Original Study

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Japan: The Earliest Evidence of Complex Technology for Creating Durable Coloured Goods

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Abstract: The invention of lacquer technology is significant in history as the first evidence of the use of an organic substance in creating durable coloured objects. By focusing on the evidence from the Jomon Period, Japan, this article clarifies the nature of complex technology and knowledge required for lacquer production, presents how lacquer technology enhanced our creative ability, and discusses its significance in human history. Lacquer technology was invented in the course of increasing human-plant interaction in the warming climate of the early Holocene. Personal ornaments coated with red lacquer are the most conspicuous throughout the Jomon Period from the beginning of lacquer technology. Strong attention to colour and intensive application on personal ornaments indicate that the creation of symbolic artefacts in social context was at the core of Jomon lacquer technology.

Keywords: Urushi, Lacquer technology, Jomon, red pigment, personal ornament

1 Introduction

The invention of lacquer technology is significant in human history as an early example of the use of an organic substance in creating durable coloured objects. Application of red pigments dates back to the early stage of anatomically modern humans, and organic material such as animal fat and plant sap may have been added as a binder to give the pigment the required texture as a paint for Upper Palaeolithic cave art. However, the development of lacquer technology in East Asia expanded the ways of producing coloured goods due to the unique nature of lacquer as a highly durable coat as well as a forming material. By focusing on the evidence from the Jomon Period, Japan, this article clarifies the nature of complex technology and knowledge required for lacquer production, presents how lacquer technology enhanced our creative ability, and discusses its significance in human history (Fig.1).

Jomon refers to the cultures that developed on the Japanese Archipelago following the Paleolithic Period and preceding the agricultural Yayoi Period (Imamura, 1996; Habu, 2004, 2014). Jomon culture can be characterized by hunter-gatherer subsistence and pottery production, although marked temporal and spatial variability is seen over more than 10,000 years (Matsumoto & Habu, 2018, Table 1). Production of rich material culture based on a sedentary lifestyle is a distinctive feature of the Jomon, which has been noted in discussions on the emergence of social complexity (Hayden, 1995). Lacquer is an important part of the specific material culture production.

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Figure 1. The location of sites mentioned in the text.

Table 1. Approximate dates (calibrated BP) for the six Jomonsub-periods.

Sub-period	Approximate age (cal BP)
Final Jomon	3300–2800/2300
Late Jomon	4400–3300
Middle Jomon	5400–4400
Early Jomon	7000–5400
Initial Jomon	11,000–7000
Incipient Jomon	15,000–11,000

It is not easy to talk about people’s cognition in the past, especially of those in societies where we don’t know what language they were speaking. We can observe striking varieties in cosmologies, religious beliefs and aesthetic standards in ethnographies, although some human universals seem to exist (Brown, 1991). Perception and cognition of colour can be an important foothold to allow further inferences on past cognition, as it is determined by the neurophysiological structure and function of the visual system (Wattenwyl & Zollinger, 1979). Based on the wide survey of colour terms around the world, Brent Berlin and Paul Kay insisted that basic colour term lexicons evolved due to the constraining effects of the language-independent processes of colour perception (Berlin & Kay, 1969; Kay et al., 1991). Berlin and Kay proposed that white, black and red appeared first in the evolution of basic colour terms as they exist in almost all

languages. Among the three basic colour terms, white and black refer to brightness and darkness without any particular hue. Thus, red is the first true colour term corresponding to certain wavelength range.

Archaeological evidence apparently supports the model of basic colour term evolution stated above. The use of colour, applied to the body or another natural or created 3D object or a flat surface is considered as the first evidence of art in human evolution, dating back to more than 100,000 years ago (Morris-Kay, 2010). Intentional production and use of red pigment powders have been known for Middle Palaeolithic sites in Africa (Watts, 2010) and also for Neanderthal sites in Europe (Roebroeks et al., 2012). Use of black pigments is not as popular or early as that of red pigments, although some examples are found from Middle Palaeolithic sites (Bonjean et al., 2015). Tools for production of red and black pigment by grinding rocks such as hematite and manganese dioxide have been found from Upper Palaeolithic sites in Japan (Naganuma, 1998). Utilization of sea shells, animal teeth and ivory for making beads might have been based on the cognition of their white colour. It is not easy, however, to decide whether their colour was a significant reason for exploitation in cases of natural colour. The shells, which happen to be white, may have been picked up because of their shape or any other reasons. When colour was intentionally applied to the surface of something, we can confidently assume that the colour was important.

