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Evaluation of the Physicochemical Stability of Paintings with Modern Tempera Gouache Exposed to Gamma Radiation for Conservation and Restoration Applications

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1. Introduction

The conservation/restoration of pictorial cultural heritage on textile supports requires strategies that respect the material integrity of its multilayered structure [1], [2], [3]. Modern gouache tempera paint contains organic materials in its composition, such as gum arabic [4], [5] and synthetic organic pigments [6], [7], [8], which are vulnerable to biodeterioration by agents such as fungi, bacteria, and insects [09]. Chemical products commonly used for disinfection may penetrate the paint layers and react with the paints or materials from previous restorations, causing stains and irreversible damage [10]. This study investigates the stability of three gouache tempera paints applied on textile supports and subjected to gamma radiation doses ranging from 1 to 25 kGy for biological decontamination. The methodology is based on a multi-technique approach, using colorimetry and infrared spectroscopy (FTIR-ATR) to monitor possible changes in the binder and pigments. The aim is to validate the safety of gamma radiation as an intervention method, ensuring the conservation of cultural heritage without compromising the aesthetic appreciation and structural integrity of the irradiated materials, proving to be a method in line with the ethics of the conservator/restorer.

2. Methodology

The selected paints are from the Tempera Fine line by the Maimeri brand, in the colors: orange 050, emerald green 356, and black 530, all containing synthetic organic pigments. The textile support used was unstarched linen fabric with sizing and preparation layers, both with an acrylic base and acrylic gesso. The support was fixed to a rigid pH-neutral paper base to prevent cracking in the samples.

The pigments composing each paint are: hansa yellow 10 G code PY3 and chlorinated phthalocyanine code PG7 (emerald green 356), lamp black code PBk7 (black 530), and benzimidazolone code PO62 (orange 050). The exact composition and percentage of each component in gouache tempera paints are not described on the packaging; however, Werneck (2009) indicates the addition of white fillers such as calcium carbonate ($CaCO_3$) and gypsum ($CaSO_4 \cdot 2H_2O$), which confer its characteristic opacity. It is a paint compatible with supports such as paper, wood, and canvas [5], [11].

The samples were irradiated at the Radiation Technology Center (CTR-IPEN-CNEN/SP) using a multipurpose ^{60}Co irradiator. The absorbed doses applied to the samples were 1, 3, 6, 10, 15, and 25 kGy, with dose rates ranging from 1.20 to 1.94 $kGy \cdot h^{-1}$.

3. Results and Discussion

Colorimetry

Spectrophotometer readings were performed seven days after irradiation. The system adopted was CIELAB - CIE Lab*, which represents the quantitative relationship of colors across three axes: the L* value indicates lightness, while a* and b* are chromaticity coordinates [12].

All colors showed ΔE* variations below 1, which are almost imperceptible and therefore acceptable [13], with a loss of lightness in the green and orange colors and a gain in the black color. Among the three paints, the green showed the greatest changes in Δa*, with a reduction in the yellow tone of the color. The orange paint exhibited chromatic changes, showing the appearance of greenish and bluish tones. These changes are illustrated in Fig. 1, 2, and 3.

