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Undervalued cultural heritage: Technical study and conservation issues of 17th-century French straw marquetry

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The Musée du Hiéron, located near the pilgrimage site of Paray-le-Monial, France, houses two engravings of Saint Matthew and Saint Ursula set in octagonal straw-mosaic frames, a technique also referred to as straw marquetry.

Although widely produced by nuns in convents during the 17th-century, straw-decorated objects remain understudied. A collaborative project involving the *Centre de Recherche et de Restauration des Musées de France* (C2RMF), the *Centre de Recherche sur la Conservation* (CRC), and three independent conservators combined scientific research with conservation treatment to improve knowledge of their materials, techniques, and preservation.

Material study

Observations and analyses were conducted by the C2RMF and the CRC.

Digital microscopy

- Plant materials were confirmed to be straw, although the species could not be identified, as wheat, barley, oat, and rye straws share similar microscopic morphological characteristics.
- Lining papers and backing board were made of linen rag pulp (flax fibers).

Hyperspectral imaging

- Azurite was identified in the blue paper flowers scattered on the background, as well as on the engravings themselves.
- Vermilion was applied to parchment supports.
- A tannin-based organic colorant was used to color the straw flowers red.

pXRF

- Copper acetate was identified on the green straw.

FTIR and GC-MS multi-omics approach

- *Astragalus gummifer* (gum tragacanth) was used as an adhesive.
- *Acacia Senegal gum* (gum arabic) was employed as a binder for the background color.

Frame deformations visible under raking light © C2RMF/Anne Maigret.

Map of the probable colours of the straw elements © C2RMF/B. Massiot

Lifting and shrinkage of the black Arabic gum ground © C2RMF/ B. Massiot.

Soiling of the straw, obscuring its golden luster and sheen © C2RMF/ B. Massiot.

Two engravings in straw mosaic frames

- Both engravings were produced on parchment using the burin technique and were published by Flemish publishers around 1620–1630. Although both depict figures inspired by Rubensian models, their differing formats suggest separate origins before being assembled into a unified ensemble with straw-marquetry frames and polychrome enhancements.
- The octagonal frames are made of cardboard supports composed of ten reused paper sheets, covered with black paper and reinforced with layered linings.
- The frames are decorated with vegetal motifs and geometric friezes, creating a golden and polychrome mosaic effect enhanced by three-dimensional floral elements.

Engravings and frames of Saint Ursula and Saint Matthew before treatment © C.Kasprzak.

Condition assessment

The main degradations consisted of cupping, lifting, and flaking of the black background, and localized paint loss. Heavy surface soiling affects all areas and is associated with staining, tidelines, and silica-rich dust.

Other condition issues included:

- Deformations and losses in the cardboard leaves and the straw elements.
- Paper yellowing, straw discoloration, and evidence of a previous silverfish infestation.

Straw surface cleaning

The surface of the straw is covered by a thin waxy cuticular layer that becomes increasingly sensitive over time to water, acidic and alkaline solutions, as well as to mechanical abrasion. The gums, colorants, and relief decorative elements exhibit similar sensitivity.

Mock-ups

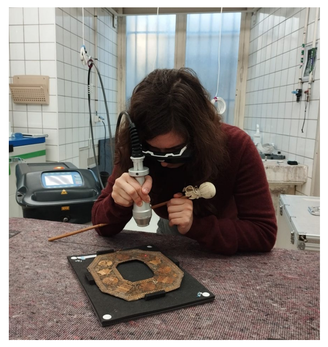
- Straw marquetry mock-ups made from new rye straw.
- A non-museum straw-marquetry object featuring dyed straw applied to a cardboard support.

Cleaning tests

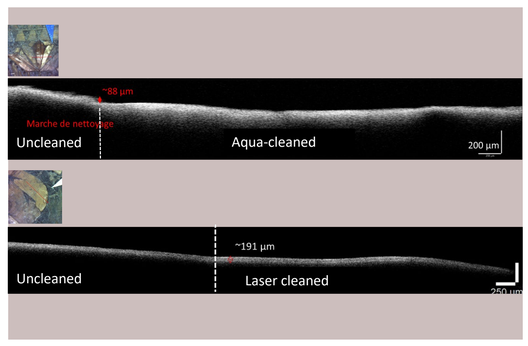
- Dry cleaning methods: Evolon® polyethylene nonwoven fabric, Deffner® polyurethane sponge, Staedtler® PVC eraser, and extra-fine foam swabs.
- Chemical methods: ethanol, pH 6-adjusted water combined with mechanical cleaning, and Nanorestore® hydrogel.
- Laser cleaning:
  - Nd Eos Combo laser, 1064 nm wavelength, LQS mode, 150 mJ, 1 Hz, T25 lens, focal distance 8, fluence 0.76 J/cm^2.
  - QS El.En® laser, 10 mJ, 1 Hz, T25 lens, focal distance 10, fluence 0.14 J/cm^2.