Invention of lacquer technology brought new possibilities in the production of red objects. While the term lacquer is used for many kinds of hard and potentially shiny finishes applied to materials including recent industrial products with artificial resin, the word specifically refers to the treated and dried sap of Japanese Sumac, or *urushi* tree (*Toxicodendron vernicifluum*) in this article. *Urushi* trees only grow in east and Southeast Asia, and lacquerware was a special product in these areas. The beauty of lacquerware was ‘discovered’ by Europeans in the 16th century and many items were imported into Europe. The shiny surface is not only beautiful to the eyes, but also very effective in enhancing the durability of the object coated by lacquer against water, heat and acid (National Museum of Japanese History, 2017).

The sap of *urushi* tree contains urushiol, which polymerise in the presence of moisture to form a hard lacquer. The name urushiol is derived from the Japanese word for the lacquer tree, *urushi*. Another unique feature is that urushiol can cause an allergic reaction, such as a severe skin rash on contact, for most individuals. A third unique feature is that lacquer can be used not only as a binder to make paint, but also as a glue, filling or forming material. This feature made it possible to create new kinds of objects that humans had never obtained before. An example of this might be a more complex form such as a lacquered comb. As lacquer can be applied to many kinds of material including wood, fiber and pottery, it can transform both organic and inorganic materials with dull colour and porous surfaces into bright red, shiny objects.

2 Earliest Evidence of Lacquerware

The origin of lacquer technology is a hotly debated topic (Kudo, 2017). The possibly earliest evidence of lacquer was found from Kakinoshima B site in Hokkaido, Japan, based on a radiocarbon dating of 9000 cal BP (Minamikayabe-cho Maizobunkazai Chosadan, 2002; Yotsuyanagi, 2009, Okamura, 2010). The date is, however, controversial as the dating was carried out with soil samples taken from the floor of the burial that was presumed to contain residue of the brain and small flakes of lacquer (Kudo, 2017). If the dating is not sound enough, contextual information of the burial indicates that it belongs to the late Initial Jomon Period (8000–7000 BP). A lacquered comb from Mibiki site, Ishikawa prefecture, has the earliest direct radiocarbon date of 7200 cal BP (Kudo & Yotsuyanagi 2015). Another lacquered comb from Torihama shell midden, Fukui prefecture, is also directly radiocarbon dated to be 6100 cal BP (Kudo & Yotsuyanagi, 2015). The earliest evidence of lacquer production is a pottery vessel containing refined lacquer from Sorete site, Shimane prefecture, which was radiocarbon dated as 6800 cal BP (Nagashima & Kobayashi, 2007). Increasing findings of lacquered objects, tools for lacquer production, and palaeobotanical evidence for the *urushi* tree, suggest that lacquer technology existed in the Japanese archipelago from the Early Jomon Period (7000–5500 cal BP) onwards (Noshiro & Suzuki, 2004).

Until the discovery of the earliest lacquered objects at Kakinoshima B site, a lacquered bowl from Hemudu site, Zhejiang, China, had been considered as the earliest evidence of lacquer use, dating back to the

5th millennium BC (Li, 2011). Recent examination of lacquered objects from Tianluoshan site and Kuahuqiao site, also situated in the Zhejiang province, indicate that they could date back to about 7400–8000 years ago (Cultural Relics Archaeological Institute in Zhejiang Province, Xiaoshan Museum, 2004; Nakamura, 2010; Jiang, 2013). It had been considered that the sumac tree and lacquer production technology diffused from China to Japan, but currently, Kakinoshima B is the earliest, and the origin of this technology is not clear. A piece of *urushi* tree excavated from the Incipient Jomon period layer of Torihama Shellmidden was dated to be 10000–11000 cal BP (Suzuki et al., 2012). However, evidence of its utilization for adhesive or lacquer at this early stage has not been obtained.

Recent DNA analysis revealed three types of genetic variations in *urushi* trees: Hubei-Hebei Province type, Zhejiang Province type and Japan type (Suzuki et al., 2014). Japan type *urushi* trees grow in Japan, the northern part of China and Korea. Botanists have assumed that *urushi* trees in Japan and Korea are not native but were introduced as a cultivated species from the continent as they don't grow in virgin forest, but can be found only near human activity areas (Iwatsuki et al., 1999, Suzuki et al., 2014). We don't have enough evidence to judge whether the *urushi* tree is native to the Japanese Archipelago (Okamura, 2010) or if it was brought in from the continent with the arrival of homo sapiens about 37,000 years ago, or with the spread of microblade culture around 20,000 years ago (Kudo, 2017).

