Francesco Baudone

FUNORI: NATURAL ADHESIVE FOR THE RESIZING OF PAPER MATERIALS

Riassunto

Negli ultimi decenni si è spesso osservato che i prodotti di sintesi utilizzati per le operazioni di restauro contenevano prodotti dannosi per l'ambiente, per l'uomo e soprattutto per le opere d'arte, spesso aggravandone lo stato conservativo. Per questo motivo, trovare prodotti che possano fornire una maggiore garanzia di stabilità nel tempo sta diventando una necessità sempre più diffusa, al fine di eseguire interventi reversibili, compatibili e meno invasivi sull'opera. In quest'ottica si è inserita la ricerca e la sperimentazione sul prodotto adesivo comunemente conosciuto come Funori, sempre più diffuso negli ultimi anni nel mondo del restauro. L'obiettivo di questo studio è stato quello di individuare se la sua applicazione per il rinsaldo di manufatti cartacei potesse essere un valido sostituto degli eteri di cellulosa comunemente impiegati.

Keywords: Funori, seaweed, resizing, paper materials, cellulose ethers

Introduction

From the moment of its invention and its dissemination, paper has undeniably replaced other supports such as papyrus and parchment as the material mostly used by mankind to record its testimonies. Official records of chancelleries and state institutions, private documents with legal and non-legal value, notebooks of sketches, drawings, annotations, prints, engravings, gazettes, and newspapers are part of a cultural background of inestimable historical, social, economic, and artistic value. Like all organic materials, paper is destined to perish over time, with wear and due to the environment within which it is confined. To avoid this loss, it is necessary to study programmes that prevent wear and, at the same time, allow the safeguarding of already damaged works of art.

Any conservation intervention requires an extensive knowledge of the materials on which it is necessary to operate and an equally high level of familiarity with the products to be used, bearing in mind their composition, their structure, and the possible responses to interaction in an environment with particular conditions of temperature, humidity, light, and atmospheric pollutants. It is, therefore, necessary to find methods, to study products and treatments that are able to forecast or, at best, slow down the natural degradation of paper.[1] For the analysis of deterioration mechanisms, it is essential to know the nature of the material itself. The early European handmade paper was obtained from linen, cotton and hemp rags or even from a mixture of these, while the papers produced since the 19th century contain within them pulp extracted from wood through complex mechanical and chemical procedures.[2] The internal structure of paper is an overlap and interweaving of fibres on each other, and the final product is highly absorbent, unsuitable for writing. The operation of sizing is necessary, that is to add adhesive substances that regulate the absorption of liquids while giving the paper certain physical and mechanical characteristics.[3] The most commonly used adhesive substances in the history of Western paper production consist of wheat starch paste (not glue); animal glue produced from the scraps of skins, bones, horns, animal hooves; the adhesive mixture of rosin and potassium alum. Since the mid-20th century, synthetic products of various kinds have appeared, which soon superseded all previous materials due to their lower costs and greater simplicity of application.

Moreover, over the centuries, additives have been added to improve the optical and surface characteristics of the paper. Intervening on a work of art, regardless of its nature and type, is an extremely complex and delicate procedure. Without going too far into the details and methodologies that regulate the interventions on paper artefacts, be they library books or archival documents, engravings or drawings, the fundamental point is always the respect for the artefact on which we are to intervene. The conservation treatments on a paper object are always indicated by the object itself, from the type of paper support to the graphic mediations present and the artefact's usability. All the operations that we are to perform on an object, with all the necessary precautions and cautions, are themselves manipulations and constitute a modification of the nature of the artwork, changing and altering its physical and chemical characteristics. The restoration intervention must respect the parameters of minimum intervention, carrying out those operations that are strictly indispensable for the conservation and preservation of the object, using (theoretically at least) totally reversible products that should be unable to trigger forms of degradation, due to the alterations of the material of the work of art and of the materials that are used for all the necessary interventions.

