paul Jett et al., Proceedings of the Second Forbes Symposium at the Free Gallery of Art (2005), 65–74; Gang Chen, Kyoko Saito Katsumata and Masamitsu Inaba, 'Traditional Chinese Papers, their Properties and Permanence', *Restaurator* 24 (2003): 135–44; Catherine H. Stephens and Paul M. Whitmore, 'Comparison of the Degradation Behavior of Cotton, Linen and *Kozo* Papers', *Cellulose* 20 (2013): 1099–1108.

2 Inaba and Sugishita, 'Permanence of *washi*', 3.

3 Agnieszka Helman-Wazny, 'Recent Research on Historic Paper Components in East Asian Art Objects', in *Scientific Research on the Practical Arts of Asia—Proceedings of the Second Forbes Symposium at the Freer Gallery of Art*, ed. Paul Jett et al. (Archetype Publications, 2005), 62.

Fig. 1 Paper mulberry tree. Image copyright Aimee Lee.

Having observed historic papers made from paper mulberry which are up to 200 years old, the author has not found significant decrease of physical strength; the most noticeable problems are staining and foxing. It would be important to investigate the causes of these problems, as they have a significant impact on conservation treatments.

In order to understand the chemical changes in historic papers, a non-destructive or micro-destructive testing method would be useful. Unfortunately, this method requires highly sophisticated and expensive instruments. Still, there is high demand for non-destructive or micro-destructive analytical methods, since they can help to assess the current condition of historic papers and reveal the degradation mechanism.[4]

Contemporary Eastern fibres used in conservation

1 Paper mulberry

Paper mulberry is a key fibre in Korean and Japanese papermaking (Fig. 1). The varieties of paper mulberry, *Broussonetia kazinoki* Sieb. and *Broussonetia papyrifera* Vent., have been crossbred for a long time, and now it is difficult to distinguish between them. Paper mulberry is the most versatile fibre; it can produce extremely thin but strong and durable paper. It grows all over East Asia and in some areas of South Asia. Higher quality paper mulberry producers are mainly Korea and Japan. Nowadays, due to a shortage of paper mulberry, Thai and Laos paper mulberry is exported, and gradually a higher percentage of Japanese and Korean paper is made from Thai and Laos paper mulberry.

Paper mulberry that grows in colder areas tends to be finer, shorter and stronger, compared to one that grows in warmer climate. Nasu *kōzo* in Ibaraki prefecture, located north-east of Tokyo, can be an example here.[5] Paper mulberry grown in a much warmer climate, in Thailand and Laos, has a high content of resin and oil in the bark, sometimes visible as black or brown dots on the bark itself.[6]

In terms of soil, it has been reported that paper mulberry grows well in soil that is rich in nitrogen, phosphorus and calcium, and is pH neutral.[7]

Mulberry (*Morus alba* L.), *sang* in Chinese, belongs to the same family as paper mulberry, but it is a different fibre. Because of the similar name, it is often confused with paper mulberry. Mulberry fibre is not used to make conservation quality paper. It is planted for the cultivation of silkworms, and used to make paper in northern China, together with hemp and paper mulberry.[8] Historically, in Korea and Japan, when there was a shortage of paper mulberry, mulberry was mixed with paper mulberry (20% to 40% of mulberry) rather than used alone.[9]

4 Maria Cristina Maria Area and Herve Cheradame, 'Paper Aging and Degradation: Recent Findings and Research Methods', *BioResources* 6, no. 4 (2011): 5329.

5 *Minogami* and Berlin tissue are made from Nasu *kōzo,* from Ibaraki prefecture, *tengujo*, *udagami*, *misugami* are made from Tosa *kōzo,* from Kochi prefecture in Shikoku Island, and *sekishushi* is made from Shimane *kōzo*, grown near Hiroshima.

