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Original article

THE CONSERVATION OF AN EGYPTIAN POLYCHROME WOOD COFFIN FROM LATE PERIOD

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Abstract

This paper describes the treatment and conservation of the polychrome wooden coffin for the unknown mummy of the late period that was in Saqqara stepped pyramids` stores. It suffered from aspects of damage represented in damaging into large fragments, infecting by micro-organism, accumulation of dusts and cracks that are varied in shapes and sizes in the different layers of painting. The components of the polychrome wooden coffin were studied through investigation and using various analysis methods such as X-Ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), light Optical microscope (LOM) and Scanning electron microscopy with energy-dispersive analysis of elements (SEM-EDX). The results indicated that the type of the coffin wood is Cypress (Cupressussempervirens), and there are five types of fungi that had been grown on it. They are Aspergillusniger, Aspergilusflavus, Alternaria alternate, Emericella nidulans and Penicillium steckii. The ground layers consisted of two layers; coarse layer (clay plaster) and finer coat (lime plaster).The black, pink, and yellow pigments consisted of Pyrolusite, Hematite mixed with Gypsum and Goethite consecutively. The medium color was animal glue. Therefore, the current study included making conservation and maintenance of the coffin, mechanical and chemical cleaning, fixation of the paint layer flakes, facing (surface protection), sterilization, reinforcement...etc.

Keywords: *Saqqara, Polychrome, Coffin, Pigments, Animal Glue.*

1. Introduction

During the excavation in Onas pyramid's road in Saqqara- located 28 km. to the south of Cairo- carried out by Dr. Selim Hassan in 1958, the polychrome wood coffin for the unknown mummy of the late period was discovered. It was registered under No.13356. Then, it was transferred to the stepped pyramids' stores. In 2010, it was transferred to the museum's store No.2 in Saqqara. There are many studies that included a study of polychrome wood coffins, such as a painted coffin in the Arizona State Museum at the University of Arizona in the city of Tucson, state of Arizona, United States of America, and was made of local Sycamore [1]. Therefore, there is a sample of these coffins in Al-Arish Museum illustrating the many aspects of damage caused by severe moisture in the region. This resulted in fungal infection and weakness of painted wood leading to the rapid intervention of conservation [2]. There is, also, a project that focused on (a)

developing of a method to ‘de-restore’ and reassemble the lid of the ancient Egyptian wooden anthropoid coffin belonging to **But-har-chonsu**, a chantress in the cult of Amun, who lived during the 3rd Intermediate Period (Dynasty 21/22, c. 970-900 BC). In 1893, its lid was presented to Vienna’s Kunsthistorisches Museum. It, also, focused on (b) realigning and stabilizing the lid’s wooden structure with carbon-fiber composite dowels [3]. There is, also, polychrome wood coffin base that suffered from shrinking the wood as a result of Egypt's arid climate. Because of this shrinkage, the many joints throughout the coffin’s structure opened up and moved a bit. This caused the layers of mud plaster and the painted white plaster to crack and lift in many places and even to fall off entirely. Therefore, using a cellulose-based adhesive, which would not adversely cause effect, was chosen to stabilize the flaking paint as well as using a micro balloon as a filler [4]. There was a study that included a treatment and conservation of an Egyptian wooden coffin box dating back to ca. 1st century. Treatment procedures entailed cleaning, removal of dust, securing severely damaged wooden fragments and damaged resin as well as the use of a suitable gap filler [5]. A third object that was treated was an ancient Egyptian polychrome wood coffin held by the Burke Museum. It appeared that it was previously treated with a carelessly applied dark orange lacquer resembling shellac. This darkened coating obscured the painted design causing a fear that its further degradation would continue to jeopardize the remaining polychrome layers. Plans were considered for the removal of the coating, followed by the consolidation and stabilization of the coffin. After further investigation, however, it was discovered that the disfiguring resin had been applied by the coffin makers themselves [6]. The conservation project of an ancient Egyptian polychrome wooden coffin chest, Ca. 960-900 BC. entailed securing severely damaged resin, paint, gesso, and mud layers to a substrate; consolidation; cleaning; treatment of degraded wood; and removal of previous restorations. The work was carried out in a temporary laboratory set up specifically for the purpose. Health and safety considerations are discussed, including the problem of using consolidants and solvents in a temporary working environment with no fume extraction, and how this influenced the choice of treatment. [7]. The polychrome wood coffin was one of the most important archeological materials as it contained colors, scenes, texts, and ancient writings, revealing many facts, historical information and secrets [8]. These coffins were often highly decorated with various geometric design, an assort-ment of deities and inscriptions, which included verses from the Book of the Dead [9]. The coffin was closed and contained unknown mummy. It was 176×47cm and approximately 24 cm high. It was built from many pieces of wood that were joined together with wooden dowels and pegs of about 5 cm in length with a sharpened end of the same substance. It was carved from two large pieces of wood forming the lower half (i.e. coffin box) and as mummy was lying inside. There was an old black resin covering the place under the mummy, while the top half formed the cover (i.e. coffin lid). All the outer parts of the coffin were then coated with mud plaster of about 3 mm in order to smooth out the joins between the wooden pieces. A fine white plaster, of about 1.5 mm, was applied to the outer surface, followed by anotherlight yellow one. It was of the characteristics of the late period [6,10]. While the lower half of the coffin (i.e. coffin box) was left without decoration, while the top half (i.e. coffin lid) the mask and the wig were overlying the head area. In

addition, the face was decorated with a winged sun disk with four horizontal lines of floral and architectural decoration. It was even decorated, in the lower part, with representations of some gods where there was a vertical line of hieroglyphic writing extending to the foot of the coffin. The coffin, under study, was in a bad condition because of inappropriate storage; it was covered with accumu-lation of dust and muddy grimes. Despite the arid climate of the area where the coffin was preserved, it suffered from a permanent harmful effect by permanently shrinking the wood. Consequently,the many joins throughout the coffin's structure opened up and moved a bit, and the wood decomposed. Then, multiple cracks and loss of the mud plaster and painted layer in many places occurred. This made the coffin vulnerable to further damage. The warping and loosening of the gesso layer were natural phenomena in all polychrome wood, due to expansion and contraction of the wood [11]. In the coffin lid, there were many parts below the face and shoulders that were totally lost. The occurrence of the warping in the upper part caused differences in the dimensions of the lid and losing and fragment of the painting and plaster layers to the extent that some of them were intermediating with skeleton. Additionally, the mask was completely separated from the lid of the coffin, so it was removed and registered until the end of the conservation of the lid. There was breaks in many parts of the lid and loss of the wooden dowels that joined the parts of the coffin, fig. (1-a, b, c, d, e, f, g, h)