In our study, the operation on which we concentrate is that of resizing, the intervention necessary and indispensable to reintroduce the correct quantity of adhesive inside the paper fibres, which was naturally lost or solubilized during the previous wet operations, such as washing. Resuming what has already been mentioned, the presence of glue is essential to paper, since it allows it to have those characteristics of writability, resistance, and protection from atmospheric agents, wear and the natural degradation of time; and the joining and cohesion of the fibres, which constitute the paper support thanks to the reduction of capillarity due to the adhesive. The importance of resizing is clearly evident during the various procedures that accompany the restoration of a work of art on paper. Naturally, this operation is bound to the type of support that must be treated, to its problems and to the final objectives of the intervention that will have to be performed. Similarly, the products used are various, consisting of cellulose ethers and prepared starting from aqueous

1 C.G. Lalli, P. Kron-Morelli, A. Brogi, F. Baudone, I. Tosini, *Funori, adesivo naturale per pitture murali e materiali cartacei* (Chieti: Linea Grafica editrice, 2016), 91.

2 A. Smith, 'Cellulose: In paper and textiles', in: *Paper and Textiles the Common Ground* (Preprints of the conference held at the Burrell Collection, ed. by F. Butterfield, L. Eaton, Glasgow, The Scottish Society for Conservation and Restoration, 1991), 1-17; C. Fellers, T. Iversen, T. Lindström, T. Nilsson, M. Rigdhal, *Ageing. Degradation of Paper. A literature survey*, FoU-projeket för papperskonservering, Report No. 1 E, (Stockholm, 1989); D. Hunter, *Papermaking. The History and Technique of an Ancient Craft* (New York: Dover Publications, 1978, 2nd edition).

3 M.T. Roberts, D. Etherington, *Bookbinding and the Conservation of Books. A Dictionary of Descriptive Terminology* (Washington: Library of Congress, 1981).

or non-aqueous solutions, depending on the type of object to be handled and the consequent reactions evoked on the paper surface following graphic mediations. The percentages also change, depending on the type of material to be treated, according to its thickness, flexibility, rigidity, porosity and the graphic mediations present. With an eye on these elements, an alternative to the more common cellulose derivatives used in resizing operations was sought. The research was directed towards a product that had adequate physical and chemical characteristics compatible with those of cellulose: good adhesive and cohesive power even at low percentages; low viscosity; complete affinity with aqueous solutions and total reversibility in the latter; neutral pH where possible, or at least one that does not, with the passing of time, lead to an acidic environment or a chromatic alteration of the paper's surface. The algae extract known as *Funori* seems to respond very well to all of these requests, as confirmed by the results obtained during the experiments performed.[4]

Funori: composition, preparatory methods, traditional use, and application in conservation

The seaweed species from which *Funori* is extracted, commonly called *funorans*, are substantially three and all very similar to each other: *Gloiopeltis tenax*, *Gloiopeltis furcata*, and *Gloiopeltis complanata*. There are many other subspecies all related to one of these.[5] *Funori* is the generic name given to the algae species of the genus *Gloiopeltis*, used for about three hundred years, having been mentioned for the first time in 1673 in Japan[6] as a sizing agent for textile and paper materials, as an additive and thickening agent for mortars, plasters, and ceramic products, in the field of food production and in that of the cosmetics and pharmaceutical industries. This algal derivative is a lightweight adhesive, which allows for its use in controlled operations, even when carrying out several substance applications in succession. It is considered a good surfactant, capable of increasing water wettability and is often used together with starch paste or animal glue, allowing better control of the viscosity of the solutions. It has a substantially neutral pH, variable according to the solution,[7] and good optical characteristics, able not to alter the refractive index of the treated surface.[8] A guarantee of its properties also comes from tradition. In the previous fifteen years, studies and research regarding this product have recorded a considerable increase, although to this day it remains relatively unknown. However, the mere fact that it has been used for more than three hundred years as an adhesive for paper materials is a sufficient stimulus to study in depth a product that could be a valid alternative to the most recent synthesis systems used in the restoration of paper materials.

In Japan a mixture of three seaweeds is used: *Ma-funori* (*Ma* - true, from *Gloiopeltis tenax*), *Fukuro-funori* (Fukuro - balloon, from *Gloiopeltis furcata*) and *Hana-funori* (*Hana* - flower, from *Gloiopeltis complanata*), which differ from each other in some key characteristics concerning mainly adhesive power, viscosity, and water solubility. These differences are also linked to the method of extraction, the place of origin and the mixing of these three types of Funori. The *Ma-* has a more effective adhesive

4 F. Baudone, *Il Funori e la carta. Studi e applicazioni pratiche per il rinsaldo di materiali cartacei* (unpublished dissertation, Istituto per l'Arte e il Restauro - Palazzo Spinelli, Florence, 2016), 50-51; Lalli, Kron-Morelli, Brogi, Baudone, Tosini, note 1, 102-103.