Whichever the case, the development of lacquer technology should be considered separately as there is more than 3000 years between the earliest evidence for the *urushi* tree and that of lacquer technology in Japan. It is possible that lacquer technology was invented independently in southern China and Japan (Okamura, 2010). This hypothesis may be supported by the observation that early lacquer applications in the Jomon are found on ornamental objects such as threads and combs, while those in southern China are on utility goods such as bows and bowls. It is also possible that lacquer technology in Japan was introduced from the continent as the dating of Kakinoshima B example is not sound enough. Although direct evidence for interaction with, or migration from, the Chinese continent to Japanese archipelago in Initial Jomon is lacking, the sudden appearance of slit stone earrings at the end of the Initial Jomon may indicate a cultural influence from the continent (Kawasaki, 2004).

The invention of lacquer technology dates back to the early Holocene in East Asia. The archaeological contexts of the early examples suggests sedentary lifeways such as settlement or cemetery, indicating that lacquer technology was invented in the course of increasing human-plant interaction in the warming climate. We need more evidence in order to resolve the debate pertaining to the time and place of its origin.

3 Complex Nature of Lacquer Production Technology

3.1 Systematic Production

Although the *urushi* tree has been growing in the Japanese archipelago since the Incipient Jomon Period, detailed planning and control of complex technologies are required in order to obtain enough sap for lacquer production. Firstly, constant tending is necessary to utilize the sap effectively. The tree grows well in a warm climate with a lot of sunshine and good ventilation. In order to maintain the best condition for the trees, it is necessary to control the forest so that taller trees will not block the light and *urushi* trees grow at appropriate intervals (Nagashima, 1996; Noshiro, Suzuki, & Sasaki, 2007).

Effective management and utilization methods for the *urushi* tree in the Jomon Period are reconstructed based on the examination of the abundant material remains excavated at the Late Jomon Period site, Shimo-yakebe Tokyo (Chiba, 2014). Examination of 44 stakes of *urushi* trees suggests that periodic thinning of the forest was practiced by cutting down young *urushi* trees of five to six years, and possibly redundant shoots, to maintain the best environment for *urushi* trees. Systematic cuts are seen on the excavated stakes, indicating that the sap was collected before cutting down the tree. Examination of growth rings revealed that the trees were cut down from early summer to late fall when the amount of sap increases (Noshiro & Sasaki, 2006).

3.2 Colouring Technique

The sap freshly tapped from the tree is a milky white, oily liquid. It consists of about 80% of urushiol, 20% of water, and a nominal volume of gum, carbohydrate, and so on. The sap must be stirred in mildly heated conditions to reduce the amount of water to a few % in order to produce lacquer that can be applicable to the surface of objects. If this process is done successfully, brownish, translucent lacquer is obtained, which can be mixed with pigment to produce coloured lacquer. Intentional colouring of lacquer was mostly restricted to red during the Jomon period.

There are a number of examples with apparently black lacquer, including many pottery and bows showing red on black patterns. However, most of the blackness comes from natural blackening by oxidization as a result of a thickening process. Carbon powders are occasionally mixed into the naturally blackened lacquer, however, it may not be for colouring but for making the texture more suitable for a base coat or forming material.

There are two kinds of pigment used for producing red lacquer in the Jomon period: red iron oxide “*bengara*” (Fe₂O₂) and cinnabar “*shu*” (HgS). In addition to hematite, which has been utilized since the Palaeolithic, Jomon people began to use bog iron as a raw material of *bengara*. Bog iron forms in the water when iron bacteria sticks to a vegetable fiber; it shows a unique tube-like structure that can be identified with microscopic analysis (Okada, 1997).

While the source of *bengara* is ubiquitous, that of cinnabar is restricted to around the Median Tectonic Line. Many sources are known in Mie, Nara, Tokushima and Hokkaido prefectures. Currently the earliest evidence of the use of cinnabar is a grinding stone from the Miyanotaira site, Nara prefecture, dating to the end of the Middle Jomon (Archaeological Institute of Kashihara, 2005). Cinnabar was actively used in Kinki region and Hokkaido where the material is available from nearby mines in the Late Jomon Period. While *Bengara* was more universally used to manufacture red lacquer in the northeastern part of Japan throughout the Jomon Period, cinnabar was obtained from Hokkaido to make red lacquer (Nagashima, 2014).

In order to get a beautiful, even coating of lacquer, it must be applied to the surface of an object several times. Microscopic examination of the section of a lacquer coating from the Kitaekoda site in Tokyo shows four layers of lacquer (Fig. 2). Red lacquer was applied three times on top of the base coat of uncoloured lacquer mixed with carbon powder. Red lacquer with *bengara* is used for the first layer, followed by the layer with coarse grained cinnabar, and the top coat with fine grained cinnabar (Nagashima, 2014). In addition to the difference in redness between *Bengara* and *shu*, Jomon people were also able to control the colour by way of grinding the pigment; the finer the pigment, the more vivid and bright the colour (Yotsuyamagi, 2009). In cases where both *bengara* and *shu* were used, *shu* is used for the top coat over the layers of red lacquer with *bengara* in the Late Jomon period. Such a difference in the usage of *bengara* and *shu* clearly indicates that Jomon people were aware of the difference in redness, and preferred a vivid, bright red.