Figure (1) Shows deterioration phenomena affected coffin lid covered by dust and muddy grimes at all; **a**. longitudinal cracks, **b**. losing part of the lid and appearance of the mummy, **c**. warping and cracks and appearance the wooden dowels, **d**. separation of the mask, **e**. loosing of the edge, **f**. separated coffin mask, **g**. cracking and accumulation of dust, **h**. the occurrence of damage along the lid

Because it became fragile, the base of the coffin was almost completely separated. It was noticed that it became darker and it's easy to be transformed into powder on being exposed to friction. Its upper part had a warping caused by transverse and longitude cracks. The interior part had small piles of debris left from the disintegrating mummy that was displayed from it for a long time, fig. (2-a, b, c, d, e, f). Photographs and a detailed map were used to document the condition of the wooden coffin was recorded with details of deterioration in each part.

Figure (2) Shows deterioration phenomena affected coffin base **a**., **b**. & **c**. almost completely separated, **c**., **d**. losing part of the base, **e**. losing parts of plaster layer, **f**. small piles of debris inside the base

2. Materials and Methods

2.1. *Light optical microscope (LOM)*

The samples were first observed using Wild M20 Heerbrugg, and recorded with a digital camera of ×-40 magnification to study their surface. LOM could provide information of the damaged layer, particle size, color and texture of painting layer. It was also used for the examination of wood samples and its identification after being prepared into sections, as well as identifying the types of fungi and bacteria infections.

2.2. *Scanning electron microscopy (SEM-EDS)*

The samples were examined by JEOL JXA-840a, SEM attached with EDX unit combined with system energy dispersive spectrometer. It was used for examining the wood's surface, fungi infection and analysis of the plaster and pigments in order to find out some elements.

2.3. *X-Ray diffraction (XRD)*

In order to identify the composition of plaster and pigments, the samples were analyzed with X-ray diffractometer using X-ray powder diffraction analyses performed by Philips diffractometer, using Cu Kα radiation (40kV, 25mA).

2.4. *Fourier transforms infrared spectroscopy (FTIR)*

The samples were analyzed using JASCO FT/IR-460 plus spectrumeter. They were prepared as KBr pellets, in the 4000 to 400 cm.1 range. This method was used to identify binding medium.

3. Results

The different techniques used in the current study led to the presences of many results which could be summarized as follows:

3.1. *Wood*

3.1.1. Microscopic investigation

The wood was identified by examining both its longitude and cross sectors. To study the fiber and its distinguished parenchyma texture, small and unclear parts were selected as samples. According to the anatomical characteristics of the spread of pores, their order in the rings and the time of comparing them to the standard samples, it turns out that the type of wood used was Cypress wood (*Cupressussempervirens*), fig. (3-a, b). *Cupressus* is distinguished microscopically from most other conifers by abundant parenchyma, ray cells with pitted horizontal walls and smooth vertical walls and cupressoid cross-field pits [12].

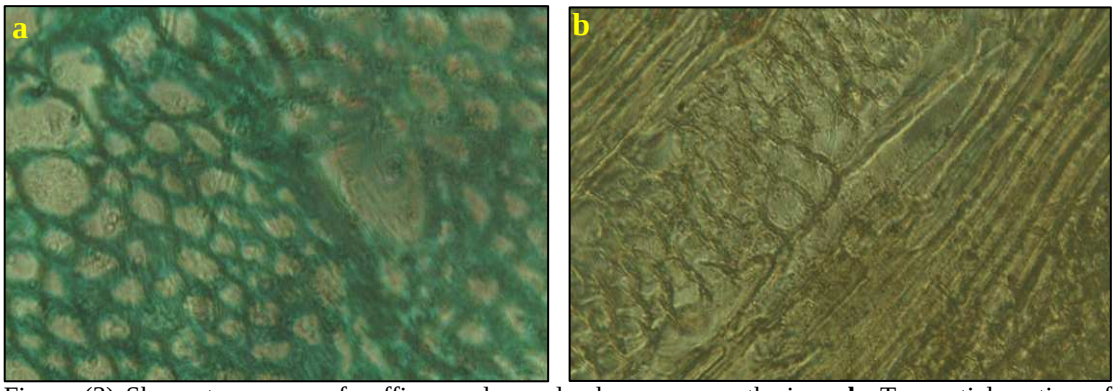

Figure (3) Shows transverse of coffin wood sample shows **a**. growth rings, **b**. Tangential section of wood

3.1.2. Microbiological Investigation

Scanning electron microscopy showed that there was a clear evidence of microbiological attacks in various parts of the coffin. Additionally, the fungal attack was observed in the inner part of a timber, fig. (4-a, b).

