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Funori and JunFunori: Two Related Consolidants With Surprising Properties

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Abstract

Funori and JunFunori are highly suitable for the consolidation of matte, powdery paint layers. They minimize the risk of optical changes such as the formation of tide lines, darkening, or unintended gloss. Case studies have identified other interesting applications for the two consolidants: as cleaning agents for the removal of water stains and as media for matte retouching.

JunFunori is a new algae-based consolidant. Its traditional Japanese counterpart Funori shows considerable fluctuations in quality. For example, the pH value of 10 different samples was found to vary from 6.2 to 10.4. This inconsistency led to the development of a new purification process that was used to produce JunFunori. Unlike Funori, the first generation of JunFunori (2003–2006) was an almost standardized product. However, recent studies indicate that the quality of JunFunori produced after 2006 fluctuates considerably. Both consolidants are made from red algae. Funori is sold as bleached and dried yellowish-brown mats of algae, which can be soaked in water, warmed, and filtered to produce a yellowish-brown, cloudy adhesive solution. The algae used for JunFunori are not bleached. A gentle extraction and filtering process removes most of the colourants, salts, and proteins. Dissolved in water, the purified product produces a colourless, odourless, and pH-stable consolidant.

Titre et Résumé

Le Funori et le JunFunori : deux agents de consolidation apparentés aux propriétés étonnantes

Le Funori et le JunFunori constituent des matériaux très adéquats pour assurer la consolidation de couches picturales poudreuses et mates. Leur emploi permet de réduire au minimum les altérations visuelles comme la formation d'auréoles, le noircissement ou la production involontaire d'un brillant. Les résultats d'études de cas ont permis d'identifier d'autres applications intéressantes des deux consolidants, soit leur utilisation comme agents nettoyants pour éliminer les taches d'eau et comme médiums de retouche de plages mates.

Le JunFunori est un nouvel agent de consolidation à base d'algues. Le Funori, qui représente son homologue japonais traditionnel, se caractérise par des variations importantes de la qualité du produit. Ainsi, la valeur du pH déterminée pour 10 échantillons différents varie de 6,2 à 10,4. Ces résultats non uniformes ont entraîné la mise au point d'un nouveau procédé de purification qui a été par la suite utilisé pour produire le JunFunori. Contrairement au Funori, le JunFunori de première génération (période de 2003 à 2006) constituait presque un produit normalisé. Toutefois, des études récentes indiquent que la qualité du JunFunori produit après 2006 varie grandement. Les deux agents de consolidation sont fabriqués à partir d'algues rouges. Le Funori est vendu sous forme de mats d'algues blanchies et séchées, de couleur brun-jaunâtre, qui peuvent être trempés dans l'eau, puis chauffés et filtrés, ce qui permet d'obtenir une solution

d'adhésif trouble et brun-jaunâtre. Les algues employées pour produire le JunFunori ne sont pas blanchies. Un procédé d'extraction et de filtration dans des conditions peu sévères permet d'éliminer la plus grande partie des colorants, des sels et des protéines. Le produit purifié, lorsqu'il est dissous dans l'eau, permet d'obtenir un agent de consolidation de pH neutre, incolore et inodore.

Introduction

Funori was investigated in a joint research project of the Institute for the Preservation of Historical Monuments and Buildings (ETH Zurich), the Swiss Federal Laboratories for Materials Science and Technology (EMPA) and the Center for Conservation of the Swiss National Museum (SNM). *Funori* was tested in comparison with other aqueous consolidants such as gelatin, sturgeon glue, hydroxypropylcellulose (Klucel E) and methylcellulose (Methocel MC) (Michel 2002). The algae-based consolidant performed very well in terms of its flexibility after accelerated aging, susceptibility to microorganisms and optical properties. *Funori's* adhesive strength, on the other hand, was found to be comparatively weak. Unfortunately, considerable fluctuations in the quality of traditional *funori* were observed. The importance of consistent quality led to the development of a new purification process that was used to produce JunFunori, a nearly standardized consolidant containing the same polysaccharide and as shown in the test results, the same good properties as *funori* (Geiger 2005). With the production of JunFunori, further use of the traditional *funori* seemed questionable. This however is not the case. On the one hand excellent results can also be achieved with *funori* of good quality. On the other hand the JunFunori which since 2007 is manufactured by a new producer shows as serious variations in quality as the traditional *funori*.