5 Lalli, Kron-Morelli, Brogi, Baudone, Tosini, note 1, 16-28.

6 V. J. Chapman, *Seaweeds and their uses* (London: Methuen, 1970), 143.

7 *Funori* solution does not develop an acid environment, as is claimed by A. Finozzi, C. Lodi, C. Sburlino, *Utilizzo della colla funori nel restauro* (Padova: il Prato, Speciale 4 - Supplemento a Progetto Restauro n. 62, 2012), 7.

8 T. Geiger, F. Michel, 'Studies on the Polysaccharide JunFunori Used to Consolidate Matt Paint', in: *Studies in Conservation*, 50, III (2005), 193-204; F. Michel, T. Geiger, A. Reichlin, G. Teoh-Sapkota, 'Funori, ein Japanisches Festigungsmittel für matte Malerei', in: *Zeitschrift für Kunsttechnologie und Konservierung*, 16 (2012), 257-275.

function, the Fukuro- has less adhesive power but is easily soluble in water, while the *Hana-* does not show the adhesive characteristics of the other two so it is tendentially used as a surfactant or colloidal substance, since it allows the extracted materials to remain dispersed in the aqueous solution.[9] *Funori* is a complex polysaccharide, a sort of fractioned agar containing sulphate elements (agarose-6-sulphonate),[10] and has a great affinity with cellulosic materials, such as wood and paper. It is a natural polymer whose chemical structure can show different forms that characterize its adhesiveness, viscosity, and solubility in water.

Moreover, it is a highly water-soluble substance due to the short polymeric chain, simultaneously showing good resistance to the humid environment, in addition to a certain chemical stability over time. The studies previously conducted on *Funori* show a certain variety of preparatory methods, all of them very similar to each other; we keep in mind that percentages, dilution factors, source of purchase or simply the preparation method are not always indicated. The mere fact that *Funori* is rarely treated before being put on the market can be an encouraging fact about the purity of the material to be used on works of art. Marketed in various forms, from dried algae to powder, up to the recent liquid form, *Funori* solution is used as an aqueous adhesive for the veiling operations and pre-consolidation of paper supports fixed on canvas in view of their detachment; as a consolidant at various percentages for pictorial mediums on various types of paper, silk, papyrus, wood and wall paintings; for temporary fixing of paper fragments in view of immersion washing operations; combined with other adhesives, such as isinglass or wheat starch paste, to improve its physical characteristics.[11] As can be seen, the sectors of restoration involved in these studies and applications are manifold as are the methods of use. In all cases, its qualities of mild adhesive and surfactant are exploited, capable of dissolving in water at room temperature and penetrating the supports on which it is spread. Critical is its supposed antimicrobial activity,[12] capable of inhibiting or slowing down the development of microorganisms that are harmful to the integrity of the works of art, as well as its characteristic of not altering, once dried, the optical refraction index of the surfaces on which it is laid.

Experimental

Generally, a solution can be prepared in two ways: hot or at room temperature; we are interested in the latter methodology for this study. The dried seaweed is previously rinsed in water and then put to swell in a given amount of water for a time ranging from six to twelve hours; the time is relative to the percentage that is prepared and to its intended use. Later, it is filtered through a fabric, most often cotton. The differences between these two procedures primarily concern the density of the solution, its adhesive power, the ability to penetrate the fibres and the final appearance. When in literature we talk about the physical characteristics of this product we almost always mean the solution prepared hot, in the traditional way: few and scarce studies are about the results of the preparation of *Funori* solution at room temperature. To overcome this issue and to attempt to open a new debate, the tests completed during this study were performed with a solution prepared at room

9 N. Hayakawa, T. Araki, S. Kainuma, T. Taguro, W. Kawanobe, 'Characterization of Funori-Extraction from the Red Seaweed as a Restoration Material', in: *Journal of the Japan Society for the Conservation of Cultural Property*, 48 (2004), 16-31.

10 Geiger, Michel, note 8, 193; S. Hirase, C. Araki, T. Itō, 'Constituents of the Mucilage of Gloiopeltis Furcata', in: *Bulletin of the Chemical Society of Japan*, 29, IX (1956), 985-987.