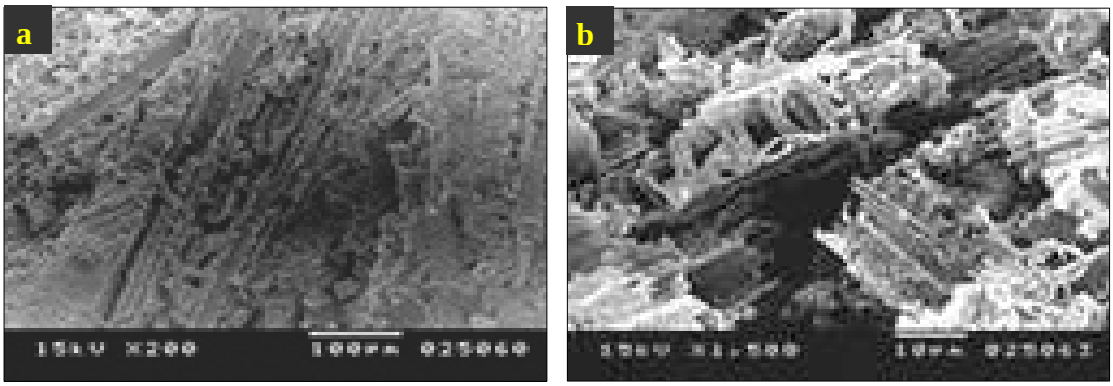

Figure (4) Shows SEM photomicrograph that shows **a**. weakness of physical structure of wood and tearing the wood fibers, **b**. fungal growth inside the wood fibers

Samples were taken from the original paint layer, plaster layers and wood. PDA (Potato Dextrose Agar Media)was used to isolate fungi. Identification of fungi was carried out on the basis of the macroscopic features of colonies and the morphological and structural characteristics [13]. Microbiological investigation indicated that the coffin was infested with the following fungi; *Aspergillus niger*, *Aspergilus flavus*, *Alternaria alternate*, *Emericella nidulans* and *Penicillium steckii*, fig (5-a, b, c, d, e)

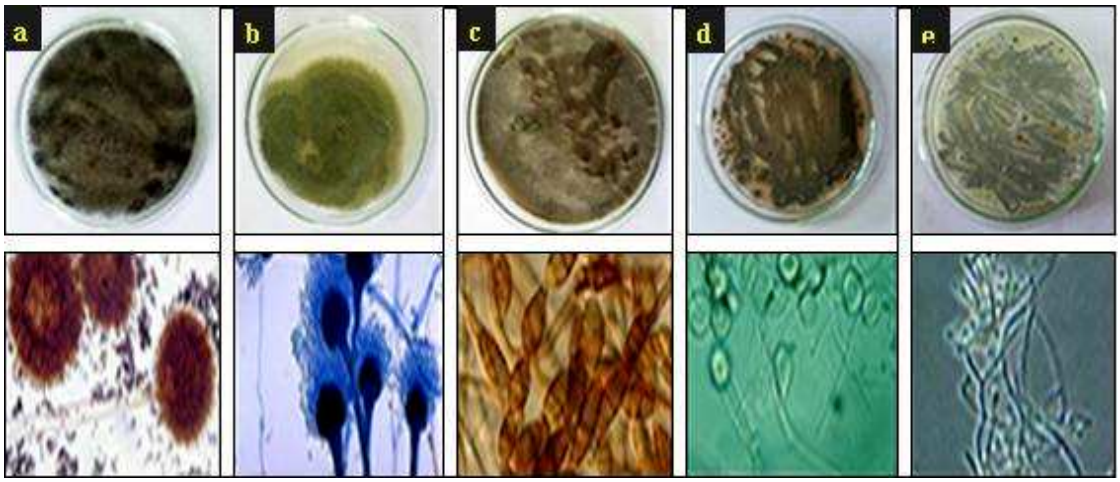

Figure (5) Shows light microscope photos of isolated fungi from coffin **a**. *Aspergillus niger*, **b**. *Aspergilus flavus*, **c**. *Alternaria alternate*, **d**. *Emericella nidulans*, **e**. *Penicillium steckii*

3.2. *The ground layers*

Wood substrates in ancient Egyptian objects were often covered with either a single-structured layer of gesso or coarse and fine layers. Coffin's ground layers consisted of two layers; coarse layer or rough coat and plaster or fine layer. Through SEM-EDX analysis of the first layer (i.e. rough coat), fig. (6-a), some mineralogical elements could be found such as Ca, Si, Mg, Al, K, S, Na, Fe and Cl, tab. (1). The obtained results of XRD analysis showed that Kaolinite, Montmorillonite and Quartz (SiO_2) were the main components, fig. (7-a). The microscopic analysis of the second layer (i.e. fine coat), fig. (6-b) illustrated that while (Ca) was the main element, other elements were found such as Si, S, Fe, Al, K, Mg, and Cl, tab. (1). This proved that its main component was only calcite (Pure white calcite), and the oxides of aluminum and potassium were from dust. In addition, XRD analysis proved that this layer consisted of calcite ($CaCO_3$) only, fig. (7-b). This could be noticed through the LOM and SEM observations. Hatchfield and Newman's analyses of Egyptian gessoes shown that they usually consisted of a calcium carbonate or calcium sulphate filler mixed with an organic binder [14].

Table (1) EDX results of samples taken from ground layers

	Elements %												
Sample	***Na***	***Mg***	***Al***	***Si***	***S***	***Cl***	***K***	***Ca***	***Ti***	***Mn***	***Fe***	***Cu***	***Zn***
Coarse layer	0.6	1.1	5.8	21.7	2.9	4.9	2.6	43.8	1.5	1.5	11.1	1.8	0.7
Fine layer	-	0.7	0.7	7.1	0.6	0.6	0.2	89.4	0.1	-	0.5	-	-

