1. Introduction
Since the beginning of the nineteenth century, the analysis of pigments on cultural heritage objects has been of great interest. The diverse studies carried out provide an intriguing insight into the materials and techniques used by the artist, which furthermore contribute to the development of scientific tests for the analysis of pigments (Rees-Jones 1990). Nowadays, the use of analytical techniques, for example, infrared spectroscopic, x-ray fluorescence and microscopic techniques, are some of the most useful techniques for the study of pigments found in several objects, for instance, paintings, archaeological materials and paper (Roldán et al. 2016; Rosi et al. 2009; Schreiner et al. 2007; Trojek et al. 2017). One aspect of our interest is the pigments found on textiles, specifically the pigments that are found in the scenography curtains of a theatre. These curtains were usually designed to work as part of the scenery in a show. It was common for these curtains to be hand-painted by artists, turning them into art objects (Corrado 1928; Little 1936). These were not produced to last as each curtain was done for a specific play in a theater. For this reason, there are very few conserved around the world. Nevertheless, to the best of our knowledge, the National Theater of Costa Rica has an extraordinary and unique collection of curtains that were used for several spectacles since 1897.

Most studies of pigments that have been carried out on textiles until today are mainly to determine the composition of the dye, colorant of organic and inorganic pigments observed in the textiles and are mostly samples of archeological interest (Korenz 1977; Meyer et al. 2018; Orna 2011). Nevertheless, little research has been conducted to address the subject of historical stage curtains, moreover within the Latin America region. The absence of information about the materials and techniques used in
the manufacturing of these items are unknown, by both artists and historians.

In the Latin American region, a great icon for protecting and promoting the cultural legacy is the National Theater of Costa Rica. This Theater was built by a Decree Number XXXIII, on May 28th, 1890, and was opened to the public until October 21st, 1897 (Salazar et al. 2015; Quesada 1996). It was declared a National Monument in 1965 and a National Symbol by law No 9521 in 2018. This building is characterized by Neoclassic German style with French and Italian influence, design by Italian and Belgian architects and engineers (Santamaría 2017).

This historic building represents an important part of the Costa Rican culture, and has also been a protector of the cultural heritage in the country. An example of this protective condition is the aforementioned wide collection of stage curtains that have been preserved since the inauguration of the building, and was commissioned as part of its original pictorial decoration. These holdings comprise 39 stage curtains, with a main-curtain of large dimensions as the star item of the collection, and the rest of it being scenography curtains (Miralles, 2017).

Despite the efforts made by the institution to preserve the curtains, the climatic conditions in Costa Rica (such as high humidity and warm temperatures), and the large dimensions of the curtains, have caused a significant deterioration in a large part of the compendium, including the main curtain.

The little information available regarding stage curtains and the even smaller documentation in existence on the main curtain itself have complicated the restoration process for the artwork. To assess this lack of technical information about the materials used in the painting of the main curtain, we performed a solid and quantitative evaluation of the composition of the pigment used in the main curtain. Furthermore, we elucidate the pictorial technique, in order to generate the necessary information for a future preservation process.

Accordingly, the article is organized in seven main sections: Section 2 outlines the historical background of the examined curtain; Section 3 describes the different methods and experimental techniques carried out; Section 4 focus on the analysis of the results; Section 5, on the other side, highlights the main conclusions of the research. Finally, Sections 6 and 7 underline the contributions to the investigation in Acknowledgments and References.

2. Historical-cultural context of the main curtain

Between 1880 and 1900, Europe saw one of the largest waves of migration to America. This exodus was the result of a crisis faced by many of the western countries including the commercial rupture with France, the rural economic crisis and several banking problems. (Duggan 2017, p. 7).

Many Italians, especially from the south, saw a new opportunity for life in Central American territory. This new opportunity was bolstered by the ideals of progress and freedom over which the emerging nations, such as Costa Rica, resolved their independence. Regarding the receptive conditions of Latin America, after the prohibitive colonial period, the liberals of the nineteenth century encouraged foreign investment and immigration, especially from Europe. In addition, the immigrant was part of the political population of the agrarian republics of Latin America, since it had been conceived for the abundance of citizens symbolizing greatness (Bariatti 1997). These migrants found a Costa Rica under construction that was sustained by liberal thinking, where the idea of progress ran deep in the social, political and cultural structures. Such thought was appealing to the image of the main artistic referents of the time, such as France and its neoclassical style. As Ferrero (2004) mentions regarding Costa Rican society of that time: “We were, in short, like a European aggregation, sustained almost completely, by the exterior”.

