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Nuclear studies of modern and historical leather

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Abstract:
Leather objects, either modern or historical, are sensitive to moisture and, in particular, to temperature and relative humidity (RH) variations, and prone to microbial attack. Such climatic changes can cause microbiological, chemical and mechanical damage to (i) historical object in uncontrolled environmental conditions as seen in old buildings and palaces, and (ii) hides, pelts and finished modern leather during processing, transport and storage. Two kinds of experiments were designed and carried out to investigate (i) the effect of gamma irradiation on collagen matrix and set the safe treatment dose for effective disinfection and (ii) the moisture uptake/loss depending on tanning type, damage condition and conservation treatment.

Keywords: historical & modern leather, collagen matrix structural stability, moisture, gamma irradiation, neutron imaging

1. INTRODUCTION

For comprehending, restoring, and conserving artefacts of our cultural heritage one must look beyond the superficial appearance of the object following an initial visual inspection, seeking to uncover every conceivable detail able to shed light into their composition, structure and behaviour. Due to the vulnerability of precious artworks, manuscripts, and other delicate items, these investigations must be conducted non-destructively or through minimally invasive methods [1-3].

Any systematic study of leather modern items and historical artefacts is essential to understand their original chemical and physical composition before and after any possible degradation processes. Nonetheless, correlations with historical and cultural contexts are also indirectly achievable. The main general objectives involved in the analysis of the leather items come together to derive the following practical information:

- Full chemical (atomic/elemental, molecular) and structural characterization,
- Discrimination between the original components, additives, contaminants and degradation products,
- Elucidation of the cause and dynamics of the mechanism behind ageing processes for preventing a possible future deterioration,
- Relevant information for proving the authenticity and detecting fraud.

These objectives include manufacturing processes and allows for the development of potential future conservation treatments to ensure good storage/display conditions and minimal deterioration. In this paper, some examples of leather assessment are provided, from a simple visual and microscopic inspection to very sophisticated and advanced technologies established in chemistry and nuclear physics, including neutron imaging experiments available at large scale facilities.

2. MATERIALS AND METHODS

2.1. Materials

New manufactured and historical leather, as well as treated mock-ups (either modern samples exposed to gamma radiation treatments or historical samples exposed to conservation treatments) were analyzed.

2.1.1. Gamma irradiation experiments

Hide, pelts and leather items are vulnerable to microbial attack promoted by high relative humidity environment and high moisture content. The purpose of this study was to gain a better knowledge of the changes in collagen matrix thermal stability and structural order after mass gamma irradiation disinfection. Pelt and leather samples (newly fabricated and artificially aged) were exposed to ^{60}Co gamma rays at the IRASM Center for Technological Irradiations of the Horia Hulubei National Institute for Physics and Nuclear Engineering (HH-IFIN), Magurele. IRASM facility is a category IV gamma irradiator. The radiation doses applied were 10, 25, 50 and 100 kGy with a dose uniformity ratio (DUR) of 1.14 [4].

2.1.2. Neutron imaging experiments

Modern and historical leather-made items are sensitive to moisture and especially susceptible to temperature and relative humidity fluctuations in their environment. These climatic changes can cause chemical degradation and mechanical damage. Hide and leather samples were put in a custom-made closed-cell and subjected to programmed cycles of RH at a regulated temperature while exposed to the neutron beam to simulate this circumstance in an experimental context [5]. Neutrons have strong interactions with only a few chemical elements, the most important of which being hydrogen, which strongly attenuates them. Because neutrons and hydrogen interact directly, they are perfect for imaging moisture transport. The neutron imaging experiments were performed at the ISIS neutron and moun source of Rutherford Appleton Laboratory of the Science and Technology Facilities Council, UK.

2.2. Analysis methods

Non-destructive surface and subsurface spectroscopic techniques involving the use of an incident beam of photons covering diverse electromagnetic regions were used, particularly InfraRed (IR), Raman, X-Rays, were used for surface excitation and deriving analytical information. Portable instruments (Alpha FTIR from Bruker, Raman microscope from BWtek and XRF spectrometer from XGLab, SEM-EDX) were used together with micro-DSC and 1H NMR to add all possible details about the bulk properties of the investigated samples.

3. RESULTS AND DISCUSSION

3.1. Gamma irradiation experiments

The results revealed significant changes in the collagen chemical matrix thermal stability and structural order in damaged leather at 10 kGy dose, while new, undamaged leather better-withstood radiation up to either 25 kGy or 50 kGy, depending on collagen species and tannin type. In particular, the collagen-tannin matrix of the new vegetable leather destabilized gradually with increasing radiation exposure, but retained its leather-like properties up to 100 kGy, while the damaged leather suffered de-tanning starting at 10 kGy irradiation dose. As the dose was raised, collagen became totally de-tanned, allowing the conversion of collagen into gelatin. Similar experiments were carried out on fresh hides to explore the possibility to replace the polluting salting process by gamma irradiation.

3.2 Neutron imaging experiments

Our experiments tracked the moisture uptake/loss and mapped its distribution in leather samples during programmed cycles of moisture sorption and desorption with the aim of investigating both the impact of consolidating treatments on the hygroscopic response of the degraded leather as well as the effect of a new tanning agent on the water permeability of a new leather prototype. This was the first time neutron radiography measurements were performed on leather. Future work will focus on studying the relationship between the moisture content and mechanical qualities of leather items.

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