This paper should clarify possible confusion between the two related consolidants *funori* and JunFunori. Similarities as well as differences in their properties and in the production processes will be outlined. Helpful instructions for use and application will be given, and current problems with the production of JunFunori will be discussed.

The SNM collection contains an artwork that clearly demonstrates the application of *funori* and JunFunori, the so-called "Landi-Bild" by Hans Erni. Using this work as an example, different application possibilities will be presented in the second part of the paper. *Funori* and JunFunori have earned an excellent reputation internationally, especially as consolidants for matt powdery paint. Matt paint can be consolidated using either consolidant without risking optical changes such as the formation of tidelines, darkening of the paint layer, or unintended gloss (Kariya 1995, Grantham 1999, Masson 2004, Ritter 2005). In addition, they have other interesting properties, such as a particular suitability as an adhesive for facings (Mürer 2003). Both consolidants can also be used as cleaning agents, as in the case of the "Landi-Bild", for the removal of water stains, and as a medium for matt retouching (Takami 2000, Michel 2003).

Funori

Funori is made from the red algae genus *Gloiopeltis*. *Gloiopeltis* typically grows in the intertidal zones of the Pacific coast of Japan, Korea, South China and North America. The alga's cell wall consists of a water-insoluble fibrillose skeleton which is surrounded by an

amorphous matrix. This matrix, known as *funoran* is soluble in hot water and consists of a mixture of sulfated polysaccharides, lipids, proteins, salts and colorants (Izumi 1971). A large amount of *Gloiopeltis* is industrially processed, and as with other red algae it is mainly used as a stabilizer and thickening agent in foods, cosmetics and pharmaceutical products (Lüning 1985). In Japan, small family-based businesses process a limited amount of *funori*, mostly using *Gloiopeltis furcata*, *Gloiopeltis tenax* and *Gloiopeltis complanata* (Chapman 1980). The mature algae are harvested in early summer, rinsed in water and bleached with a sodium peroxide solution. After a further rinsing process, the bleached material is spread on rice mats and dried under the sun. *Funori* is sold in the form of dried yellowish-brown mats of algae (Figure 1).

Figure 1 Different samples of funori.

Recipes

The dried algae material is soaked in water, warmed and filtered. The extract obtained in this way is a yellowish-brown, slightly cloudy adhesive solution (Figure 3). When poured onto a silicon-coated Mylar sheet, it dries to a thin film. Stored dry and protected from light, it keeps its properties for several years. The film dissolves easily when soaked in warm water and heated (45°C - 80°C) for a few minutes. The addition of 2% isopropanol and keeping the solution in the refrigerator when not in use guarantee a longer storage life.

There are numerous recipes for the preparation of a *funori* solution. Basic and comprehensive information and a good overview are provided by Swider and Smith (2005). The concentration found in literature varies from 1 g to10 g *funori* in 100 ml water (Kremer 2011), and the extraction temperature ranges from 40°C to 100°C. Our examinations as well as the tests carried out by Swider and Smith have shown that a good extraction can be achieved between 45°C and 80°C. The solution with the highest amount of extracted adhesive can be considered as an ideal concentration. To gain this result 1 g, 2 g, 4 g and 8 g of *funori* were soaked in 100 ml of deionized water for 5 hours. The soaked material was heated for one hour at a temperature of 60°C. Afterwards the water-insoluble material was filtered off through two layers of a thin fabric. Then the solutions were dried and weighed. The results showed that the yield does not

increase linearly. On the contrary, it decreases with increasing concentration of the soaked material (Table 1). The molecule of the polysaccharide of *Gloiopeltis* has the ability to build a huge number of hydrogen bridges. This phenomenon is most likely the reason for the high amount of water that is needed to uncurl the macromolecules and dissolve them into solution. For 8 g of *funori*, 100 ml of water only swells the material but is obviously not enough to dissolve the water-soluble components. Concentrations of solutions higher than 1% diminish the yield and are therefore not recommended.

Table 1: Yield of *Funori* in Solution with Increasing Amount of Extracted Dried *Funori* Used

Extracted Dried *Funori* Used (g)	**Water (ml)**	**Yield (g)**	**Yield (%)**
1	100	0.865	86.5
2	100	1.556	77.8
4	100	2.465	61.6
8	100	0.000	00.0

This characteristic of *funori* to bind a large amount of water is probably the reason why the formation of tidelines does not occur. The transportation of dirt and microparticles with a solvent when it meets its volatility limit is responsible for the formation of tidelines. If no free water is present, this migration cannot take place. This fact is also supported by the observation that the risk of tidelines forming increases with the application of lower concentrations of *funori*.