6 Maria Miguel Ribeiro and Ika Darnhofer, 'Understanding the Supply Chain of Paper Mulberry Bark in Lao PDR using Casual Mapping', http://www.wiso.boku.ac.at/laos.html (accessed 5 January 2015), 45.

7 Dr Sungchul Park from Hanji Industry Support Center, in discussion with the author on 3 March 2015.

8 Gang Chen and Xuejin Zhang, 'The Characteristics of Traditional Papermaking Techniques in Northern China', in *Research on Paper and Papermaking Techniques: Proceedings of International Workshop*, *Senri Ethnological Studies (SES)*, ed. Naoko Sonoda et al., 85, National Museum of Ethnology, Japan (2013): 117.

9 Dr Hyunjin Cho from Chohyunjin Hanji Research Center, in discussion with the author on 4 March 2015.

2 *Mitsumata*
Mitsumata fibre is shorter than paper mulberry, and paper made of it is relatively opaque and has a smooth surface. It is good for filling losses in parchment and clay-coated paper. Compared to paper mulberry, *mitsumata* paper is weaker and is subject to surface abrasions.

3 *Gampi*
Gampi fibre is also shorter than paper mulberry, but it produces strong paper. The paper has a distinctive natural lustre. It absorbs oil well and has good printability, so it is often used for *chine-collé* prints. *Gampi* paper can be cockled easily since it is sensitive to moisture. Philippine *gampi* paper is also available on the market. It is less shiny, soft and more absorbent, when compared to Japanese *gampi*. A study showed *gampi* paper can be useful as barrier paper for applying gel poultices, since it has the right porousness to transfer moisture to treated areas.[10]

4 Blue sandalwood and rice straw
Blue sandalwood is a bast fibre and rice straw is a grass fibre. These are major fibres for Chinese *xuan* paper, mostly made in Anhui province. X*uan* paper is weaker than the other papers in the list. It contains clay filler, so it can be useful for projects requiring opacity and low physical strength.

5 *Abaca* (Manila hemp)
Abaca is a leaf fibre and is used to make lens tissue and spider tissue. It is not much used any more for repair or lining, but is still in circulation, since the price is less than 10% of high quality Japanese paper.

Paper mulberry papermaking process
Every step in papermaking is essential, and each can affect the quality of the paper.

1 Harvesting
Paper mulberry sprouts are harvested yearly in Korea and Japan, from November through February (Fig. 2). It is best to cut them between five to eight years after the parent trees have been planted. After the paper mulberry is harvested, sprouts are cut into lengths of about one metre and tied in bundles. Due to the warm climate in Laos and Thailand, paper mulberry can be harvested every three to four months.

Fig. 2 Harvesting paper mulberry. Image copyright Aimee Lee.

10 Jeffery Warda, Irene Brückle, Anikó Bezúr and Dan Kushel, 'Analysis of Agarose, Carbopol, and Laponite Gel Poultices in Paper Conservation', *Journal of the American Institute for Conservation* 46, no. 3 (2007): 273.

Fig. 3 Steaming harvested paper mulberry. Image copyright Aimee Lee.

Fig. 4 Removing black and green layers of bark. Image copyright Aimee Lee.

2 Steaming and stripping

The cut sprouts, tied in bundles, are steamed for several hours to soften the bark and remove impurities (Fig. 3). The bark is then removed from the woody core by stripping. Thai and Laos paper mulberry does not require this steaming process because the bark can easily be peeled off. Although, if the steaming process is skipped, some impurities are not removed. Farmers in Thailand and Laos are requested by Japanese companies—who are the biggest client—to steam the paper mulberry after harvest. However, most farmers do not have access to proper equipment and the difficulty of carrying out this process means they would rather sell cheap, unsteamed paper mulberry.[11]

The peeled bark is usually dried and sold to a papermaker. Before scraping the black bark, it is soaked to facilitate the process. The bark is stripped from the woody core and black and/or green layers of bark are usually removed (Fig. 4). Conservation quality paper mulberry papers are composed primarily of the white bark, barring a few examples made of a white and green bark mixture.