In this context, the Durini brothers, Italian migrants, came to Central America. They settled with a commercial network that would supply the region with objects such as marble, furniture, fountains and castings, amongst others. Amid these articles were the curtains, which would eventually decorate the National Theatre (Santamaría 2017). Usually, these items were commissioned to high quality scenography designers which generally divided them in main and scenic curtains.

According to Santamaría, the main curtain (see Figure 1) was commissioned to Carlo Orgero (1844–1919) between 1893 and 1894. The item was then intervened by Antonio Rovescalli (1864–1936) in 1897, a famous Milanese painter of scenography posters, and a student of Carlo Ferrario (1833–1907). The main curtain shows an iconography based on the same political and intellectual ideals that led to the construction of the Theatre, an allegorical backdrop to the progress of Costa Rica (Santamaría 2017). The curtain, dimensions 7.90 m x 11.69 m, is a large format tempera, which was conceivably painted using a preparatory layer that helped to stabilize the support and fix the pigments to the fabric. Due to the dimensions of the artwork, it was common to make a preliminary drawing with the help of a grid, built first on the support.

The historical information that is available regarding previous research and interventions is not revealing. As mentioned before, the stage curtains produced during the studied period were not materials designed to last. The drapes were ephemeral props, designed to be replaced after a short period of time. Given their fleeting state, the preparation and treatment of these curtains were not geared towards guaranteeing conditions suitable for the preservation of the artistic work.

Little interest in preserving these artifacts existed until 1934, when the first documented assessment and restoration work on the curtain was completed. The task was carried out by Antolín S. Chinchilla, according to the information found in a report extracted from the records of the National Theatre of Costa Rica (Cruz 1987). Apparently, the curtains were used until approximately 1950 (Miralles 2017) and after that, they were abandoned and stored, in an inappropriate way, under the stage of the National Theater where neither temperature nor humidity was controlled (Cruz 1987). From 1934 until 1987, no report on any additional modifications to the piece was found, so any change or process applied in that period is unknown.
Until in the year of 1987, the restorer, Paquita Cruz, performed a study on the state of the main curtain. In the report, Cruz described great deterioration caused by mistreatment, dust, humidity and termite attacks. All resulting from where the curtains were stored. Cruz also identified treated and restored zones, as well as problematic sections and highly deteriorated ones. After this evaluation, the curtain was stored in the warehouses of the institution, from where it was retrieved in 2016. The restorer, Cruz, wrapped every curtain individually with kraft paper and also stored them on a special shelf at about 25°C, free of high humidity, dust and insects located inside the National Theater. During her study in 1987, Cruz collected and stored several detached pigments that we used for our research, see the next section (Experimental methodology). Nevertheless, it is worth mentioning that although the origin of the samples is unknown since the restorer did not identify it in her report, it is very likely that these pigments belong to the highest damage areas of the main curtain, i.e. upper left and vertical-center line (see Figure 1).

To consider examining the curtain directly, one must take into account the advanced state of deterioration of the piece itself. Therefore, all the special requirements demanded by the item need to be identified. It is for this reason that the detached fragments from 1987 were used, while appropriate storage and transport conditions are achieved. Once the constraints for the optimal handling of the delicate material are met, an on-site study can be carried out, guaranteeing the security of the curtain surveyed, which is one of the future projects of our research group.

Nevertheless, the consequences of not being able to carry out an exhaustive sampling are significant. In general, for a pigment characterization, the usual practice is to work with areas of the painting in which it is certain that there are only pure colors. In this way, all the results obtained can be easily compared against patterns (Roldán et al. 2016). However, since the fragments come from all parts of the curtain, there is no certainty about the presence of pure pigments or mixtures of them, thus complicating the analysis for the results obtained.