Delicate control of colour by repeated coating can also be recognized for a red lacquered bracelet excavated from Yoneizumi site, Ishikawa prefecture. Microscopic examination identified six layers of red lacquer with *bengara* on the lacquer base containing carbon powder that worked as a forming material (Yotsuyamagi, 2009). Heavy mineral pigments in the urushi layers of both Kitaekoda and Yoneizumi cases are evenly dispersed, indicating that the craftsperson probably rotated the object after each coating to prevent the pigment from sinking, as the colour becomes darker if that happens (Nagashima, 2014; Yotsuyanagi, 2009).

While both red and black were two very important colours all through the Jomon period, intentional control of red colour was prominent. Red and black were also conspicuous in the following Yayoi and Kofun periods, supporting the theory of universal tendency in colour cognition based on human neurological foundation. Which of the two dominates seems to depend on the sociocultural situation, and also on the nature of the object. The focal colour of Jomon lacquer was red, but in the Yayoi period, intentionally blackened lacquer became dominant (Yotsuyanagi, 2009)

Figure 2. Red lacquer coating on wood and microphotograph of its section. Photographs kindly provided by Masaharu Nagashima with permission.

3.3 Unique Nature of Urushi

The urushi tree and its products have a number of unique characteristics that would enhance the symbolic significance of lacquer production. Firstly, urushiol causes allergic contact dermatitis on humans and several higher primates (Fisher, 1996). Although the urushi tree only grows in Asia, other *Toxicodendron* species, such as poison ivy, causes the weeping, itchy rash on 10–50 million people in North America per year (Gladman, 2006). The level of allergic reaction varies according to one's genetic susceptibility and the level of sensitization. While about 10% of people don't have any allergic reaction, the majority would have a minor to serious rash on contact with the sap. It has been known among Japanese lacquer craftsmen that frequent contact with lacquer leads them to develop an immunity to it. Experimental researches have confirmed that hyposensitization to urushiol does occur (Epstein et al., 1981; Kawai et al., 1991). As the experiments show that tolerance is weakened with time, constant contact with urushiol is required to keep hyposensitivity.

The poisonous nature of urushiol would promote a specialized production by a restricted group of people. As urushiol sensitivity seems to be genetically determined to some extent (Epstein, 1987), and some

people show persistently strong reactions, inheritance of lacquer technology through particular lineage may have been encouraged.

A second unique feature is a counter-intuitive drying process of lacquer. Other kinds of paint dry faster under lower humidity. Contrary to our common expectation, however, lacquer hardens in warm and humid atmosphere. The hardening occurs by the chemical reaction of urushiol to humidity. Thus, the rainy season in early summer is the best season for lacquer production in Japan. Such intricate knowledge about the nature of lacquer is indispensable for lacquerware production (Matsuda, 2001).

The third unique feature is the extraordinary durability of this organic substance. Although it is affected by direct sunlight and extreme change of temperature, lacquer is resistant to water, heat, acid and other chemical influences. The amazing stability of lacquer coating is evident in well preserved excavated artefacts, even when the organic object under the coating is almost completely decomposed. Its colour also does not change over thousands of years.

4 Specific Nature of the Jomon Lacquer

Lacquer was applied to various kinds of material and objects in the Jomon Period, including various forms of containers, clay figurines, bows, and various kinds of ornaments. At the Korekawa-nakai site, Aomori prefecture, a large number of lacquered artefacts were found from in a water-logged peat layer, showing the variety and sophisticated technology of lacquer use in the Final Jomon Period (Hachinohe City Board of Education, 2002; Okamura, 2010). More than 70 pieces of pottery sherds, 14 woodenware, 3 bark containers, 10 baskets, 1 sword-shaped object, 19 bows, 10 combs, 11 bracelets and 5 earrings were found coated with lacquer. Most of them are of applied red lacquer with *bengara* on black basecoat. Such a wide application of lacquer is not surprising because it not only enhances the appearance, but also increases the durability, of the object. Pieces of large bark containers coated by black and red lacquer are examples of the unique nature of lacquer that works both as an adhesive and as a hardener. By applying lacquer on the surface of bark, large, water-proof, and very light containers can be created.