3 Cooking with alkali

The cooking process removes the non-cellulosics, such as lignin, pectin, waxes and gums, from fibres by solubilizing them in a hot alkali solution. This process aids the disintegration of bark into fibres. If these non-fibrous components are not removed, it is very difficult to separate fibres during the beating process. The bark is immersed in water in a cauldron, and when the water boils, alkali is added. It takes several hours, depending on the type of fibre, its age, quality, the kind of alkali used and the projected type of paper. If the fibre is sufficiently cooked, all strands part easily with very slight resistance with and against the grain (Fig. 5).

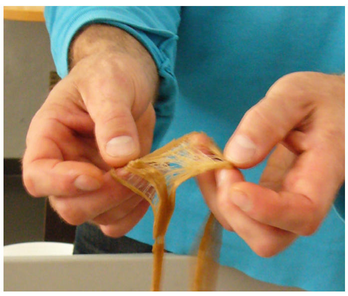

Fig. 5 Checking cooked paper mulberry. Image copyright Minah Song.

11 Ribeiro and Darnhofer, 'Understanding the Supply Chain', 44.

Fibres can be cooked with mild alkali or strong alkali using 15% to 20% of the weight of the dry fibre. Mild alkali does less harm to the fibres, so the finished paper will have characteristics of gentle crispiness and light glossiness. If mild alkali is used, workers have to hand-pick impurities for long hours.

Traditionally, papermakers used wood ash. Wood ash is produced from different types of wood, such as hardwood or softwood, soybean husks, reeds, chilli husks, buckwheat husks and rice straw.

Paper cooked with wood ash has a distinguishable lustre compared to other papers. Wood ash is rich in calcium, potassium, magnesium, manganese and silica.[12]

Because burning a large amount of plants and collecting ashes is getting more difficult, in contemporary papermaking for conservation quality paper, mild alkali, soda ash (sodium carbonate) is mostly used and some papermakers use potassium carbonate and slaked lime (calcium hydroxide). Slaked lime is not a popularly used alkali, compared to soda ash, but still some papermakers use it in China and Japan. It is not clear if slaked lime is either strong alkali or mild alkali. In previous studies, it has been considered as a strong alkali compared to wood ash and soda ash.[13] In practice, however, it is regarded as a mild alkali.[14] Paper cooked with a strong alkali such as caustic soda (sodium hydroxide) does not have natural lustre since fibres are more damaged by the cooking agent.

4 Refining fibres

After cooking, fibres are thoroughly rinsed to remove residual alkali. Interestingly, *sekishushi* does not go through a rinsing process after cooking.[15] Fibres are then washed again in cold water and any remaining specks of black bark are hand-picked. It requires care to produce paper without any dark spots. In the papermaking process of *misugami*, scars or hard spots are cut with scissors and a knife before cooking, so the extra refining process is not generally required.[16]

This process is one of the most tedious stages in papermaking (Fig. 6). If it is not properly done, it becomes more difficult to pick the specks after the fibres are beaten. Any dark spots can lower the quality of finished paper. The paper mulberry fibre is too long to be cleaned by any mechanical device; manual work is the only option. It is not an easy task to wash the white bark and not to waste it. The only way to do it is to pick out impurities

12 Dr Park, in discussion with the author on 3 March 2015.

13 Inaba and Sugishita, 'Permanence of *washi*', 4; Uyeda et al., 'Effects of Cooking Agents', 125; Inaba et al., 'Effect of Cooking Agents (Part II)', 144.

14 Mr Hiroyoshi Chinzei from Hidaka Washi, in discussion with the author on 15 January 2015; Dr Park, in discussion with the author on 3 March 2015.

15 Masazumi Seki, 'Database of Traditional Papermaking Centers in East Asian Regions', *Research on Paper and Papermaking Techniques: Proceedings of International Workshop*, *Senri Ethnological Studies (SES)*, 85, National Museum of Ethnology, Japan (2013): 73.