Fluctuations in quality

Funori, like other natural products, shows a certain degree of heterogeneity. To get a better understanding of the variations that occur, *funori* from seven suppliers were compared in 2001 (Tanaka, Wakai, Mizokawa, Paper Nao, Aiko's, Hiromi, Kasuri). From three suppliers a second sample from another harvest was also included (Wakai2, Mizokawa2, Hiromi2). The pH value of eight samples varied from 6.6 to 7.5. Two samples with a significantly higher salt content and a pH value of 10.2 (Aiko's) and 10.4 (Mizokawa2) respectively were unsuitable for conservation work.

By rinsing the dry *funori* under dripping water before soaking (Swider 2005) some soluble material is lost in the process but the salt content can be reduced considerably. The same applies to the colorants. Although negative impacts caused by these salts were not observed, reducing salt content is a good way of both limiting risk and obtaining a cleaner product. The pH value of the *funori* solution has to be checked with each new lot.

Fluctuations in quality of *funori* can probably be explained by differences in processing methods adopted by the small family-run businesses in Japan. Finally, in 2002 the desire for a consolidation medium of consistent quality and with the same good properties as *funori* led to the development of JunFunori (jun = pure in Japanese).

JunFunori

Unlike in the production of Funori, the algae used for JunFunori are not bleached with sodium peroxide. In addition, only *Gloiopeltis furcata* is used for the production of JunFunori. It has the same good properties as *Gloiopeltis tenax* but the rate of yield is significantly higher. The dry material is rinsed in deionized water to remove all soluble salts. The soaked algae are chopped and the *funoran* is extracted. After extraction, charcoal is added. The solution is centrifuged and pressure-filtered through a fiberglass filter. The purified extract is dried at 60°C. It forms a thin film which is ground for later use. This process removes most of the colorants, salts and proteins. The purified algae product is a ground whitish powder (Geiger 2005) (Figure 2).

Figure 2 JunFunori.

To dissolve JunFunori in water it has to be warmed and stirred for several hours at a temperature of between 50°C and 60°C. A consistent flow of the liquid indicates complete dissolution. JunFunori solution (1 g in 100 ml of deionized water) is a colorless, transparent, water-like and odorless consolidant with a viscosity of about 90-125 mPas and has the same good properties as Funori (Figure 4). For the viscosity three samples of JunFunori produced before 2006 were measured at a shear rate of 100 s^{-1}at 20°C with three measurements per sample (Measurement by: Tracomme AG, analyzer: HAAKE Controlled Stress Rheometer RS6000, temperature control: Peltier, measurement geometry: Cone Ø 60mm/4°, software: HAAKE RheoWin 4.30).

A solution of 0.5%-1% has proven to be best for consolidation. A repeated treatment is more advisable than a concentration > 1%. The addition of isopropanol guarantees a longer storage life. For insensitive surfaces an addition of 2 % proved to be of value. The isopropanol functions as a biocide as well as surfactant. Higher concentrations must be treated with caution, because JunFunori (and *funori*) precipitates in pure isopropanol. When adding it, sometimes a local increase of viscosity can occur. Streak-like structures develop temporarily but redissolve after stirring. Despite the fact that a JunFunori solution can be applied cold since it does not gel

at room temperature, a warm application is recommended to improve the penetration of the solution. Like *funori*, JunFunori solutions should be kept in the refrigerator and warmed up before each use.

Figure 3 Left bottle: dry funori, right bottle: extracted funori solution.

Figure 4 Left bottle: JunFunori film not yet ground, right bottle: JunFunori solution.

Treatment

"Landi-Bild"

The impulse for the research project into *funori* and JunFunori was given by the so-called "Landi-Bild" by Hans Erni. The "Landi-Bild" is a casein tempera painting consisting of 136 plywood panels. Measuring 91 meters wide by 5 meters high, this monumental work encased the exterior façade of the tourism pavilion at the "Landesausstellung" (National Exhibition) in Zurich, in 1939 (Figure 5). After the exhibition, the panels were placed in storerooms belonging to the Swiss National Railway. Their survival was more or less a matter of chance. The work has been in the possession of the Swiss National Museum since 1990.