3. Experimental methodology

This section describes the procedures employed in the sampling process. The segment also states the limitations and drawbacks of the sampling mechanism and features the necessary equipment and characterization techniques applied to collect and analyze the samples.

3.1. Sampling

An assortment of fragments (detached pigments of the curtain), which originally belonged to the main curtain, was used as a sample for this research. These pieces were accidentally detached from the support of the curtain during the last evaluation made in 1987. The fragments of the allegory were then collected and stored in a glass jar by Cruz. These collected fragments can be found in the National Theater in a controlled environment. A selection of these fallen pigments was used as a working material for the present investigation. The reason why it is necessary to work with these pieces, instead of making a direct measurement on the curtain, is that the curtain is not currently available for handling due to its fragility. As was mentioned in the previous Section, although the exact origin of the samples is unknown, it is very likely that these pigments belong to the highest damage areas of the main curtain, i.e. upper left and vertical-center line (see Figure 1).

Figure 1: Original main curtain of the National Theatre of Costa Rica. Large format tempera. Painted by Carlo Orgero in 1893–1894 and intervened by Antonio Rovescalli in 1897. Photo: Juan Pérez Miralles (2016), reproduced with permission of the photographer.
Thirty samples were selected according to observed differences in their apparent color. Among these, ten show brown like tones, another ten green like tones and the ten remained, red like tones, as seen in Figure 2. A criterion for the specimens was to have a minimum area of at least 2 mm². In this way, it was possible to evaluate a total of thirty samples from different areas of the curtain. These samples were labeled as follows: 1–9 the brown like tones, 10–19 the green like tones and finally from 20–29 the red like tones.

3.2. Techniques and Equipment

This subsection contemplates the operative conditions and equipment specifications deployed for each characterization procedure. The method of scanning electron microscopy (SEM) along with spectroscopic techniques such as energy dispersive X-Ray (EDX), Fourier-transformed infrared (FTIR) and X-Ray fluorescence (XRF) are featured. Statistical treatment for the obtained data was also applied.

3.2.1. Transmitted light microscopy, Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray spectroscopy (EDX)

With the objective of identifying the constituent materials of the curtain fabric and its reinforcement, a transmitted light microscopy and scanning electron microscopy (SEM) study was applied. The equipment used for the SEM measurements corresponds to a HITACHI model S-3700n, with variable pressure and emission field by ultra FE scanning and digital camera and optical resolution between 3 nm and 10 nm. On the other hand, for transmitted light microscopy a Craic Technologies Microspectrophotometer coupled with a Nikon LV100ND eclipse stage with objectives ranging from 100× to 5× was employed.

The energy dispersive spectroscopy (EDX) technique, on the other hand, was developed to acquire surface information on the elemental composition of the constituents of the curtain. The EDX measurements were carried out by using an IXRF Systems equipment, model 550i, at 15 kV and takeoff angle of 35°, with an elapsed live-time of 100 s. The measurements for both SEM and EDX were made in a vacuum system. For both techniques, a fabric sample of the curtain painted with the original green pigment was used, as well as a piece of the reinforcement fabric of the curtain. The tested snippets were provided by the conservator of the National Theater of Costa Rica and extracted from the samples taken in 1987 by Paquita Cruz. A thin film of gold was deposited as pretreatment for the fabric fragments in order to obtain high resolution in the images. Cross-sections of the samples were not carried out since it was not experimentally possible to obtain characteristic images with the present samples.

3.2.2. Fourier-Transform Infrared spectroscopy (FTIR)

The Fourier-transform infrared spectroscopy technique (FTIR) is applied to discern the binder used. The information on the binder employed is of much importance since it largely defines the mechanical and chemical characteristics of the paint, as well as the pictorial technique to be used. The infrared spectra was measured using the Thermo Scientific Nicolet 6700 instrument, with an MCT/A detector and an iTR accessory, with diamond window and KBr beam splitter, using the following conditions: 64 scans, 4 cm⁻¹ resolution with a wavelength of 4000–650 cm⁻¹ and a background for each measurement.