16 Seki, 'Database of Traditional Papermaking', 71.

Fig. 6 Picking out impurities. Image copyright Aimee Lee.

Fig. 7 Beating cooked fibre by hand. Image copyright Bohyung Kim.

one strand of bark at a time, which is mostly done by local women. Longer hours of this hand-picking process are needed, in particular, if the fibres are cooked with a mild alkali. In order to save time and labour involved in the hand-picking process, some papermakers use strong alkali, to produce lesser quality paper.

5 Beating

The purpose of beating paper mulberry is to separate the fibres, causing them to disintegrate. In the case of cotton or hemp fibres, beating refers to fibrillation that involves partial delamination of the cell wall, resulting in a microscopically hairy appearance of the wetted fibre surfaces. Beating changes the shape of the original fibres and stimulates water absorption, so that hydrogen bonding among fibres can be increased.[17]

Because paper mulberry fibre is long and tends to tangle and intertwine easily, it does not require this fibrillation process. Traditionally, beating was done by hand with a wooden mallet or a stick, on a stone or wooden p anel (Fig. 7). Hand-beaten paper mulberry fibre retains its length and well-beaten fibre floats freely, without clumps, when submerged in a cup of water and mixed.

In order to expedite the process, in contemporary papermaking mechanical beaters have been adapted, such as a stamper and *naginata* (Fig. 8). These beaters are designed to simulate hand-beating process. The curved and

17 Cathleen A. Baker, *From the Hand to the Machine—Nineteenth-Century American Paper and Mediums: Technologies, Materials, and Conservation* (The Legacy Press, 2010), 32–33; Anna K. Vainio and Hannu Paulapuro, 'Interfiber Bonding and Fiber Segment Activation in Paper', *BioResources* 2, no. 3 (2007): 445.

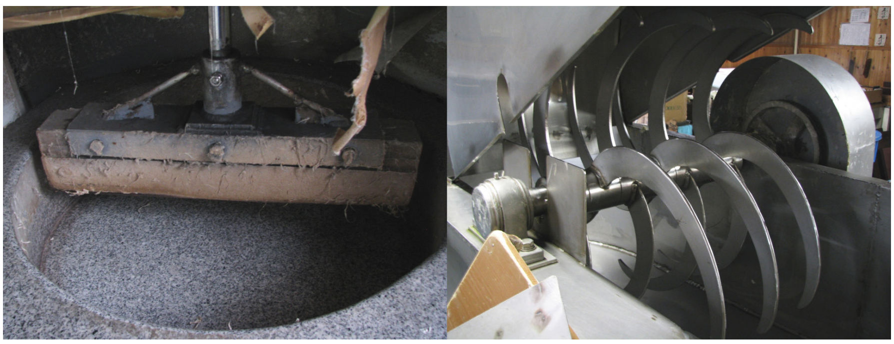

Fig. 8 Stamper (left), *naginata* (right). Image copyright Aimee Lee.

blunt blades of *naginata* beater have been invented to separate fibres without compromising the length. Depending on the age or condition of paper mulberry—or the projected paper—different methods of beating process are chosen: either hand-beaten only or a combination of hand-beaten and mechanically beaten. A Hollander beater is used if maintaining length of fibre is not important, normally for lesser quality paper.

It is often considered that the length of the paper mulberry fibre contributes to the strength of the resulting paper. Poorly beaten fibres, however, cannot produce paper with good fibre distribution, which is an important factor of the strength of paper.

6 Forming sheets

During this step, the processed fibres take the form of paper. Papermakers work in a dynamic and rhythmic movement that requires high concentration and a great sense of momentum.

