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Review article

Lorenzo Lotto's painting materials: an integrated diagnostic approach

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A B S T R A C T

This paper presents the results of a comprehensive diagnostic investigation carried out on five paintings (three wood panels and two paintings on canvas) by Lorenzo Lotto, one of the most significant artists of the Italian Renaissance in the first half of 16th century. The paintings considered belong to 1508–1522 period, corresponding to the most significant years of Lotto's evolution. A wide array of non-invasive (reflectance spectrometry and X-ray fluorescence) and micro-invasive analytical techniques (optical microscopy, scanning electron microscopy with energy dispersive spectroscopy, micro-FTIR spectroscopy, micro-Raman spectroscopy, gas chromatography coupled with mass spectrometry and high performance liquid chromatography coupled with photodiode array detection and mass spectrometry) were applied in order to provide a large set of significant data, limiting as much as possible the sampling. This study has proved that Lotto's painting palette was typical of Venetian practice of that period, but some significant peculiarities emerged: the use of two kinds of red lakes, the addition of calcium carbonate and colourless powdered glass, the latter frequently found in pictorial and ground layers. Moreover, the integrated investigation showed that Lotto's technique was sometimes characterized by the use of coloured priming and multi-layer sequences with complex mixtures. Chromatographic analyses allowed to identify in all specimens: azelaic, palmitic and stearic acids, generally referring to the presence of drying oils. The extension of additional non-invasive examination to about 50 paintings by the same author, spanning from 1505 to around 1556, helped to verify the evolution in the use of some pigments, such as the yellow ones, where Pb-Sb yellow was used alongside Pb-Sn yellow.

Contents

1. Introduction . . . 111
2. Experimental . . . 111
   2.1. Instruments and methods . . . 111
      2.1.1. Energy dispersive X-ray fluorescence (ED-XRF) . . . 111
      2.1.2. Reflectance spectrometry (vis-RS) . . . 111
      2.1.3. Optical microscopy (OM) . . . 112
      2.1.4. Scanning electron microscopy and environmental scanning electron microscopy coupled with energy dispersive X-Ray (SEM and ESEM/EDX) . . . 112
      2.1.5. Micro-Raman spectroscopy (MRS) . . . 112
      2.1.6. Fourier transform infrared spectroscopy with micro-attenuated total reflection (µ-FTIR-ATR) . . . 112
      2.1.7. Gas chromatography - mass spectrometry (GC–MS) . . . 112
      2.1.8. High performance liquid chromatography coupled with high resolution time of flight mass spectrometry (HPLC–HR-ToF-MS) . . . 112
   2.2. Samples . . . 112
3. Results and discussion . . . 112
   3.1. Supports . . . 113

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3.2. Ground layers . . . 113
3.3. Blue pigments and violet colours . . . 115
3.4. Green pigments . . . 115
3.5. Yellow and orange pigments . . . 116
3.6. Red pigments . . . 118
3.7. Brown, black and white pigments . . . 119
3.8. Flesh tones . . . 120
3.9. Organic materials . . . 120
4. Conclusions . . . 120
Acknowledgements . . . 121
References . . . 121

1. Introduction

Lorenzo Lotto (Venice, 1480 – Loreto, 1556 or 1557) was one of the most interesting painters of Venetian 16th century, besides Titian, Giorgione, the late Giovanni Bellini, and before the new generation of Veronese and Tintoretto, both for the elegance of his work and for his iconographic and chromatic innovations, with a special feel for opposite colour juxtapositions and for cold and saturated hues. His painting technique was investigated during the last years [1–2], but never with a complete approach including non-invasive examinations together with micro-invasive analyses over a broad range of works. Many features of Lotto's technique, taking into account literature and a first screening of new collected data (mainly non-invasive) have recently been discussed in non- technical essays in Italian [3]. More specific results have been published about almost each single painting placed in Marche [4,5] and Veneto regions [6], and about three works of Bergamo [7], but without detailed micro-chemical data.

We based this study on large paintings by Lotto, particularly three wood panels and two paintings on canvas. The three wood panels are: the polyptych of the church of St. Dominic (1508) and the *Transfiguration of Christ* (1511–12), both in Recanati (Museo Civico, Villa Colloredo Mels), and the polyptych of Ponteranica, near Bergamo (1522). The two paintings on canvas, dated 1521, are the altarpieces of the churches of St. Bernardino and of the Holy Spirit in Bergamo (Fig. 1, see also Figs. S1-S4, Supporting material).

Fig. 1. Lorenzo Lotto, *Holy Spirit* altarpiece (1521), Bergamo, Church of Santo Spirito. During the cleaning intervention.

The respect for conservation issues and the analytical needs suggested the application of an integrated approach based on the use of both non-invasive (first step) and micro-invasive techniques (second step) to investigate painting materials and techniques [8]. As a first step, a non-invasive in situ campaign was carried out on about 50 paintings of Lotto using portable instruments, in order to collect as much information as possible by minimizing the sampling. Spectroscopic techniques, like reflectance spectrometry in the visible range (vis-RS) and energy-dispersive X-ray fluorescence spectroscopy (ED-XRF) were chosen as informative first-step analyses, preceded by photographic, UV fluorescence and IR reflectography campaigns to identify the best areas to be sampled as well as to record conservative issues and some features about painting technique, like underdrawing and changes [5–7].

As a second step, after carefully collecting, a minimum set of micro-fragments on the 5 aforementioned paintings was analysed by several analytical techniques with the aim to obtain a characterization of the inorganic and organic components: optical microscopy, environmental scanning electron microscopy with energy dispersive spectroscopy (ESEM/EDX), micro-FTIR spectroscopy, micro-Raman spectroscopy, gas chromatography coupled with mass spectrometry (GC–MS), and high performance liquid chromatography coupled with high resolution time of flight mass spectrometry (HPLC–HR-ToF-MS).

2. Experimental

2.1. Instruments and methods

2.1.1. Energy dispersive X-ray fluorescence (ED-XRF)

X-ray fluorescence analysis (ED-XRF) was carried out using two Bruker Tracer III SD energy dispersive spectrometers, both operating at 40 kV, with X-Flash SDD detector and 4 mm diameter spot, one with an Ag target X-ray tube operating at 22 μA, the other with a Rh tube at 11 μA, with proper Al-Ti-Cu filter. They are both particularly sensitive to Sn and Sb K-lines. Bruker Artax software was used to elaborate spectra.

2.1.2. Reflectance spectrometry (vis-RS)

Reflectance spectroscopy measurements, mainly in the visible range (vis-RS), were obtained using a handheld spectrophotometer Minolta CM 2600d: 360–740 nm range, 10 nm acquisition step, integrating sphere included, UV source included, d/8 geometry, 3 mm diameter spot. This choice enables fast data acquisition and reliability in identifying spectra as tested on the field during many campaign of analyses on ancient and modern pigments, considering the typical broad bands of RS spectra and the little variability in the position of the features of the spectra (reflectance minima and shoulders) when pigment concentration changes, usually in the order of a few nanometres. RS instruments with higher spectral resolution (1 nm or lower) are usually not necessary to identify a large class of pigments. A wide personal