3.2.3. X-ray fluorescence spectroscopy (XRF)

This characterization technique of X-ray fluorescence (XRF) is employed with the purpose of identifying the elemental composition of the paint samples from the main curtain. This information is taken as a basis to reconstruct the palette of pigments used on the curtain. The spectra were obtained using a portable ELIO system from XG Labs. The apparatus comes with an X-ray generator that has a rhodium anode and a silicon detector (SDD), with an energy between 140 eV to 180 eV. Given that the area of the beam (1 mm spot size) does not cover the fragment in its entirety, for each sample, two different points were studied. Two replications were made in both cases, operating on a fixed current and voltage configuration (100 μA, 35 kV respectively) with a power of 3.5 W, for the equipment Rh source. All measurements were made with a sampling time of 60 s, while the distance between the sample and the detector was set about 5 mm.

3.2.4. Statistical Analysis Software

The developed statistical analysis provides the necessary guidelines in order to corroborate a possible statistical correlation between the chemical compositions of the samples, aiming to determine the existence of different color pigments in them. This study also yields the basis for identifying anomalous or atypical data (outliers). The statistical treatment was done using the XLSTAT and MINITAB.

Figure 2: Examples of the fragments measured for each color shade analyzed.
software. For this treatment, the number of counts per second obtained through the XRF technique for each element and replicate, are taken. In all the cases the main emission lines are the only ones scrutinized. The data acquired for the replicates was then averaged and divided between the standard deviation for its normalization.

4. Results and discussion
The remaining part of the paper proceeds as follows: the first subsection will examine the scanning electron microscopy (SEM), dispersive spectroscopy (EDX) and transmitted light microscopy, secondly, we explore about the pictorial technique of the curtain by means of Fourier Fourier-Transform Infrared spectroscopy (FTIR), and finally, X-ray fluorescence spectroscopy is used along with statistical correlations in order to infer connections between the variables and the samples.

4.1. Scanning electron microscopy (SEM)
As mentioned before, the purpose of the scanning electron microscopy applied is to establish the support materials employed by the artist.

The evidence from the SEM analysis performed on the fabric of the main curtain, show the presence of interlaced fibers that indicate a polygonal cross-sectional area. Nonetheless, the form of some fibers seems to have been affected by the handling and aging of the material, given a degree of heterogeneity regarding the cross-sectional shape of the samples. Previous studies conveyed by Čaprinš (2009), specify that the cross-section of flax fibers in linen exclusively presents a polygonal shape, confirming the observed results. We also compare these observations by means of using transmitted light microscopy. Figure 3a shows the cross-sectional shape previously described. On the other hand, as it can be seen in Figure 3b, the diameters measured for the curtain fibers, range from 11 μm to about 17 μm. According to Čaprinš (2009) the nominal diameter for flax fibers range between 10 μm and 25 μm. It is important to notice that the diameter of cotton fibers also match this range, but not the polygonal shape found in the samples.

The SEM photographs obtained for the curtain also show the deposition of a layer of solid particles on the fibers. The EDX analysis performed on these particles confirms the presence of elements such as silicon, calcium and sulfur, which are commonly associated with components from the soil, or pollutants in the air (Fahim et al. 2013; Viljus et al. 2013). These depositions could be related to storage and climatic conditions suffered by the curtain.

The results exhibit for the reinforcement fabric of the curtain display similarities with the shape and cross-section area of cotton fibers, which are flattened as shown in Figure 3c. These outcomes are consistent with those reported by Timar-Balazsy & Eastop (1998), due to the ovoid and flat shapes shown by the fibers.

Just as with the fabric of the main curtain, the fibers of the reinforcement sample show a significant deterioration when compared against a cotton pattern. This situation is expected if one considers that the climatic and storage conditions mentioned above also affect the reinforcement of the main curtain.

Summarizing, the characteristics of the samples of cloth analyzed through transmitted light microscopy along with the SEM technique, such as the diameter of the fibers and their cross-section, allows for the distinction between two main types of fabric, which were common at the time. Based on the results obtained, it can be suggested that the fabric of the main curtain is linen, while the reinforcement fabric is probably identified as cotton. In both cases, the climate and storage conditions seem to have affected the fibers, given the degree of deterioration observed and the amount of pollutants in them. This technique sheds light on the textiles utilized for the fabrication of the main curtain and its reinforcement.