In papermaking using paper mulberry, there are different types of sheet formation with local variations. These are developed by papermakers who work with a certain type of paper mulberry and aim to produce a certain type of paper. For example, traditionally in Thailand and Laos, paper mulberry paper is made by a pouring method: a mould is submerged in a vat, fibres are added to a submerged mould and dispersed by hand. Formed sheets are left on the mould to dry without couching.

Currently, a prevalent papermaking technique using paper mulberry is the Japanese *nagashizuki* method, adapted in Korea, China, Bhutan and Thailand. Several Western craftsmen have learned the technique and have started producing Japanese-style paper in their own countries. Some of them have also started to grow paper mulberry in their home countries. It would be interesting to know how different paper mulberry papers will be produced from paper mulberry harvested from different regions.

Historically, another Japanese papermaking technique, the *tamezuki* method, which is similar to Western papermaking style, preceded *nagashizuki*. Today it is mainly used to produce paper for postcards and diplomas. During the second half of the twentieth century, paper made with the *tamezuki* method was exported to Europe and became a popular paper for lithographs, used by, among others, Chagall and Miró.[18] Dali and Kollwitz are also known to have used those papers for their prints.

The unique traditional Korean technique of sheet formation is called *webaltteugi* (Fig. 9). The mould, made from the white pine tree (*Pinus koraiensis*), does not have an upper frame or deckle to hold the fibres.[19] The screen, twice as long as it is wide, rests on the mould, the length extending away from the papermaker. The chain lines in the finished paper are parallel to the longer edge. Korean paper made with *webaltteugi* technique is generally two-ply. A papermaker couches each sheet on top of another

Fig. 9 Korean *webaltteugi* sheet formation method by Hyunse Shin. Image copyright Bohyung Kim.

18 'Examining Oriental Papers: A Workshop with Akinori Okawa', *Looking at Paper—Evidence and Interpretation, Symposium Proceedings*, *Toronto* (1999): 251–52.

19 Aimee Lee, *Hanji Unfurled: One Journey into Korean Papermaking* (The Legacy Press, 2012), 66.

Fig. 10 Japanese *nagashizuki* sheet formation method by Satoshi Hasegawa. Image copyright Minah Song.

from the opposite direction and dries the two together as one sheet. Sadly, this centuries-old technique has almost vanished.

Nagashizuki has some local variations in terms of how many times fibres are swished back and forth or side to side (Fig. 10). A Japanese mould, made of clear-grained cypress trees, consists of a screen and two hinged frames. The mould is landscape oriented with the width extending away from the papermaker. The basic principle is paper layers are built up through multiple dips. Mastering this skill requires long years of training.

The *nagashizuki* method enables a papermaker to control the thickness of paper produced, from extremely thin to relatively thick. An essential element in this method is the formation aid because paper mulberry has long fibres and tends to entangle. Without formation aid it is difficult to form large and thin sheets of paper.

Formation aid helps to build an even thickness by slowing the drainage through the screen. By increasing the amount of formation aid in a vat, a papermaker can make very thin layers, such as *tengujo*. That is why making *tengujo* requires much more formation aid compared to other papers.

The traditional formation aid in Japan, Korea and China is extracted from the roots of the aibika plant (*Abelmoschus manihot*), known as *tororo aoi* in Japanese.[20] The other Japanese traditional formation aid is the inner bark of *Hydrangea paniculata* Sieb., known as *noriutsugi*. The natural formation aid loses its properties during continuous stirring under warm temperatures. This is one of the reasons papermakers need to keep the temperature cool in a vat.

There have been several misunderstandings regarding the function of formation aid, as presented in a couple of studies; the formation aid acts as an adhesive or sizing, and a high level of formation aid makes the paper glossy, while the finished paper may become translucent if it is treated with high heat.[21] Even though the formation aid plays a critical part in sheet formation, when the paper is dried the remaining traces are too minuscule and insignificant to affect the properties of the finished paper.

Traditional formation aid is used for most conservation quality handmade paper mulberry paper.