11 Baudone, note 4, 48-49.

12 D. Ren, H. Noda, H. Amano, K. Nisikawa, 'Antihypertensive and antihyperlipidemic effects of funoran', in: *Fisheries Science*, 60 (1994), 423-427; J. Zheng, Y. Chen, F. Yao, W. Chen, G. Shi, 'Chemical Composition and Antioxidant/Antimicrobial Activities in Supercritical Carbon Dioxide Fluid Extract of Gloiopeltis tenax', in: *Marine Drugs*, 10 (2012), 2634-2647.

Table 1. pH measurements of *Funori* solution prepared at room temperature

***Funori* solution %**	**0.3**	**0.5**	**0.7**	**1**	**1.5**	**2**
pH	7.36	7.29	7.37	7.45	7.38	7.41

temperature, using dried seaweed sheets.[13] The concentration used was established by referring to the standard percentages used for cellulose derivatives in resizing operations, in order to obtain comparable results.

Furthermore, the choice to prepare the solutions at room temperature is related to the same methodology used for the preparation of cellulose adhesives, thus making it possible to compare the density and viscosity of the two products. The choice of room temperature preparation also has another motivation: the production of an easily penetrable adhesive, with very low viscosity values and weak adhesive power, necessary and sufficient to keep the fibres cohesive inside the paper support without altering their physical-mechanical properties, qualities unlike those obtained with hot-preparation protocols. Each sample of *Funori* was subjected to pH measurements: the results of the readings (Table 1), carried out three times for each percentage analysed, all fall within the neutral range with a slight tendency to alkalinity, an optimal condition for an adhesive to be used on a material that is extremely sensitive to acidic and basic environments, such as a paper support.

A high acidity, as well as an overly accentuated presence of alkalis, can trigger chemical reactions of hydrolysis and oxidation that would affect the conservation state of the artefact, accelerating its degradation. The readings of the pH values all fall within a measurement range within which the degradation reactions are buffered.[14] The tests were performed on various types of paper supports, both ancient hand-made and modern machine-made products. This choice was dictated by the desire to observe the behaviour of a resized paper with *Funori* at various percentages, knowing its chemical and physical nature: each specimen used was analysed with an optical microscope to investigate its fibrous structure and therefore its internal nature; it was subjected to histochemical staining tests to identify the original adhesives and wettability tests to determine the resistance of a paper to water penetration; finally to measurements of thickness and pH before, during and after the tests performed to monitor their behaviour at certain times of processing. Similarly, the graphic mediations present on paper supports differed from each other, ranging from ancient and modern printing inks to manuscripts (both ancient iron-gall ink and modern Indian ink). Solubility tests and pH measurements were carried out on each specimen, in order to obtain a framework including all the main aspects concerning the paper samples to be processed.[15]

Observations and discussions

The conclusions achieved from these experiments have confirmed our theories on the use of *Funori* algae extract instead of

13 For an accurate description of the preparation procedures of *Funori* solution and the comparison with the hot extraction protocols, see Baudone, note 4, 55-60; Lalli, Kron-Morelli, Brogi, Baudone, Tosini, note 1, 29-35.

14 Lalli, Kron-Morelli, Brogi, Baudone, Tosini, note 1, 91-100.

15 All the operations carried out for these studies, which lasted almost two years, are very long and to describe them exhaustively in this restricted space would be very difficult. In short, we report that all the paper samples were mechanically dry cleaned; tested the solubility of the inks and measured pH value; washed by immersion in deionized water and left dry at room temperature upon frames, measured again the pH of the washed paper; resized with *Funori* solutions at various percentages and left to dry again on frames, subsequently completing the drying operations under light weight; further pH measurement for a comparison value with the initial reading and finally the conservation of the various samples in environments with different level of relative humidity and temperature, in order to observe the behavior of the adhesive in various environmental conditions; see Baudone, note 4, 61-93; Lalli, Kron-Morelli, Brogi, Baudone, Tosini, note 1, 109-130.