4.2. Fourier Fourier-Transform Infrared spectroscopy (FTIR)
On the other hand, to infer information about the pictorial technique ( pigments, dyes, mediums), an infrared spectroscopy study was carried out. In this case, these functional groups are signatures of the binders used to provide stability for the pigments in the artwork. The binder plays

![Figure 3: a) Transmitted light microscopy and b) SEM photograph acquired for the main curtain fabric sample, concluded to be Linen, and c) SEM image for the main curtain reinforcement, concluded to be cotton.](image)
a significant role in the restoration process, since it thoroughly defines the chemical and physical characteristics of the painting. It also defines the pictorial approach to be taken in the restoration process. All the samples taken were analyzed, resulting in identical spectra in each case. Therefore we only displayed Figure 4 which synthesizes the complete obtained information for all the fragments analyzed.

The fact that the analyzed samples not only include the binder, but also the pigment layer, represents an additional challenge when comparing against the reference spectra. Using, as a starting point, reported studies on infrared spectroscopy made on different binders (Leonor et al. 2013; Marinescu et al. 2014; Meilunas et al. 2013; Prinsloo et al. 2013), it was identified that the spectrum obtained for the samples shows a high similarity with the infrared spectra of egg yolk. The region between 4000 cm\(^{-1}\) and 3500 cm\(^{-1}\) shows the N-H signal, stretching at 3395 cm\(^{-1}\). Egg yolk contains a substantial amount of fatty acids (egg oil), in addition to proteins, with signals appearing at 2923 cm\(^{-1}\) and 2850 cm\(^{-1}\), which correspond to a C-H signals. Another important band appears at 1735 cm\(^{-1}\), corresponding to a C = O stretch signal (Leonor et al. 2013; Marinescu et al. 2014; Prinsloo et al. 2013).

### 4.3. X-ray fluorescence spectroscopy (XRF)

X-ray fluorescence spectroscopy, on the other hand, is one of the most frequently implemented techniques in the field of cultural heritage conservation. Its usefulness lies in the ability of identifying pigments from the elemental composition of the samples. In addition, the electron dispersive X-ray technique is used to confirm the results obtained through XRF (Favaro et al. 2005; Roldán et al. 2016).

The data acquired using XRF spectroscopy, makes possible the identification of some common elements, such as Zn, Ba, Ca, Ti, Cr, Pb, Sr and Fe. Samples from 1 to 8 (labeled as brown), show a clear signal of Fe corresponding to its K\(_\alpha\) line at an energy of about 6.40 keV. These results suggest the presence of brown pigments in these samples, which are essentially earth compounds whose composition is rich in iron (Larsen et al. 2016; Roldán et al. 2016).

It is also possible to relate certain brown tones with yellow pigments, which are commonly associated with elemental compositions of Fe, Pb, Ba, Cr and Sr (Larsen et al. 2016; Roldán et al. 2016; Rosi et al. 2009; Trojek et al. 2017). On the other hand, it is plausible to consider a possible relationship between some brown and red pigments, the latter being in some cases a mixture of elements such as Fe and Pb.

Samples 17 to 23 (labeled as green and red pigments) are the only ones to present a differentiated Cu signal, absent in the rest of the fragments analyzed. Copper is an integral component of the green pigments widely used by artists throughout the history of arts, suggesting the presence of this pigment in the mentioned samples. Malachite, verdigris, green Scheele and emerald green are some examples of this case (Zieske 1995).

The presence of the same Fe signal is observed in this set of samples, although it is not common for green pigments to have Fe in their composition (Larsen et al. 2016). This could be explained by noticing that the samples analyzed maybe whether pure pigments or blends mixed by the artist.

**Figure 4:** FTIR transmittance spectrum obtained for the studied samples. The specific bands displayed suggest the presence of egg yolk as a possible binder.
Samples from 9 (labeled as brown pigment) to 16 (labeled as green pigment), on the other hand, show in their composition elements such as S, Se and Cd, which are not present in the other colors analyzed. These elements are particular in pigments such as cadmium red (Larsen et al. 2016), which allows the hypothesis of these materials as part of the original pallet.