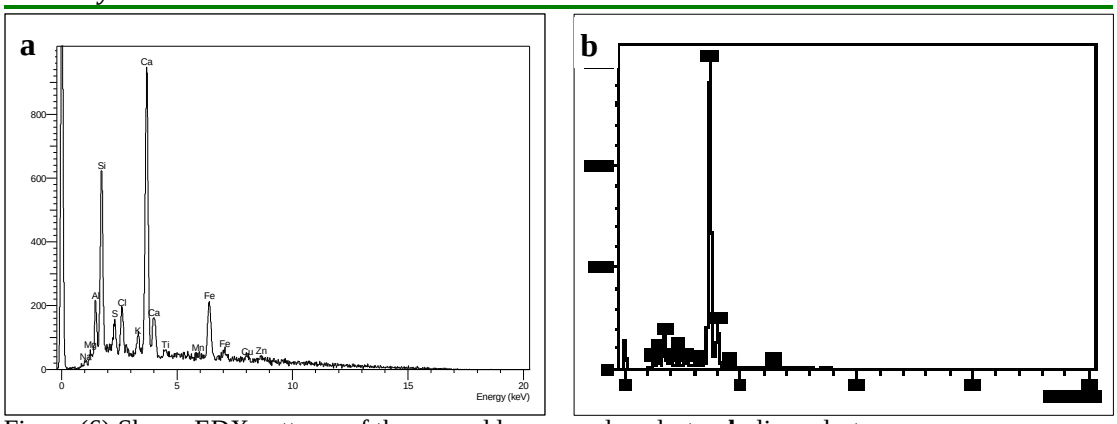

Figure (6) Shows EDX patterns of the ground layers **a**. clay plaster, **b**. lime plaster

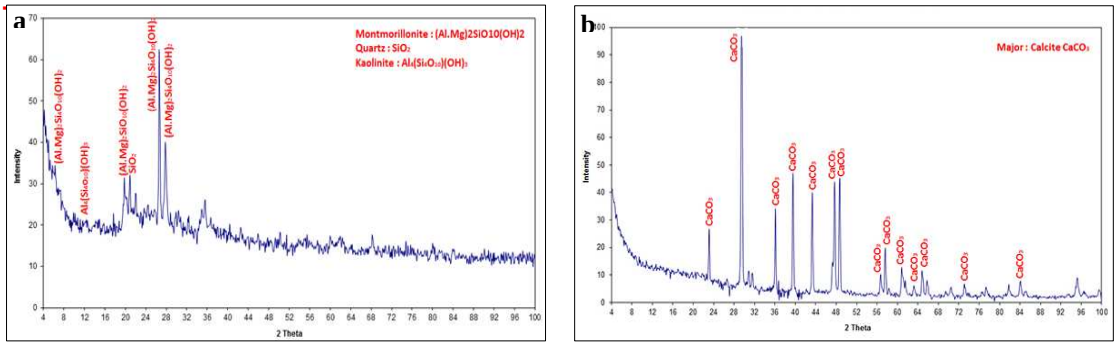

Figure (7) Shows XRD patterns of the ground layers **a**. clay plaster shows "Motmorillonite, Kaolinite and Quartz", **b**. lime plaster "Calcite"

While LOM showed the coarse morphology of the ground layers' surface, SEM investigation showed the structure of the plaster layers' grains, voids, missing parts and fungal growth, fig. (8) These microorganisms could cause harmful damage to the mineral constituents of coffin layers.

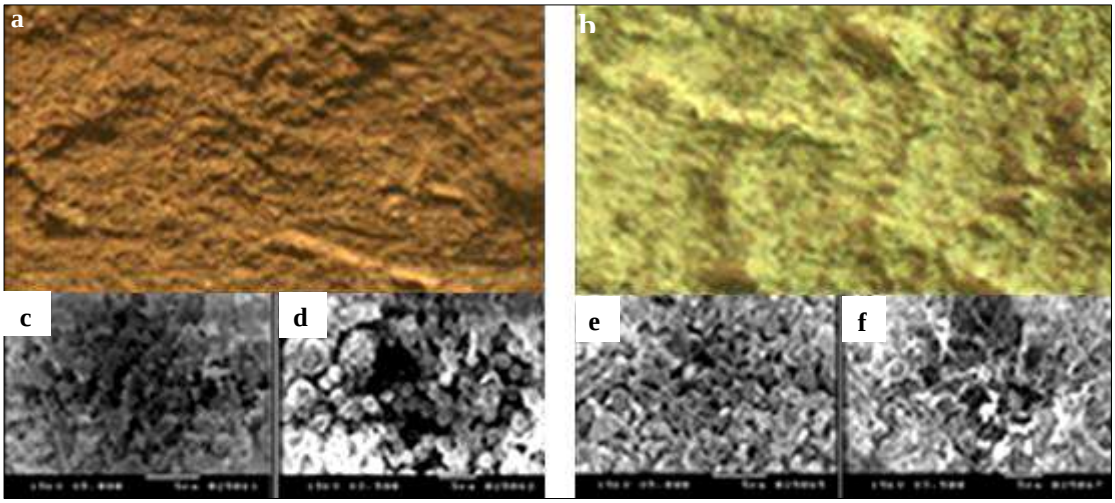

Figure (8) Shows LOM and SEM photographs **a**., **b**. coarse morphology of the ground layers surface **c**. the presence of Quartz, Kaolinite **d**. fungal growth inside the clay plaster **e**. showing the structure of calcite grains, **f**. fungal growth inside the lime plaster

3.3. *The paint layer*

3.3.1. Yellow color

SEM-EDX analysis indicated that the main elements of coffin layers were Ca, Si, Fe and small amounts of Al, Mg and K, tab. (2) and fig. (9-a). (Ca) was related to the ground layer that contained calcite ($CaCO_3$). (Al) and (Si), indicating the existence of an alumino-silicate material probably from the clay minerals, were associated with ochre. The existence of (Fe) indicated that the yellow pigment is Goethite FeO(OH). These results completely agreed with others indicated by XRD, fig. (10-a). Examination of the yellow color by LOM, fig. (11-a) showed that the paint layer was very thin, but SEM, fig. (11-d) illustrated the structure of calcite grains.