Monitoring of the cleaning process

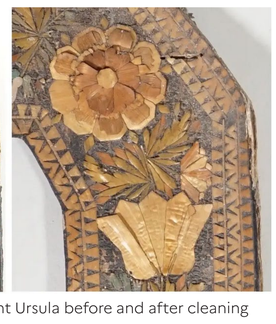
- 3D digital microscopy.
- Optical Coherence Tomography (OCT). Observations confirmed that laser cleaning allows controlled, progressive removal of surface soiling through optimized parameters and multiple passes. It produced a smoother surface and a visible sheen, without detectable alteration at the analyzed depth resolution (≈3 µm) while preserving the transparent surface layer, unlike aqueous cleaning.



Eos Combo laser cleaning using LQS mode, with Camille Benecchi © C. Romeggio.



OCT (Thorlabs) measurement (wet cleaning and laser) © X. Bai.



Detail of the straw mosaic of Saint Ursula before and after cleaning © C. Romeggio.

Straw mosaic of Saint Ursula after treatment © C.Kasprzak.

Results : selection of the cleaning method

- Laser cleaning yielded the best overall results, enabling precise removal of surface soiling without mechanical damage or the risk of hydrolytic degradation of either the straw fibers or the support. It also significantly reduced treatment time.
- Among the aqueous methods, cleaning with pH 6-adjusted water, applied using an extra-fine microporous foam swab, followed by gentle blotting with an ophthalmic cotton applicator, proved to be the most suitable. This method was used as a complementary treatment in areas where laser cleaning was not appropriate.
- Mechanical cleaning methods used alone required excessive pressure and were therefore excluded from the treatment protocol.

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The Musée du Hiéron hosts a sacred art collection near the pilgrimage center of Paray-le-Monial, France. The collection includes two engravings, depicting Saint Matthew and Saint Ursula, framed within a pair of straw-marquetry frames. These works were created by nuns using modest and repurposed materials and served as devotional objects in convents or were sold to achieve financial independence. Although straw objects have been produced across many cultures, they are often largely ignored, such that knowledge of their materials remains limited. Their rediscovery has prompted a renewed appreciation of these extraordinarily skillful productions. Devising a conservation treatment required an in-depth study of the straw elements, material analyses, and comparative cleaning tests using mechanical, chemical, and laser methods. The frames were decorated using the straw mosaic technique. The straw was dyed, cut using a die cutter, shaped, and finally glued onto a contrasting black background cardboard made from several layers of paper. At the Centre de Recherche sur la Conservation (CRC), the species of the straw and paper fibers were examined using digital microscopy. However, the similar structures of the straw prevented a determination of the plant species, either wheat, barley, oats, or rye. The lining papers and backing board were found to be made of linen rag pulp (flax fibers). Hyperspectral imaging carried out at the CRC allowed a partial characterization of the inorganic colorants and pigments. Notably, azurite was identified in the blue paper flowers scattered on the background, as well as on the engravings themselves. This suggests that the nuns had colored the engravings while creating the frames to enhance the aesthetic value of the final product. The binding media were analyzed at the Centre de Recherche et de Restauration des Musées de France. Fourier-transform infrared spectroscopy and gas chromatography coupled with mass spectrometry revealed the presence of a gum, both in the adhesive used to mount the straw onto its support and in the binder for the black background. A complementary integrated multi-omics approach, combined with a machine learning flowchart for gum identification, carried out in collaboration with the École Supérieure de Physique et de Chimie Industrielles de Paris, further refined the gum's identification and provided insights into the production technique. It also confirmed the presence of cupping, lifting, and flaking of the black background only in areas containing the gum. To best

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adapt the cleaning strategy to the complex, water-sensitive, three-dimensional, and colored surfaces, tests were conducted on both new and aged straw. The trials demonstrated that pH- and conductivity-adjusted water, applied with a microporous sponge, together with laser treatment (Nd:YAG Eos Combo laser), produced the best results. The frames were then cleaned using this method, with the process controlled under 3D microscopy and optical coherence tomography. A better understanding of both the objects and the technique used in their production led to a renewed appreciation of this little-known heritage and enabled appropriate conservation treatment, rehousing, and storage of the artworks.

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