Elements such as Zn, Ba, Ca, Ti, Pb and Sr are characteristic of white pigments (Hochleitner et al. 2003; Rosi et al. 2009). White is one of the base colors in painting and is often used to obtain different shades of the same color or in the composition of preparatory layers. Considering this information, is not difficult to suggest that the presence of elements such as Ca and Zn is due to the employment of some of these white pigments, among which stand out chalk (Ca), zinc white, gypsum (Ca, Sr), titanium white, white lithopone (Ba, Zn) and lead white.

The analysis of the XRF data can sometimes present certain limitations. Since this technique only allows to identify of the elements present in the sample, and not the ratio of elements in the form of compounds present in it, the results can lead to a series of ambiguities in the identification of the pigments. In order to complement the results obtained through XRF, an EDX analysis is recommended (Ferrero et al. 2002), as done in this case, which allows for contrast the information obtained through both techniques.

Based on the results obtained with the EDX technique, for sample 17 (green like pigment), the presence of characteristic elements such as Zn, Pb, Ba, Ca and Cu is corroborated. It is also determined that the analyzed samples contain Si, previously indicated as common pollutants.

### 4.4. Statistical correlations

Finally, in order to infer statistical correlations between the variables and the samples, a Principal Components Analysis (PCA) was conducted. For the purposes of this investigation, the average of the replicas was used, as explained in the methodology section. The analysis is performed for a total of 23 samples, due to high statistical differences observed in the standard deviation among seven of them. The main components selected (PC1 and PC2) describe 53, 72% of the total variance of the data and exhibit greater contribution from variables such as S, Se and Cd and Cu and Pb, respectively. As it is possible to observe in Figure 5, it is confirmed that there is a clear correlation between some of the elements analyzed, suggesting a separation by colors.

Thus, in the first quadrant (upper left in Figure 5) it can be observed that the samples from 17 to 23 are mainly related to elements such as Pb, Cu and Ba. As mentioned, Cu is a characteristic element of the green tones, complementing therefore the results obtained with the XRF technique. The relationship with Ba and Pb may be due to the presence of white pigments attributed to some mixture.

In the third quadrant (lower left in Figure 5) it is observed that there is a relationship between the samples 1 to 8, excluding 3, and elements such as Zn, Sr, Fe, Ca, Cr.
and Ti, these last two having the greatest statistical influence on the data. This suggests that the mentioned samples are mostly related to elements that are characteristic of brown and white pigments.

In the fourth quadrant (lower right in Figure 5), on the other hand, it can be observed that samples 3 and 9 to 16 can be associated with elements such as Se, Cd and S, which, together with the information obtained through XRF, supports the hypothesis for the presence of cadmium red in the palette of the artist.

In order to identify similarities between the different samples analyzed and to determine whether existing differences between shades of the same color or mixtures of pigments, a multivariate cluster analysis was carried out, as is possible to observe in Figure 6. This analysis makes possible to identify, according to their percentage of similarity, nine different color groups of data.

Figure 6 shows three very define clusters identified with the level of similarity as follows: (1, 7, 19, 21, 23, 22), (3, 16, 20, 11, 15, 12, 17, 18, 9, 10, 13, 14, 4, 5, 8) and (2, 6). The multivariate cluster analysis shown in Figure 6 is therefore compared with the PCA described in Figure 5. We noticed that samples make clusters as defined by the apparent color but also a clear indication of mixtures between the pigments are shown. For instance, samples labeled as brown (2, 6) generate a very define cluster and also constitute a group in the PCA with samples (1, 5, 4, 7, 8). Furthermore, an indication of the mixture is also displayed with samples (17, 18) which are part of a cluster along with (19, 21, 22, 23) who belong to a different cluster. The fact that the results show an association between samples with “different colorations”, could be an indicator of mixtures between the pigments.

Accordingly, the high percentages of similarity between samples 1 and 7 (defined as brown-like pigments) lead to a grouping of them. However, the new cluster (1, 7) is linked to samples associated with green-like pigments, of which 21 and 23, show high similarity, thus resulting in a new cluster compared with sample 19. This new association of three green pigments (21, 23, 19) is then linked to the group (1, 7) and finally to sample 22. These differences could consist of a small increase in the amount of a given element, lead or titanium for example, which would drive to an association of the cluster (1, 7) with the samples identified as “green”, heavily influenced by elements such as Pb.