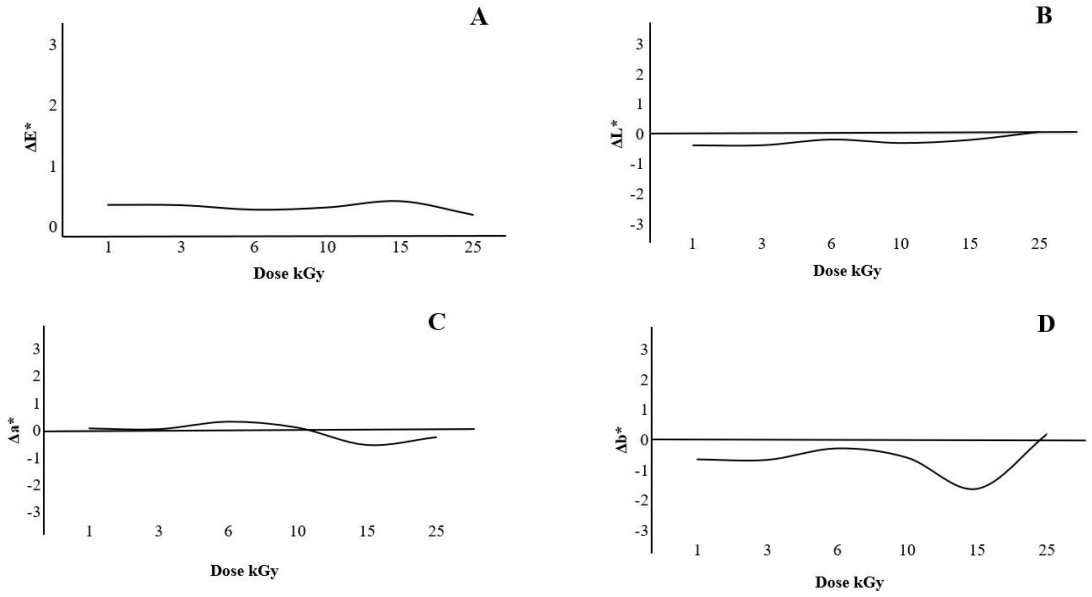


Figure 1: Colorimetry curves for the orange sample: (A) ΔE* total color change, (B) ΔL* lightness difference, (C) Δa* red-green difference, and (D) Δb* yellow-blue difference.

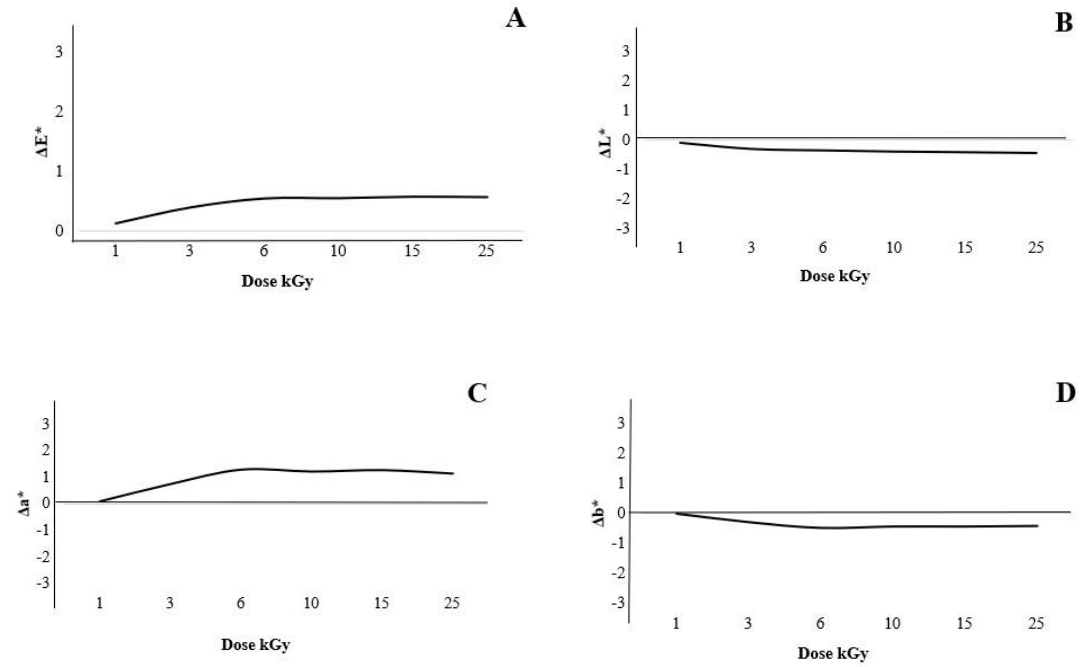


Figure 2: Colorimetry curves for the green sample: (A) ΔE* total color change, (B) ΔL* lightness difference, (C) Δa* red-green difference, and (D) Δb* yellow-blue difference.