Figure 5 Detail of the "Landi-Bild" at the "Landesaustellung" 1939 in Zurich.

Poor storage conditions and two open-air exhibitions took their toll on the painting. The porous surface was dirty, and rain had left countless water marks. In some places the veneer layers of the plywood were separated and broken. The paint layer was powdering and had detached from the wooden support in several areas (Figure 6).

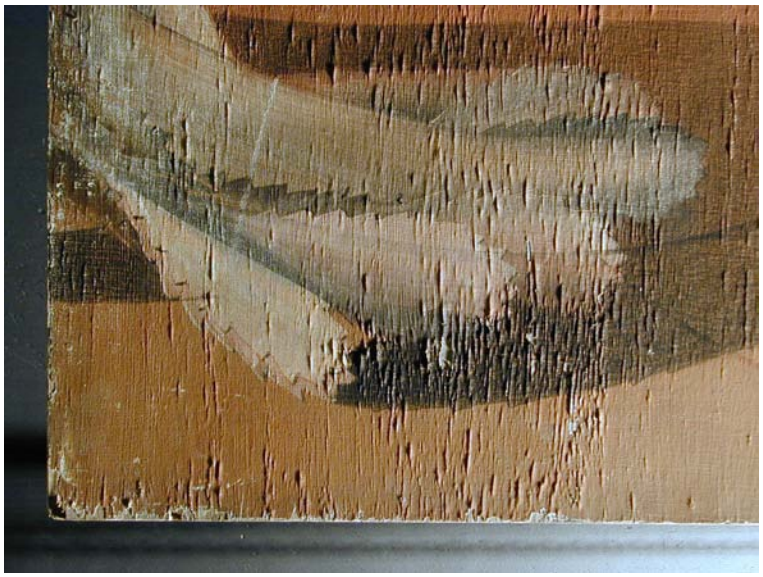

Figure 6 Tenting paint layer, following the wood grain of the support.

In 1991 the first attempts at consolidating the painting's surface were carried out. The matt casein tempera proved to be highly sensitive to all consolidants that were tested (sturgeon glue, gelatin, methylcellulose, hydroxypropylcellulose, Paraloid B72, Acronal 500D, Mowilith, Plextol D 360). Satisfactory results could only be achieved with *funori*. A number of questions regarding the ageing stability of *funori* were subsequently scientifically investigated which resulted in the development of JunFunori (Michel 2002). Originally JunFunori was intended to

be used as a consolidant for powdery surfaces, and – when modified with sturgeon glue – for consolidating loose paint flakes. However, practical application rapidly revealed that JunFunori has other very interesting properties. In the case of the "Landi-Bild" for example, JunFunori was used as a cleaning agent, as a solvent to remove the old consolidant and as a retouching medium.

Consolidation

To consolidate the powdery and tenting paint layer of the "Landi-Bild" an area of approximately 150 cm² was dampened with an ultrasonic mister. A mixture (1:1) of JunFunori (1%) and sturgeon glue (4%) was injected between support and tenting paint flakes. After this JunFunori (0.5%, 1%) was applied on the powdering surface with a brush through a sheet of a thin wet strength repair tissue (Figure 7). Placing the tissue between the paint layer and the brush allows the consolidant to be distributed and loose flakes to be consolidated without particles being displaced. As long as the tissue remains wet, it can easily be removed without causing any damage (Figure 8). Residues of the consolidant were dabbed off with a paper tissue. The area was covered with Mylar and lightly pressed down with weights. When dried, the adjacent area was treated in the same way. Although it was impossible to avoid an overlapping of the consolidated areas, no tidelines appeared (Figure 9, 10).

Figure 7 JunFunori is applied through a thin tissue.

Figure 8 Removing of the tissue.

Figure 9 Tenting paint layer.

Figure 10 Consolidated with JunFunori.

Cleaning and removal of water stains

It was not possible to clean areas where the surface was badly powdering prior to consolidation. During the consolidation treatment it was gratifying to discover that surface dirt and numerous water stains on the painting were significantly reduced by the chosen method (Figure 11). A correlation between the concentration of the JunFunori solution and the cleaning effect on the surface could be observed. With a solution of 0.5% the cleaning effect was remarkably higher than with one of 1%. This suggests that the higher amount of water has a positive effect, since more dirt can be dissolved. Accordingly, the panels were first consolidated and cleaned with a 0.5 % solution of JunFunori as described above. If the paint layer was still powdering, the treatment was repeated with a 0.5% or 1% solution.