3.3.2. Pink color (light red)

SEM-EDX analysis, tab. (2) and fig. (9-b) of this color indicated that Ca, S, and Si were the main elements. In addition, Fe, Na, K, and Mg were detected in small amounts. (Ca) is related to the ground layer which contained calcite ($CaCO_3$). (Fe) is the main component of red iron oxide (i.e. Hematite) (Fe_2O_3) and the present of S might be caused by gypsum. Therefore,

Red ochre was used from the beginning of the 5th dynasty till the Roman times [15]. XRD, fig. (10-b). LOM, fig. (11-b) and SEM, fig. (11-e) showed the rough morphology of the sample surface.

3.3.3. Black color

The analytical results of SEM-EDX, tab. (2) and fig. (9-c) and XRD, fig. (10-c). showed that the elements found in the samples were: Ca, S, Si and Mn. Traces of Mn was detected representing Pyrolusite (MnO_2). However, there were not elements related to carbon black (graphite) or other elements that were typically used to obtain a black color are present. The examination of the black color by LOM, fig. (11-c) and SEM, fig. (11-fc) proved the inhomogeneous composition of the sample.

Table (2) EDX results of samples taken from painting layers

	Elements %											
Sample	***Na***	***Mg***	***Al***	***Si***	***S***	***Cl***	***K***	***Ca***	***Ti***	***Mn***	***Fe***	***Cu***
Yellow color	-	0.9	3.2	19	3.1	2	1.5	65.2	0.4	-	4.2	0.3
Pink color	0.4	0.6	2.7	11.5	23.5	1.5	1.0	53.7	0.3	-	4.9	-
Black color	-	0.9	0.7	7.7	0.4	0.5	0.3	83.3	0.1	5.7	0.3	-

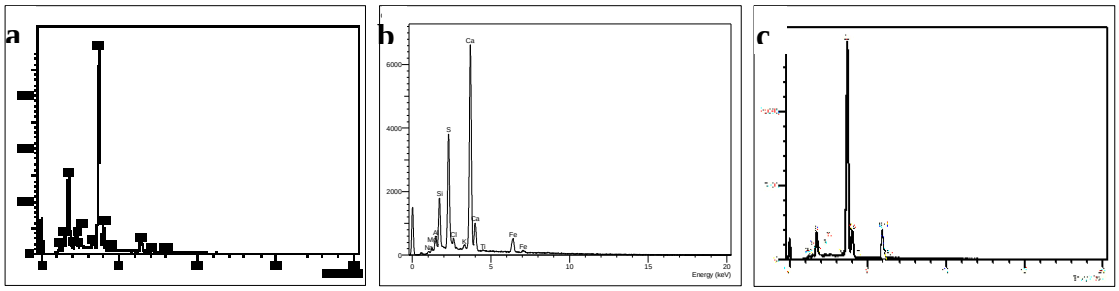

Figure (9) Shows EDX patterns of the painting layer; **a**. yellow color, **b**. pink color, **c**. black color

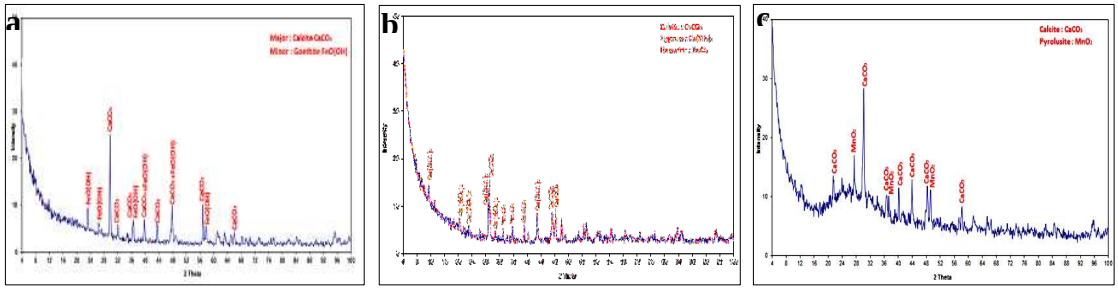

Figure (10) Shows XRD patterns of the painting layer **a**. yellow color shows Calcite and Goethite, **b**. pink color Calcite, Gypsum and Hematite, **c**. black color shows Calcite and Pyrolusite

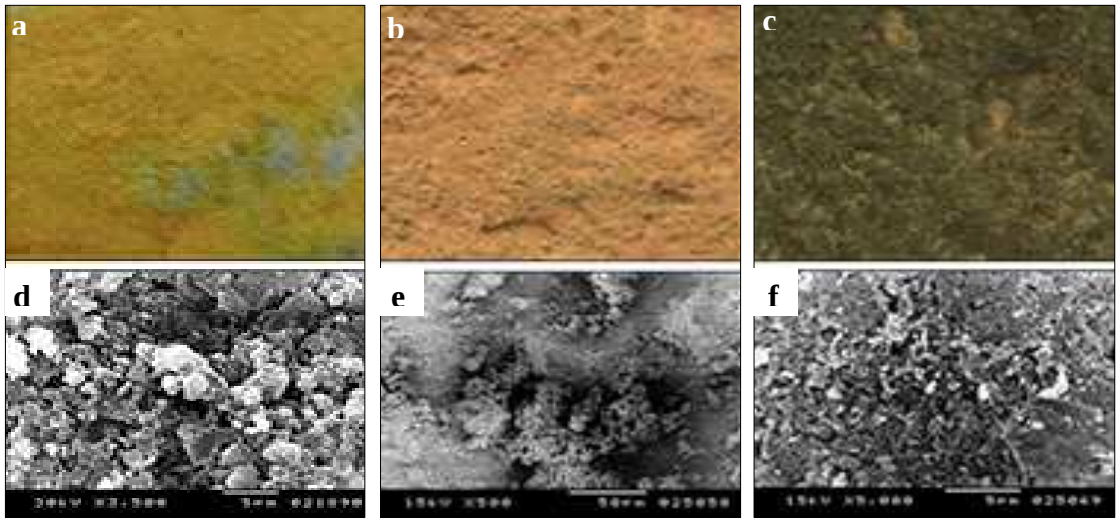

Figure (11) Shows LOM and SEM photographs **a, d**. yellow color, **b**, **e**. pink color, **c**, **f**. black color

3.4. *Identification of organic binding media*

The investigation made by Fourier-transform infrared spectrometry (FTIR) proved that animal glue was the organic binding media, fig. (12).