Synthetic formation aid, PAM (polyacrylamide), has been introduced to contemporary production since it is easily available and not affected by temperature. In particular, greater production of Japanese machine-made paper mulberry paper has adopted PAM for efficiency of time and labour.[22] There has not been information about its long-term effect on the permanence

20 Ingredients of extract from roots of aibika are lime, sugar, starch, arabinose, rhamnose, galatrouronic acid, galactose, lignin and protein; Song and Munn, 'Permanence, Durability and Unique Properties', 129.

21 Silvie Turner and Birgit Skiold, *Handmade Paper Today A Worldwide Survey of Mills, Papers, Techniques and Uses*, (Lund Humphries, 1983), cited by Martin A. Hubbe and Cindy Bowden, 'Handmade Paper: A Review of its History, Craft, and Science', *BioResources* 4, no. 4 (2009): 1764; Keiko Mizushima Keyes, 'Japanese Print Conservation—An Overview', in *The Conservation of Far Eastern Art*, ed. John S. Mills et al., preprints for the contributions to the Kyoto Congress, IIC (London, 1988), 33.

22 Hiroyoshi Chinzei from Hidaka Washi, in discussion with the author on 11 March 2015.

Fig. 11 Pressing the post. Image copyright Aimee Lee.

Fig. 12 Drying paper on wooden boards. Image copyright Aimee Lee.

Fig. 13 Drying paper on heated steel dryers. Image copyright Aimee Lee.

and durability of paper. As long as there are no undissolved lumps of PAM solution, it seems any residue of synthetic formation aid in the finished paper has a negligible effect.[23]

23 Dr Park, in discussion with the author on 3 March 2015.

7 Couching, pressing and drying

Once a sheet is formed, a papermaker removes the screen from the mould, using the support of the screen. Each formed sheet is laid flat on the post without any interleaving. Usually, a thread is placed along the edge of the paper for ease of parting. In the process of laying the screen down and then lifting it, air bubbles can easily occur if not taken care of immediately, and the traces can be visible when the paper is dried.

After a papermaker deposits wet sheets directly on top of each other, the post is left pressed overnight at moderate pressure with a wooden board weighing it down. Today, a hydraulic jack press is commonly used (Fig. 11). The pressure is raised gradually, which increases cohesion within the paper. The next day, damp paper is dried on a wooden board or on a heated stainless plate. The wooden board is mostly made of pine, ginkgo and horse chestnut trees (Fig. 12).

Drying paper on a wooden board allows natural contraction of the wet sheet, and if it is dried outside it can be whitened by sunlight. It is, however, very difficult to control the amount of sunlight, therefore the whiteness can vary by batch. Many papermakers in Korea and Japan now use steam-heated stainless steel dryers (Fig. 13). High temperatures make the wet sheet shrink rapidly and the paper surface tight and stiff. For this reason, although it is very subtle, compared to paper naturally dried on a wooden board, paper dried on a heated metal plate feels slightly stiffer.

Important factors related to properties of paper mulberry paper (Fig. 14)

1 Raw materials

The characteristics and quality of fibre and its origins influence almost every part of final characteristics of paper. Nasu *kōzo*, grown in a colder climate, is shorter, so it produces slightly stiffer and denser paper compared to paper made from Tosa *kōzo*.[24]

24 Seki, 'Database of Traditional Papermaking', 67.

Korean and Japanese paper mulberry fibres have similar content of α-cellulose with Thai paper mulberry—about 77% to 88%. However, Thai paper mulberry requires strong alkali to remove impurities, resin and oil in the bark, so the fibres are more damaged during the process.