Table 2. Test results on sample B, made of ancient handmade printed rag paper ink

Samples	pH value unwashed paper	Initial thickness	pH value washed paper	Resizing solution %		pH value after resizing	Thickness after resizing
				Funori	Cellulose ethers		
B_1	6.77	0.083–0.106	7.11		**0.5**	7.74 [+0.63]	0.083–0.106
B_2	6.79	0.075–0.098	7.24	**0.3**		7.82 [+0.58]	0.075–0.098
B_3	6.69	0.084–0.104	7.18	**0.5**		7.77 [+0.59]	0.084–0.104
B_4	6.81	0.083–0.110	7.29	**0.7**		7.86 [+0.57]	0.083–0.110
B_5	6.66	0.091–0.113	7.12	1		7.75 [+0.63]	0.091–0.113
B_6	6.71	0.077–0.088	7.16	1.5		7.81 [+0.65]	0.077–0.088
B_7	6.74	0.069–0.086	7.10	2		7.73 [+0.63]	0.069–0.086

cellulose ethers.[16] The percentages between 0.3 and 0.7% gave us the best results for all types of papers tested, a concentration similar to that used with cellulose ether (Table 2). The adhesive perfectly penetrated the paper fibres, giving them suitable mechanical consistency without altering their flexibility, elasticity and, at the same time, giving the paper a natural and uniform sound.

These tests also revealed other critical factors: first, on the surface there were no halos or lucidity of any kind, showing that a dried filmogenic application of *Funori* does not alter the paper surface on which it is spread; moreover, there were no variations in thickness with respect to the same measurements made before proceeding with the resizing operations, confirming the excellent penetrative capacity of the adhesive solution. As can be well noted, all the values of the tests fall within a slightly alkaline environment, within that range of values capable of buffering the chemical reactions of hydrolysis and oxidation. A preliminary conclusion about the results of these first tests led us towards encouraging considerations. In fact, the *Gloiopeltis* extract would appear to be a more than valid alternative to the common synthetic adhesives derived from cellulose, capable of transmitting the correct amount of adhesive needed and sufficient for the paper support in the correct concentrations to reacquire its natural mechanical properties.

The properties of an adhesive are also assessed by its ability to make itself susceptible or not to the proliferation of microorganisms. These elements can participate in the degradation process of the work of art, with damage that is often unrecoverable on paper. Their development can be favoured by many environmental factors, and their growth is often disjointed from the optimal conditions for their proliferation. There are various types of microorganisms that attack paper materials, attracted by the cellulose itself or by those substances present on its surface, such as adhesives. The ease of alteration due to biological elements of the starchy and proteinaceous glues, both materials of organic derivation, is well documented.[17] Although the *Funori* solution extracted from *Gloiopeltis* must also be included in this last

16 Generally, the percentages used in resizing operation are between 1 and 2%, according to the reference standard for the conservation treatments of paper materials. We must emphasize that each product has unique characteristics, and this does not correspond with the practice of generalizing the products. The cellulose ethers used for the comparison with the *Funori* solutions (Tylose® MH 300 p, Glutofix® 600 and Klucel® G), applied with the percentages commonly indicated, gave us a completely erroneous result. For each test, the percentage of cellulose ethers was found for that particular type of sample and, at the end, we have been obtained good results with Tylose® MH 300p at 1%, Glutofix® 600 at 0.5% and Klucel® G at 1.5%; see Baudone, note 4, 50-52, 80-81.

17 See *Handbook of Adhesives*, ed. by I. Skeist, (New York: Robert E. Kreiger Publishing Co., 1977), 170.

category, unlike the other two adhesives, numerous studies have proven the capacity of *funorans* to resist the development of mould and bacteria, slowing or altogether inhibiting their proliferation. Upon completion of the research, it was considered essential to perform vitality tests to confirm or disprove these statements, as well as to have at the same time a complete picture of the performance of *Funori* employed in the restoration of paper materials. In this study, two different vitality tests were carried out using Petri dishes with agar and microscope slide holders to observe the development of microorganisms in environments that had or did not have a nutritional substrate. A small and identical quantity of each adhesive was placed inside the sealed Petri dishes, while on the slides each adhesive[18] was applied in five consecutive layers. The results obtained were significant for the answers we were looking for: *Funori* seaweed extracts opposed a total resistance to the proliferation of biological agents even when in extremely favourable environmental conditions. Therefore, we can justifiably expect a similar result even in the conditions of the conservation standards indicated for paper materials, with humidity rates of around 30–40% and a temperature near 10 °C,[19] although indeed a generalization appears out of place given that the combinations of the elements that can lead to the proliferation of microorganisms are multiple and not linked solely to the conservation environment but also to the nature of the material itself and its usability.