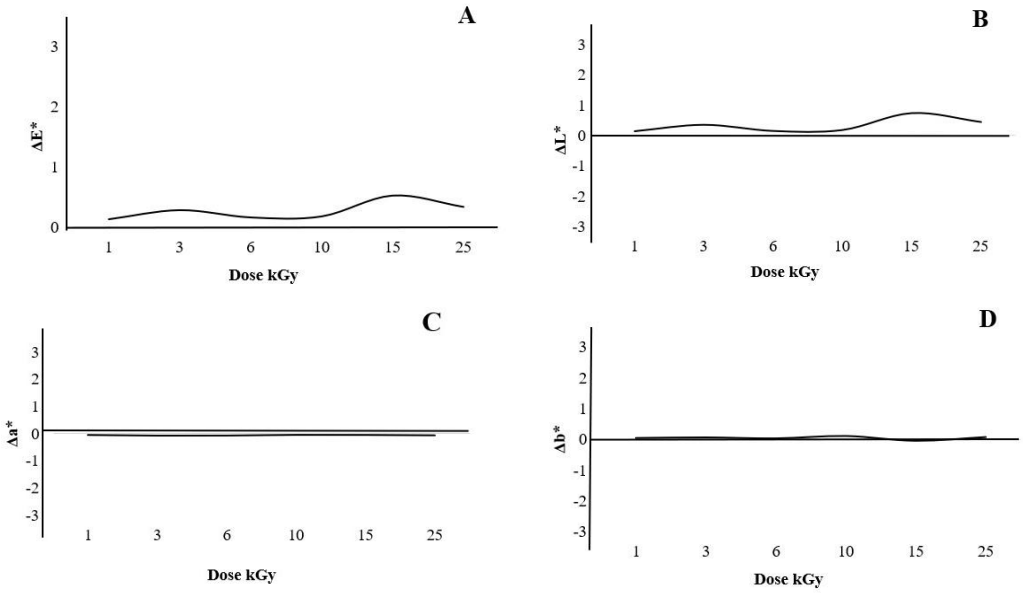


Figure 3: Colorimetry curves for the black sample: (A) ΔE* total color change, (B) ΔL* lightness difference, (C) Δa* red-green difference, and (D) Δb* yellow-blue difference.

FTIR

In the green and black paints, the overlap of gum arabic C-O-C bands and carbonate and silicate peaks at 1425 and 876 cm^{-1} is noticeable; these act as stable inorganic skeletons, protecting the chemical integrity of the materials. They also exhibited broad bands near 3300 cm^{-1} resulting from O-H stretching vibrations, characteristic of the polysaccharide chains in gum arabic, while the peak at 2889 cm^{-1} is characteristic of the C-H band in the 2800 to 3000 cm^{-1} region. The Hansa Yellow pigment (PY3) in the green paint can be identified by the N=N stretching with a peak at 1380 cm^{-1}. In the orange paint, peaks were identified at 2915 cm^{-1}, typical of C-H bond stretches, and at 836 cm^{-1} (within the 1000–650 cm^{-1} region) corresponding to aromatic alkenes, along with peaks associated with modern synthetic pigments at 1730 cm^{-1}, typical of C=O bond stretching, and 1498 cm^{-1}. The results demonstrate that in the orange paint, the application of gamma radiation at a dose of 25 kGy may have caused material oxidation, evidenced by the increase in the peak at 1730 cm^{-1} corresponding to vibrations of the hydrolysis susceptible C=O group, and the change in intensity of the 872 cm^{-1} peak, which belong to the fingerprint region of the orange paint. In contrast, in the green and black paints, the 0, 10, and 25 kGy lines showed greater overlap, indicating enhanced stability at the 25 kGy dose, as shown in Figures 4 a, b, and c.

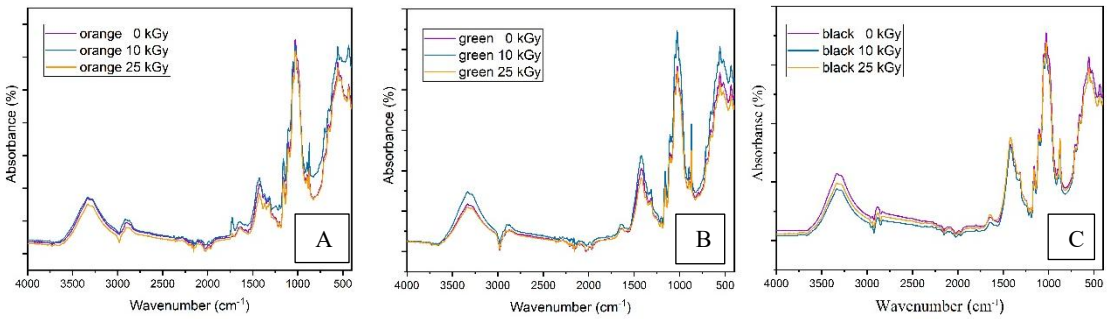


Figure 4: FTIR spectra of the paints (A) orange, (B) green, and (C) black. Reference sample at 0 kGy and with absorbed doses of 10 and 25 kGy.

4. Conclusions

Overall, considering the variations observed in the colorimetric results among the different pigments, it is concluded that the 10 kGy dose is the most suitable for gamma radiation processing of the analyzed

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gouache temperas. This condition ensures effectiveness in biological decontamination without inducing structural alterations, as evidenced by the stability of the FTIR peaks. These findings reinforce the reliability of the procedure adopted and indicate the feasibility of continuing the investigation.

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