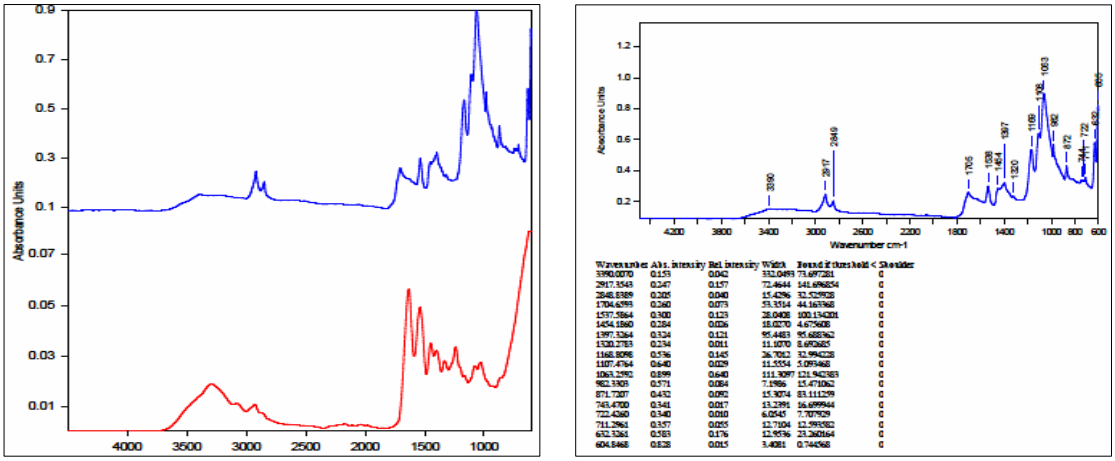

Figure (12) Shows FTIR spectra of the samples taken from the coffin

4. Treatment

4.1. *Initial treatment of the coffin while it is closed*

4.1.1. Cleaning

This process was applied, only, the exterior surface cleaning for the coffin as it was covered with dusts, sands, and accumulation of mud. Therefore, mechanical cleaning with soft brushes was used to remove these accumulations, cosmetic sponges, and cool erasers but it was away from the color. Mechanical cleaning was proceeded by chemical cleaning to remove the remains of adherent dirt. However, other methods were examined. Results indicated that a mix of ethyl alcohol and water (1:1) was the best solvent even in the colored areas. It was applied by immersing cotton swaps in this solution, then cleaning the parts cautiously.

4.1.2. Fixation of the paint layer flakes

The poor condition of the wood was the main reason why the paint was no longer on the ground. Numerous cracks appeared and the polychrome became entirely detached [16]. The fixation of separated crusts paint layer was done by using emulation of 10 % primal AC33. It was applied with syringe under the detached flakes. This was followed by kindly applying pressure to hold them in place until the adhesive was set. While there were separated parts of the plaster and painting layers in the places of the decomposed, weak and lost wood, they were documented and registered in a good way and reserved till completing the conservation and assembling wood panels and then replaced safely. Then, the painting surfaces were consolidating by using paraloid B72 with a ratio of 3-5 % in trichloroethylene by spraying them on the surface.

4.1.3. Facing (surface protection)

Various facings were used depending on the object and the purpose of the facing [17]. This process was carried out to preserve the colors and funeral paintings that existed on the lid of the coffin. It was carried out by using Japanese tissue after being cut into 5×5 cm and using Klucel G. (Hydroxy propyl cellulose) in (IMS) with a concentration of 10 %.

4.1.4. Levitating of mummy remains

It was impossible to conserve the wooden coffin while it was closed, so it was opened. Then, the remains of mummy (i.e. skeleton) were removed by using sheets of compressed carton of 20x60 cm. They were carefully passed under the skeleton, then it was submitted at once. Then, a suitable support stuffed with sponge and topped with two layers of cloth in larger size was prepared. After that, the skeleton was put on the new support and wrapped by the cloth where it was preserved till the completion of the conservation to be replaced.

4.1.5. Cleaning and sterilizing the inner part of the coffin

On the base of the coffin, a collection of pigment crust and parts of the plaster layer were found. These crusts were removed and recorded. Then dusts, sands, grimes, and mud impurities were removed using wide brushes and scalpels. The lid and base did not have any decoration. Both of them were sterilized using Cideal L-50 of 3 % concentration. It was affected by the wood [18].

4.2. *Conservation of the coffin's parts (base and lid)*

4.2.1. Consolidation

The base was consolidated as it was in a great danger of being completely decayed. This was done using Paraloid B72 with a gradual ratio on three stages of 4 %, 7 %, and 10 %, respectively with a 24 hours break, at least.

4.2.2. Treatment of the buckling

The base and the lid were put on a flat surface. The buckling parts were wetted by a mixture of distilled water and ethyl alcohol (2:1) and adding drops of Thymol as a pesticide to prevent the growth of any fungi during this process. While the base was putt under the appropriate loads until it retook its original form, the lid was joined by using iron clamps from the four parties, and the middle. It was put on layers of foam and sponge. They were not used in the base because of its extreme weakness.

4.2.3. Assembling process

Rreinforcement and consolidat-ion processes were carried out for the parts that suffered from weak points in the wooden structure, as the separated wooden panels were collected and fixed correctly. In addition, reinforcement of the deep and micro cracks, voids and missed parts was performed. The separated wooden parts were assembled from the lid by making wooden tenons with the same size of the old lost ones. They were adhered to it by using concentrated paraloid with a ratio of 50%. However, in the base, the wooden tenons could not be used due to the erosion of the edges and the weakness of separation zones.