To conclude this study and to observe the behaviour of both paper samples and *Funori* solutions over time, each test performed was subjected to monitoring in environments with different temperatures and relative humidity percentages, in order to determine whether the adhesive could lead to changes or variations, such as stiffening, yellowing, increased acidity or alkalinity, analysing the physical properties and measuring the pH at regular intervals of three months. There are many different ways and environments of conservation for works of art on paper. Unfortunately, not all objects can benefit from these conservation standards, and the risk of deterioration of the paper artefact, whatever its nature, due to incorrect storage is very high. The environmental conditions that have an effect on the object and all the individual elements from which it is composed: from the type of paper to graphic mediation, up to the materials of which its binding is constituted, whether it is a library book or even of an archive register.

Even the adhesive substances are involved in the search for the balance between the artefact and the environment that surrounds it, playing an essential role in the protection of the work of art or in the acceleration of its degradation. Each adhesive substance has its particularities that make it react and behave differently in the various types of conservation environments. In order to observe the environmental integration of a resized paper with *Funori*, the various samples used for the experiments were conditioned in different conservation rooms, carrying out a quarterly rotation of the environments with pH measurements for each paper support studied. All the papers tested in this study were located inside a folder made of thin cardboard sheet with a neutral pH, inserted between two thick pieces of cardboard for storage at neutral pH and the whole package wrapped in paper. These measures were used to keep the sample papers in an acid-free or alkali-free environment, in order to avoid an unnatural alteration of the pH values with consequent inaccurate readings, while the outermost coating paper served to protect the samples from dust and atmospheric particulates of various nature that would have been deposited on the surface during the period of alternation in the conservation

18 Modified wheat starch paste, animal hide glue, Vinavil®59, Glutofix®600, Tylose®MH300p, Klucel®G, *Funori* solutions. All the samples were subjected to 100% of relative humidity and temperature between 15-25 °C, with sunlight exposure of about six hours daily for a total period of three months; see Baudone, note 4, 91-93; Lalli, Kron-Morelli, Brogi, Baudone, Tosini, note 1, 49-52.

19 See 'IFLA Principles for the Care and Handling of Library Material', ed. by E.P. Adcock et al., in: *International Preservation Issues*, 1 (Paris: IFLA PAC, Washington DC: CLIR, 1998).

Table 3. pH measurements of handwritten supports on handmade (A-B-C) and machine-made paper (D) after one year of environmental monitoring

			Values of the first environmental monitoring cycle			
Samples	***Funori* solution %**	**pH value after resizing**	**I 10°C + 40% UR pH ±**	**II 25°C + 40% UR pH ±**	**III 10°C + 60% UR pH ±**	**IV 25°C + 80% UR pH ±**
A	0.3	7.56	7.54 [-0.02]	7.60 [+0.04]	7.58 [+0.02]	7.55 [-0.01]
B	0.3	7.52	7.57 [+0.05]	7.50 [-0.02]	7.53 [+0.01]	7.56 [+0.04]
C	0.3	7.62	7.64 [+0.02]	7.59 [-0.03]	7.60 [-0.02]	7.63 [+0.01]
D	0.3	7.35	7.39 [+0.04]	7.41 [+0.06]	7.40 [+0.05]	7.39 [+0.04]

environments. The decision to use a paper made of pure cellulose with a neutral pH was dictated by scrupulousness and by the desire to isolate in the most neutral way possible the samples treated with *Funori*. The premises for the execution of this monitoring were chosen based on two essential elements in the field of conservation: temperature and relative humidity.[20] For these two factors, four different combinations have been found that are capable of ensuring the change of at least one of the two components. The samples were stored separately, grouping them according to type and avoiding putting them directly into contact with each other.

After one year of monitoring (Table 3), none of the values recorded on the samples underwent drastic variations. We have also found that *Funori*, like the most commonly used cellulose ethers, manages to maintain its physical and chemical characteristics when the environmental conditions of temperature and relative humidity change.