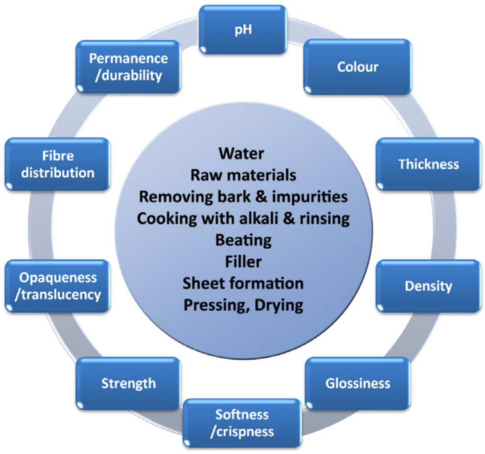

Fig. 14 Key factors in the papermaking process and properties of paper. Image copyright Minah Song.

2 Water

Water is one of the most important factors in papermaking because papermakers have to use water throughout the process. Traditionally, papermakers built a paper mill in the mountain in order to have continuous supply of water without heavy metal ions that can cause stains or foxing in the paper. Soft water helps the swelling of cellulose fibre which leads to easy beating and good sheet formation. Heavy metal ions in water can make paper darker and may catalyse degradation of cellulose in the presence of oxygen or moisture.[25]

25 Hubbe and Bowden, 'Handmade Paper', 1754.

3 Removing bark and impurities

The process of removing bark and impurities influences colour, fibre distribution, strength and permanence of paper. Steaming stalks after harvesting is not only to aid stripping of the bark but also to remove impurities. If impurities are not cleanly removed, they interfere with beating and the following sheet formation process. Most paper mulberry produced in Thailand and Laos is not steamed before the bark is removed, which can cause resin specks, visible as tiny white spots in the finished paper.

Having a green layer of bark can have an effect on the colour of paper because a green layer has higher content of lignin (5% to 10%) and hemicellulose (9%). These can contain chromophores, parts of molecule that appear coloured due to selected absorption of light. For example, Japanese paper, *sekishushi,* is made of both white and green layers of bark (40:60), so the finished paper has a slightly greenish hue.

4 Cooking

The cooking process affects visual specifications, strength and permanence of paper. If fibres are not sufficiently cooked, beating fibres becomes difficult, and well-beaten fibres are critical for good sheet formation.

Typically, unbuffered paper made from paper mulberry has a pH in the neutral range. If the papers do not have an alkaline reserve—often obtained from fillers—yet have a high pH value, it is possible to consider that the cooking alkali was not thoroughly washed out and left residues in the fibres. A study showed that residual mild alkali can improve the buffering capacity of paper.[26] If the pH of finished paper, however, is higher than neutral ranges, conservators should consider the working properties of the paper with pH sensitive objects.

26 Chen et al., 'Traditional Chinese Papers', 140.

Paper cooked with wood ash and soda ash has more natural tone and glossiness, since those are gentler with fibres. On the other hand, paper cooked with caustic soda exhibits a whiter, cleaner, less glossy appearance. Cooking with slaked lime produces softer paper and gives a slight yellowish to pinkish hue to the paper.

5 Refining fibres

After cooking, the more the fibres are rinsed, the whiter they become. Even if the colour looks 'natural' to our eyes, it does not mean the fibres have not been chemically bleached. Sometimes, papermakers use chemical bleach to further whiten the fibres after cooking with strong alkali, and colour the paper during sheet formation. However, even if the colour looks unbleached, the finished paper lacks the lustre produced by healthy fibres.

6 Beating

The purpose of the beating process of paper mulberry is to cause the disintegration of fibres to facilitate good formation; therefore, it is directly related to even fibre distribution in sheet formation which influences physical strength of paper, and permanence.

7 Fillers

A common practice to make paper mulberry paper opaque is to add fillers. One of the Japanese papers, *udagami,* has clay loading, and *misugami* is loaded with *gofun* (calcium carbonate obtained from shell of oyster or clam). Fillers such as calcium carbonate can contribute to buffering capability. The fillers can also minimize the shrinkage of paper by filling spaces between fibres.[27]

27 'Examining Oriental Papers', 250.