Figure 11 On the left: water-stains, on the right: after consolidation treatment.

Removal of Klucel-E film

At the beginning of the 1990s, the surfaces of twelve panels of the "Landi-Bild" were consolidated with Klucel-E. This treatment resulted in a darkening of the colors and a glossy surface, presumably due to the evaporation of the Klucel-E, which was dissolved in alcohol, causing it to migrate to the surface and accumulate as a film. During the consolidation of tenting paint flakes with JunFunori it could be established that the film of Klucel-E could be dissolved and removed using the algae-based consolidant. The panels which were treated in this way regained their original matt surface appearance (Figure 12).

Figure 12 Red framed area: removed glossy Klucel E –film.

Retouching

Some of the panels showed signs of previous retouching treatments that had discolored badly over the years and were therefore considered to be undesirable. Since these areas could not be removed without damaging the porous paint layer, former retouching areas were integrated into the surrounding surface, i.e. matched in color. For this treatment, pigments were mixed with JunFunori. As JunFunori does not wet all pigments equally it is advisable to use pigments that have been previously soaked in water. JunFunori is notable as a retouching medium due to its good spreadability, its matt finish when dry and its excellent reversibility.

Current Quality Problems with JunFunori

The good results attained using JunFunori have been overshadowed by variations in its quality since 2007. In 2006 the rights of JunFunori were sold and the new producer has increased the amount of *Gloiopeltis furcata* used per extraction process. The new product was tested for its consolidation and optical properties on loose pigment layers on canvas and subsequently approved by the author. However, in 2008, when conservators of the workshop for wooden objects and furniture at the Collection Center of the SNM ordered JunFunori it became obvious

that the quality of the consolidant did not correspond to that of samples tested in 2007. The JunFunori powder had a yellowish appearance – instead of the whitish color of the original product – and the solution was nonviscous and had no adhesive strength. The producer responded immediately, stopped the sale, and promised to re-examine the production process and improve quality control. When new material was ordered in 2010 the quality of the JunFunori had improved, but it has yet to attain the standard of the previous producer's product.

It is a well-known problem that recipes of conservation products can be changed and modified by the manufacturer. Therefore one can never be sure that the properties and quality of a product will remain the same in the future. However, the problem with JunFunori is all the more in that it is a new product and has only been on the market for a short time. Only a few conservators have had experience working with JunFunori and understand its properties in terms of color, viscosity and adhesion; most conservators have therefore not had the opportunity to compare good and poor batches of the product. The producer is aware of the problem and is making efforts to improve the manufacturing process.

Conclusion

Flawlessly produced JunFunori is, in contrast to *funori*, a pH-stable, salt-free, colorless, transparent and odorless consolidant with the same good properties as *funori*. *Funori* and JunFunori are highly suitable for the consolidation of matt, powdery paint layers. They minimize the risk of optical changes such as the formation of tidelines, darkening, or unintended gloss. Their adhesive strength is weak but can be reinforced for the consolidation of flaking and tenting paint layers by adding, for example, sturgeon glue. Both consolidants can also be used as cleaning agents for the removal of water stains and as mediums for matt retouching.

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Materials and Suppliers

Fabric

Stabiltex No.4: Sefar Holding AG, Töberstr. 4, CH-9425 Thal/SG

Funori

Aiko`s Art Material Import, Inc. 3347 N.Clark St. Chicago, Ill. 60657 www.aikosart.com

Hiromi Paper, Inc. 2525 Michigan Ave Unit G-9 Santa Monica, Ca 90404 www.hiromipaper.com

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Tissue

PEL Wet Strength Repair Tissue, Preservation Equipment Ltd, GB-IP224HQ Norfolk. www.preservationequipment.com

JunFunori: Lascaux Colours & Restauro, Barbara Diethelm AG, Zürichstrasse 42, CH-8306 Brüttisellen, Phon +41 44 807 41 41, Fax +41 44 807 41 40, www.lascaux.ch

Methocel MC: Fluka, Sigma-Alderich Chemie GmbH, CH-9471 Buchs, www.sigmalderich.com

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