While both aesthetic and utilitarian aspects of lacquer were fully recognized and exploited in the Jomon Period, it should be noted that personal ornaments such as strings, combs and bracelets appeared from the early stage of lacquer production. This suggests that the original motivation behind the invention of lacquer technology was symbolic and social rather than practical.

At the Kakinoshima B site, bundles of string that probably decorated the head, shoulders, arms and legs of a buried person were found in a pit grave (Fig. 3). Some of them could be a part of the clothing. Close examination revealed that it was made by twining lacquer-coated thread around string. Lacquer becomes very hard when dried, but microscopic observation indicates that each thread had been coated by lacquer two or three times before twining (Nagashima, 2002). It is considered that wild sesame oil was mixed with lacquer to maintain flexibility in the drying process. This observation suggests that those who produced the string gems coated with lacquer already had a deep knowledge about the nature of lacquer from the Initial Jomon period.

A number of bundles of red lacquered string have been found from the Late and Final Jomon sites in Hokkaido, Tohoku, Kanto and Hokuriku regions. Their production method is basically the same as the Kakinoshima B example, in that each string is first coated with red lacquer and then bound up. It is called *Itodama* in Japanese, meaning a string gem. Otherwise, vulnerable plant fiber is transformed into durable ornaments by lacquer. How string gems were used is unknown, but the act of tying red thread might have had a symbolic significance in the Jomon Period (Yotsuyanagi, 2009).

The use of lacquer as a forming material is another conspicuous feature of the Jomon lacquer technology. Combs in the Jomon Period are not for combing hair but are personal ornaments worn on the head. Jomon combs are made either by sculpting the teeth from a piece of wood, or by binding a number of thin sticks to make teeth. In the case of the latter, Lacquer is used very effectively as an adhesive, forming material and paint. At the Karinba site, Hokkaido prefecture, 56 red lacquered combs were excavated from 16 pit burials of the Late Jomon Period. All of them are of the stick-binding type, and their production method is

Figure 3. Lacquered strings excavated from Kakinoshima B site, Hokkaido a) Excavated state, b) Lacquered strings on the left shoulder of the buried person, c) Close-up of the excavated state, d) and e) Microphotographs of the section of a lacquered string. Photographs kindly provided by Hakodate City Board of Education (a, b) and Masaharu Nagashima (c, d, e) with permission.

reconstructed based on close examination of the Karinba combs (Uwaya & Kimura, 2016). About half of the combs have delicate openwork decoration, which was made by carving hardened lacquer.

It is also noted that many kinds of red can be observed. At the pit grave no.123, remaining teeth indicate that five individuals were buried together on a layer of *bengara* which is about 4 cm thick (Fig. 4). Each individual wore two to three combs on their head. The colour of the combs varies from pink and scarlet to orange, indicating a sophisticated technique of colour control (Uwaya, 2003). There are three more multiple burials similar to the burial No.123 at the Karinba site. Why four to five individuals were buried together in the same grave is still not clear. Uwaya and Kimura suggest a possibility of martyrdom. Although poor preservation of bones makes it impossible to identify the sex of buried individuals, Uwaya and Kimura assume that the combs belong to female shamans who played a significant role in the process of social stratification (Uwaya & Kimura, 2016).

Lacquer was also applied to containers and tools to enhance their symbolic importance. Lacquered objects have a very impressive appearance, as the application of lacquer transforms the surface texture of an object, be it pottery, wooden object, or strings, to red and shiny. Red and shiny objects are rare in the natural world and it appeals to the eye of human beings.

Figure 4. Excavated state of the pit grave no.123 at Karinba site, Hokkaido. Photograph kindly provided by Eniwa City Board of Education with permission.

5 Conclusion

The invention of lacquer technology was a significant step in human history as the first method to create durable coloured artefacts. Although it is not clear how and when the urushi tree was introduced to the Japanese archipelago, lacquer technology developed in the course of increasing human-plant interaction when sedentary lifeways emerged in the early Holocene. Lacquer production requires constant control of the forest with strategic planning and successful transmission of complex technological knowledge. Thus,

it certainly signifies the development of complex society. At the same time, it is also possible that lacquer production was one of the factors driving social complexity. From the beginning to the end of Final Jomon, red lacquer continued to be the center of production. This is additional supporting evidence for the earliest appearance of red in intentional colouring practice. It is also significant that lacquer technology allowed the pursuit of various shades of red. The quest for more saturated, bright, or nuanced red was developed during the Jomon Period. The strong attention to colour and intensive application on personal ornaments, indicate that the creation of symbolic artefacts in the context of emergent social complexity was at the core of Jomon lacquer technology.

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