- Reinforcement of cracks and gaps

The deep longitudinal cracks that were found along the base and those penetrating across the wood were reinforced by embedding rope of braided cotton in concentrated paraloid with a ratio 25 %. Before inserting the rope in the deep cracks; the surfaces of the edges were impregnated with a paraloid with a ratio 5 % to consolidate the surface of the wood and prevent the media from impregnating it, in order not to cause weakness of the other parts. The micro-cracks and small gaps were reinforced using a mixture of glass micro- balloon and a paraloid dissolved in acetone with a condensation ratio of 15 % as adherent. Therefore, the mixture would be fluid and fit this purpose. Then, the color that fit the mixture was added. The glass of micro- balloons

was a filler, inert, non-toxic, and easy configuration and applying material [4,19]. It was applied during the various stages as every layer was applied after the previous one became dried.

▪ Reinforcement of loosed places

Small loosed places were reinforced by embedding a rope of braided cotton in concentrated paraloid B 72 with a ratio of 25 %. Then, these places were covered by using a micro-balloon with a color that fitting the paraloid. The large loosed wooden part in the lid was replaced by a piece of balsa wood of the same size after consolidating the edges- which would be related to it by using paraloid B 72 5 %. It was fixed using concentrated paraloid with a ratio of 25 % with adding a little micro- balloon to fill any gaps that might be found between welding lines. Although the best way of completion was that the completed part should be of the same wood type [20]. However, it used balsa wood because of its characteristics, e.g. light weight, durability, and sappiness, it belonged to the hardwood and it had an easy formation and a bad heat conductor, fig. (13-a, b, c, d). [21].

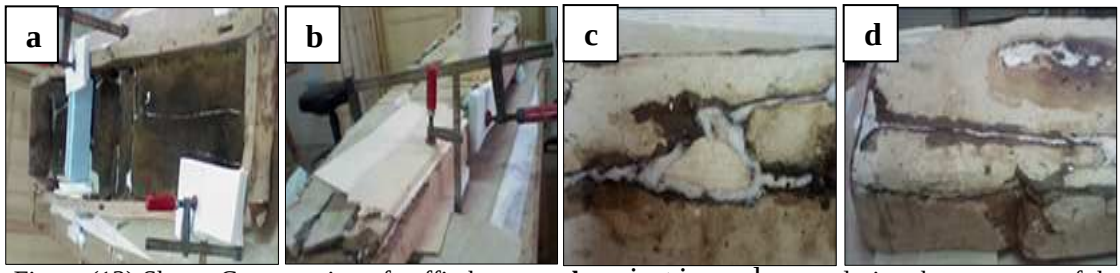

Figure (13) Shows Conservation of coffin base; **a**. , **b**. using iron clamps during the treatment of the buckling, **c**. , **d**. using embedding rope of braided cotton in concentrated paraloid B 72 for reinforcement the loosed places

▪ Re-adherence of the separate painting layers

After the wooden parts were completely stabilized, the separated parts of plaster and painting layers were replaced in their original positions. The parts of plaster layers were fixed with the wood by using Klucel G. 5 % (hydroxyl propyl cellulose aqueous solution, viscosity of 75-400cp), while Klucel G. worked on consolidating the wood underneath the plaster. After a complete dryness this layer, it was wetted by a mixture of water, ethyl alcohol to open the pores. Parts of the painting layer were pasted using Primal AC33 15 % with the help of a little gentle pressure [2].

4.3. *Conservation of the coffin's mask*

The mask was removed from the destroyed lid. Facial parts and lateral elements of the wigs were mechanically cleaned in order to remove dust and sand grains from the surface by using different tools, while the solid parts were removed after being wetted using water and ethyl alcohol. Then, the mask was reinforced from the back by filling the voids using embedding rope of braided cotton in concentrated paraloid (25 %). After that, the face was adhered and assembled in its original position by using concentrated paraloid with a 50 % ratio. Then, the edges were covered with glass micro-balloons paste with paraloid and adding the appropriate color. After the completion of cohesion, the edges were polished using sandpaper and some scalpel and engraving tools and forming it according to the general look of this position, taking into consideration its decline from the surface about 2 mm. The surface of the paint layer was trickled with a 3-4 % solution of

Plexisol P550 in trichloro ethylene (it was of acrylic resins, aging resistance, and external weather conditions) [22]. The substance was being brushed on three times. This reinforced the layer of polychrome and increased its adhesion to the ground, fig. (14-a, b, c, d, e, f, g, h, i, j)