Groups as (11–15–12) are associated in the same way that has been explained, being that all the samples in this cluster are identified as red-like. The group (17–18), on the other hand, consists of samples identified as green-like, while the cluster (3–16–20) consists of a “brown”, a “red” and a “green” sample respectively. In the last case, samples 3 and 16 have the highest percentage of similarity found. Considering that the brown and red pigments have elements such as iron in common, as well as similar shades, the association is not surprising. In the case of sample 20, classified as green-like, the results obtained through XRF could be helpful. As mentioned, the samples identified as “green” have Cu in their elementary matrix, which distinguishes them. However, it was also observed that these present a signal of Fe, rarely linked to green pigments. This signal could be attributed to the presence of brown or red pigments, which could be painted or mixed with the greenish parts of the curtain, or could also be due to contaminants in the studied fragments.

On the other hand, the clusters (9–10) and (13–14) are made up entirely of samples that show reddish colors, suggesting that the relationship between them could be given by their composition of S, Cd or Se. Contrarily, the group (4–5–8), as mentioned, is made up of brown-like samples, so an association through their Fe content with the last explained groups would make sense in this case.

Figure 6: Cluster Analysis developed for the studied data, using a Ward linkage method and Euclidean distance measure. The identified clusters suggest the presence of a mixture of pigments.
The high percentages of dissimilarity observed in the case of the group (2–6) suggest that there is no relationship between the two samples, nor between them and the rest of the analyzed clusters. This could be due to an anomalous increase or decrease in some of the constituent elements of these two samples, classified as brown-like, being this peculiarity the reason why they are grouped in the first place.

This multivariate analysis shows that it is possible to determine the existence of three different colors in the palette used by the artist: brown, green and red. It is important to highlight that these three groups exist possibly as a mixture with different kinds of white pigments, which introduce differences within the composition of same-color samples. On the other hand, this analysis also allows us to identify three samples with high statistical similarity in their elemental composition, which suggests that these could be mixtures of brown, green and red pigments applied by the artist in different proportions along with the painting.

According to these results, it is possible to suggest some pigments as part of the original palette used on the main curtain. These pigments are shown in Table 1, according to the different groups of colors previously identified. The order of appearance of the elements reported is random, that is, the order is not related to the concentration percentage in any way whatsoever.

5. Conclusions
The images obtained through SEM and optical microscope techniques suggest linen as the constituent material of the textile sample from the main curtain. The fibers analyzed presented a polygonal cross-section and diameters ranging from 11 μm to 17 μm. The fabric sample from the reinforcement is cotton, as suggested by its ovoid, flattened shape, also observed by means of SEM.

Due to the use of XRF spectroscopy, it is possible to identify chemical elements such as S, Se and Cd in the red like samples, which imply the presence of some kind of cadmium red in the micro fragments. On the other hand the green like samples analyzed present Cu, which points towards the use of pigments like malachite, verdigris, Scheele or emerald green. All three analyzed shades are specially linked with some white pigments (chalk, zinc white, gypsum, titanium white, white lithopone, lead white), as reflects its elevated content in elements such as Zn, Ba, Ca, Ti and Pb.

The IR analysis suggests the use of binders such as egg yolk, which was usually used in pictorial techniques like tempera. The identification was possible due to the presence of key signals for amine groups.

The statistical analysis suggests the existence of groups of pigments identified as green, brown and red pigments, but also the presence of mixed pigments in the samples studied, while confirming the results obtained through XRF and EDX.

The chemical elements found in the samples allowed us to suggest a possible pictorial palette used on the item, the binder used and the constituents of the fabric of the curtain, information that will serve as the basis for the future process of in situ characterization of the main curtain. This information obtained and methodology applied will help to establish an appropriate conservation procedure of the main curtain, but also represents the basis to study the rest of the curtain’s collection and compare the pigments composition as well as the technique.

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Competing Interests
The authors have no competing interests to declare.

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