At the same time, at the first tactile observation, all the papers maintain their mechanical properties of elasticity and flexibility, without altering the naturalness of the sound during stress. All the pH readings taken at the end of each cycle remain within those ranges originally detected, since the small variations that are found can be explained by with the normal internal variations in the paper support in relation to the surrounding environment. All the samples reacted in the same way to the various conservation environments, finding a thermo-hygrometric equilibrium that does not alter their internal status and allows them to maintain the pH at levels optimal for good conservation. Even the presence of inks of various kinds does not alter the properties of the *Funori* adhesive, and above all the characteristics of the graphic mediations themselves, since the latter do not show any optical-chromatic alteration. The acidic nature of the manuscript inks can be an excellent vehicle for the degradation of the object support.

Similarly, the nature of the raw material and the modern paper-processing processes, which lead in a short time to the creation of a diffused acidic substrate on the whole artefact, can also accelerate its degradation. The resizing with the algae extract seems to be able to buffer these reactions and to create an optimal internal environment both for the inks and for the paper itself, as well as guaranteeing the paper artefact physical-mechanical stability. After four years of monitoring, both ancient and modern manuscript papers still present the initial tactile characteristics: no roughness or stiffness appeared more or less marked, as well as no alterations to the inks and to the seals in red

20 The factors to be taken into consideration are many more and include light, mould, insects and other pests, air and dust pollution. In this case, placing the samples between two thick pieces of cardboard and wrapped the whole package in paper, the problems caused by light, mold, insects and various pollution do not arise.

Table 4. pH measurements of handwritten supports on handmade (A-B-C) and machine-made paper (D) after four years of environmental monitoring

Samples	*Funori* solution %	pH value after resizing	pH value after the first cycle	Values of the fourth environmental monitoring cycle I 10°C + 40% UR pH ±	II 25°C + 40% UR pH ±	III 10°C + 60% UR pH ±	IV 25°C + 80% UR pH ±
A	0.3	7.56	7.55 [-0.01]	7.54 [-0.02]	7.53 [-0.03]	7.53 [-0.03]	7.58 [+0.02]
B	0.3	7.52	7.56 [+0.04]	7.54 [+0.02]	7.48 [-0.04]	7.50 [-0.02]	7.49 [-0.03]
C	0.3	7.62	7.63 [+0.01]	7.62 [±0.00]	7.65 [+0.03]	7.60 [-0.02]	7.61 [-0.01]
D	0.3	7.35	7.39 [+0.04]	7.37 [+0.02]	7.38 [+0.03]	7.34 [-0.01]	7.36 [+0.01]

wax. At the same time, the internal environment was still settled on the original values (Table 4), confirming our thesis about the suitability of the *Funori* seaweed extract for the operations of resizing paper materials.

Conclusion

The field of conservation is a sector in continuous growth, aimed at the achievement of a fascinating but arduous goal: to preserve a work of art. Every year, new methods of analysis and intervention are developed with the precise goal of making the usability of an object, whatever its nature, more and more durable. The restoration of paper materials is often considered to be a minor, secondary art, with lower visibility than that attributed to other sectors. The conservation processes of a book, an engraving or a drawing involve considerable skills and knowledge that only study and experience are able to guarantee, in addition to research and experimentation with new techniques and products. This study intends to link to this last line: to investigate and develop a new type of adhesive to be used in the paper sector. *Funori* has all the essential features for the success of the operations: it is absolutely compatible with cellulose being also a polysaccharide; if used in suitable percentages for the operations, it allows a full and total penetration of the adhesive inside the paper fibres, in virtue of its low viscosity; has a neutral pH with a slight tendency to alkalinity; it is absolutely reversible both in hot water and room temperature water; does not alter the optical properties of the support on which it is spread. Added to this is its ability to inhibit or slow down the development of paper-damaging microorganisms, although this field is still to be explored in detail. In any case, it is necessary to make a clarification: the tests conducted so far, carried out in the best possible way and in an attempt to obtain all the information necessary and indispensable to answer the questions that naturally arose during these studies, have no absolute value. The percentages used here were those we consider suitable for the papers used, but this does not exclude its use at higher percentages for the same operations on other types of paper supports, whether they are antique handmade or modern machine products. This research is intended to be a further step on the road towards a common goal. I hope that this research can serve as a stimulus to conduct further studies and experiments within a fruitful dialogue with a single protagonist: the work of art.

Francesco BAUDONE

Istituto per l'Arte e il Restauro, Palazzo Spinelli, Via Maggio, 13, 50125 Firenze, Italy

fbaudone.conservation@gmail.com