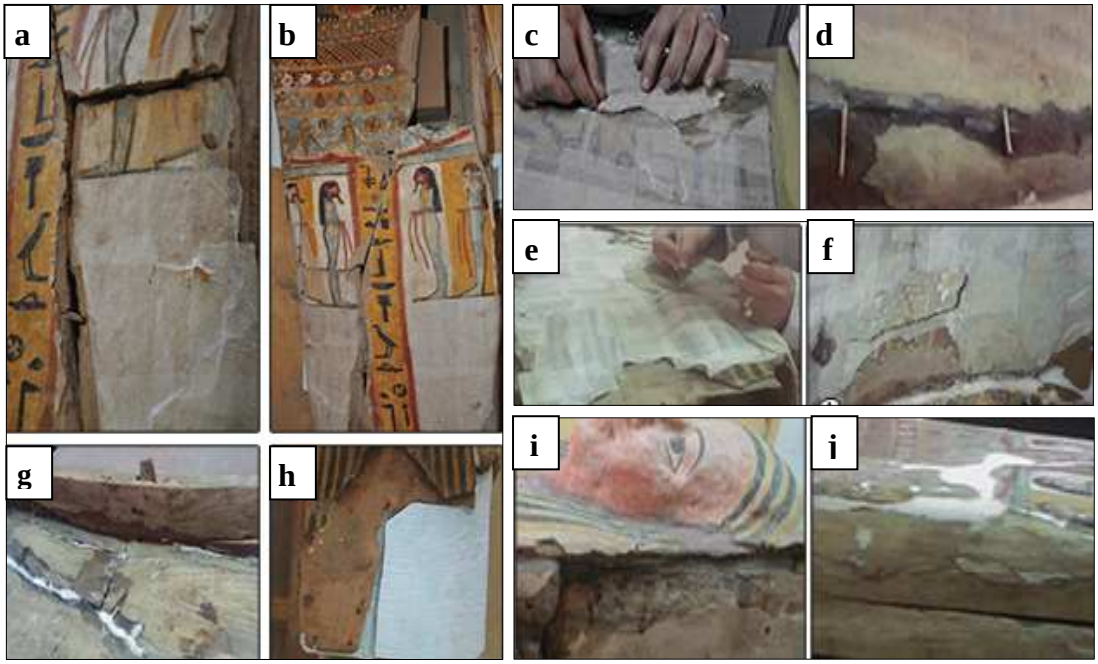

Figure (13) Shows conservation of coffin base; **a**., **b**. cleaning the accumulation of dust, **c**. surface protection by using Japanese paper with Klucel G.10 %, **d**. fixing the dowels to join the lid parts, **e**. fixing the painting crust, **f**., **g**. using embedding rope of braided cotton in concentrated paraloid B72 for reinforcement the cracks, **h**. completing by piece of balsa wood, **I**. adhering of the mask in its original position in the coffin, **j**. reinforcement of the gaps by using mixture of glass micro- balloon and paraloid B72 15 %.

4.4. *Returning the mummy to the coffin*

On completing the conservation, the Japanese paper was removed from the top of the cover using ethyl alcohol. After that, the mummy was replaced in the coffin. It was wrapped with two layers of cloths as it was, fig. (15-a, b, c, d). Then the coffin was closed and kept in store No. (2) at Saqqara.

Figure (15) Shows the coffin after conservation; **a**. coffin lid, **b**. coffin base, **c**. returning the mummy back to the coffin, **d**. closing the coffin

5. Discussion

Results of LOM attested that the wood was identified as a cypress wood (*Cupressus sempervirens*). It was important to note that, this type was rarely documented in ancient coffins and even today. However, it might be of some local importance in some countries as it was identified in some ancient Egyptian objects [5]. It also, indicated that the coffin was infected with five kinds of fungi. Most deterioration problems in the painted wood were caused by fungi and were a direct result of moisture. When wood was wetted, it was exposed to the attack of a succession of fungi. Different chemical changes occurred in wood depending on the action of the fungi. These phenomena of wood alteration were called white rot, brown rot, and soft rot [2]. The stratigraphic part of the ground layers consisted of two layers. The use of several textured plaster layers mitigated the destructive effect of the natural movement of the wood [23]. As for the paint layer, Goethite was responsible for the yellow color. In addition, it was found in both natural and synthetic iron oxide pigments [24]. The pink color consisted of a mixture of Hematite and Gypsum which was used as a white color, and the black color consisted of Pyrolusite that was a naturally occurring manganese oxide and was brown to black in color [24]. Organic binder was animal glue. It was clear that animal glue and plant gums appeared to be the most common paint binders [25]. Because the coffin was fragile and unstable, mechanical cleaning was used to remove the fragile or non-coherent dusts, sands, and accumulation mud. Then, chemical cleaning was used by mixing ethyl alcohol with water (1:1). After that, crusts were fixed using Primal 10 %, and the surface was consolidated by using paraloid B72 with a 3-5 % ratio in trichloroethylene. The surface was protected to maintain colors and paintings using Japanese paper and Klucel G. 10 %. After that, the mummy was levitated from the coffin which was cleaned from inside and sterilized using Sidial 3 %. The cracks and gaps were reinforced by embedding rope of braided cotton in concentrated Paraloid B72 with a 25 % ratio. The lost parts of the wood were completed by using Balsa wood. Finally, the painting layer and coffin mask were re-adhered after being conserved.

6. Conclusion

The coffin belonged to the Late period in Egypt; it was discovered at Saqqara Site in 1958 by Dr. Selim Hassan. The polychrome wooden coffin was in a very bad condition. It suffered from a great damage which was represented in the separation and loss of the painting and ground layers in many parts. There were also different kinds of cracks and several fractures in the wood itself, in addition to the fungus infection. LOM, FTIRE, SEM-EDX, XRD were used in both analysis and investigation processes. The results showed that the painting ground layers consisted of two layers; clay plaster and lime plaster. As for the paint layer; yellow consisted of Goethite, rose consisted of a mixture of Gypsum and Hematite and black consisted of Pyrolusite. The organic binding media was animal glue. Cypress wood (Cupressus sempervirens) was the type of that was identified. Microbiological investigation indicated that the coffin was infected with the following fungi, Aspergillus niger, Aspergilus flavus, Alternaria alternate, Emericella nidulans and Penicillium steckii. Conservation process were carried out through several stages. It started with two types of cleaning (both mechanical & chemical). Then came the stage of fixing the crusts, making the surface protection to maintain colors and paintings using Japanese paper and Klucel G 10%. After that, the mummy was levitated from the coffin, the inner part of the base was cleaned and sterilized using Sidial 3 %. In addition, the buckling of the wood was treated, reassemble using the wooden tenons, reinforcement of the cracks and gaps by embedding a rope of braided cotton in concentrated Paraloid B72 (a ratio of 25 %), completing the lost parts of the wood by using Balsa wood, re-adhering the painting layer and coffin mask at the lid. Finally, the mummy was replaced in the coffin and the coffin was shut and kept in store No. 2 at Saqqara until its show time.

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