8 Sheet formation

During sheet formation of the *nagashizuki* method, density and thickness of paper can be controlled by numbers of dips and amount of formation aid. The thickness of paper is generally built up by multiple dips. If the amount of formation aid is increased, thinner paper can be produced. Thicker paper can be also produced by couching a couple of sheets and pressing and drying them together.

A skillful papermaker can form sheets with even fibre distribution and thickness. Depending on how well or poorly it is done, the physical strength of the paper can vary. Machine-made paper tends to be less dense than handmade, even if they are of the same weight. It is probably due to the way machine operates when forming the sheet.

In the course of Japanese *mino* paper sheet formation, a papermaker adds front and back movement along with side to side, so the grain direction can be more even and less pronounced.

9 Pressing and drying

The pressing process prior to drying increases hydrogen bonding and cohesion between fibres. Consequently, unpressed paper feels softer and more supple. A kind of Japanese paper, *misu* paper, is placed on a wooden board and dried without being pressed, so the resulting sheet is noticeably softer.

Natural drying on a wooden board under the sunlight can contribute to the whitening of paper. Drying on a wooden board versus drying on heated stainless steel yields a somewhat different texture of the paper since heat causes rapid shrinkage of fibres and tightening of the surface. The differences can be slight to significant, depending on the temperature of steel dryers.

In relation to strength of the paper, the testing results are not consistent enough to draw a comparison between these two types of drying methods. This might be because natural drying conditions of the papers are too varied and uneven.[28]

28 Uyeda et al., 'Effect of Cooking Agents', 122; Song and Munn, 'Permanence, Durability and Unique Properties', 134.

Conclusion

Every step in papermaking can affect the quality of paper. Each part of the process decides the success of the following part, and what seems like a minor imperfection at one stage can lower quality as a result.

A 1985 study, conducted in the US on conservation grade Japanese papers, revealed that 23 papers out of 84 samples contained wood pulp.[29] Monitoring quality through professional communications between papermakers and conservators is important for both sides. For conservators, it helps to select proper paper for a certain project. For papermakers, it provides the specifications required by conservation community.

29 Sue B. Murphy and Siegfried Rempel, 'A Study of the Quality of Japanese Papers used in Conservation', *The Book and Paper Group Annual* 4 (1985): 70–71.

At the same time, it is not practically feasible for conservators to communicate directly with papermakers. There is a language barrier and sometimes the papermakers do not even have email access. It is vendors who can connect both sides and provide all necessary information.

The cost of paper we buy for conservation is subject to the requirements of the projects. Realistically, we cannot always buy the highest quality and the priciest paper. For papermakers, it is becoming difficult to resource good quality raw materials. Because of that, papermakers also produce lines of inexpensive papers, and unfortunately the information is often not clear. It is important for us to know what we trade the quality for.

The subject we are dealing with here is bigger than just a piece of paper. The paper mills in many regions have already vanished and in some places became tourist attractions. The conservation community can play an important role in preservation of this cultural heritage, by promoting production of high quality paper.

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Abstract
Paper mulberry paper has been favoured by conservators for its lightness, flexibility and durability. Higher quality paper mulberry paper for conservation use is mostly produced by a handful of papermakers who continue the tradition of meticulous care in preparation and intensive labour throughout the process. For conservators, judging the quality of paper can be subjective, but the awareness of the permanence and durability of paper is essential. There are many factors that directly and indirectly influence permanence of paper and its visual influence—such as raw materials, process of fibres, sheet formation and drying. Understanding the complexity of paper mulberry paper would help decision making for specific conservation projects. This research, focused on paper mulberry fibre, discusses several aspects of Eastern papermaking, its influences on physical appearance and the qualities of the paper.

Biography
Minah Song is an independent paper conservator, based in Washington DC, USA. Previously, she worked as a paper conservator at CCAHA in Philadelphia. She holds an MA in conservation from Camberwell College of Arts in London and an MA in East Asian art history from the Academy of Korean Studies in Korea.

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