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SCIENTIFIC METHODS FOR THE TREATMENT OF IBIS MUMMY'S WOODEN COFFIN

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Abstract:
The present study aims to investigate the conservation of a wooden coffin of the sacred Ibis Mummy that dates back to the Greco-Roman Period. It was found in Minia excavations and transferred to the Grand Egyptian Museum in 2012 for conser-vation. For a better unders-tanding of deterioration and raising awareness of the conservation, many examinations and analyses were done, e.g. visual examination and documentation using AutoCAD (2D), optical microscope, X-ray Diffraction (XRD), and Infrared spectroscopy to define the type of wood, preparation layer, and binder. The coffin under study was kept in inappropriate conditions, causing further deterioration. Moreover, the surface decorations could be hardly seen because of the dust. After examination, conservation was conducted, including mechanical and chemical cleaning, installing friable painted gesso layers, filling cracks and pores, reassembling of the box and the lid, and adjusting the lid. The conservation was successful. Consequently, the coffin is ready for exhibition or storing.

1. Introduction

The Ancient Egyptians achieved great succ-ess in mummification. They could preserve the bodies not only of humans but of a large group of animals and divine creatures, as well [1]. Because they believed in the hereafter, the Ancient Egyptians sought to preserve the dead bodies for eternity [2]. Therefore, great attention was paid to the mummies of animals over the ancient Egy-ptian eras. In the Greco-Roman and the Late periods, for example, breakthro-ughs occurred in animal mummification [3,4] because of the historical events, inclu-ding invasions. Thus, a set of rituals were performed to maintain the Egyptian iden-tity and pray for the local gods to offer support in hardships [5]. Recently, some mummies have been found in special cof-fins. Sometimes, the mummies were not found, only bones, mummification materi-als, and feathers. However, the real reason has not been revealed. It might be inte-ntional or caused by the rarity of animals, certain spills, or a belief that animal remains would be gods after death [6,7]. Mummi-fied animals are of four different types: Votive offerings, food offerings, pets, and sacred animals [8]. Some mummies were kept in coffins of certain shapes, while others were kept in coffins decorated with the shapes of animals or birds [9]. These coffins were of great importance and were designed with the same quality of human coffins, with the use of the same materials and methods of decoration. The present study examines a coffin that was dedicated to Ibis Mummy and dated back to the Greco-Roman era. This coffin was found in Minia excavations and measured (44 cm × 19 cm × 15 cm). The box was assembled from some panels using interleaves and joints. This method was the most common in making coffins in ancient Egypt [10]. The coffin consists of a box and a lid covered with a layer of painted gesso from the four corners. Moreover, it has some colorful motifs. The four corners are adorned with human decorations, ibis, and hieroglyphic alphabet. Unfortunately, the coffin has suffered some deterioration phenolmena, including loss of the painted gesso layers, loss of decorations, and loss and breaking of wood. The lid has severe warping. There are also manifestations of thermal degradation in the lid and the left side of the coffin, fig. (1). The present study identified some components of the coffin, such as the type of wood, the basic components of the gesso layer, and the medium used in joining the gesso layer to help conduct the treatment process. After doing the appropriate tests for the cleaning, consolidation, and strengthening materials, the most adequate conservation method was selected. Conservation works were carried out, in accordance.

Figure (1) Shows the coffin under study

2. Materials and Methods

To carry out conservation, many examinations and analyses were utilized because the study mainly aims to do appropriate conservation of the coffin.

2.1. *Visual examination*

Visual assessment by the critical eye of the conservator was applied to determine the aspects of deterioration found on the coffin surface. The visual examination helps identify the status of the monument. In other words, it helps identify most of the deterioration phenomena easily. The treatment priorities, as well as the types of examination and analysis, could also be defined [11].

2.2. *AutoCAD (2D) Documentation*

Recently, a great leap has been achieved in the computer uses in archaeology, especially AutoCAD (2D) [12]. This program is used in documenting the deterioration aspects of the coffin, as well as its real dimensions and details. A map of the damage was made, each side of the coffin was documented, and a special keynote was assigned to every type of deterioration. The map was also devel-oped to express the conservation procedures applied to the coffin. The condition of the coffin was recorded in detail, and each part was carefully recorded.

2.3. *Optical microscopy*

An optical microscope (with a focus range of 10-500 mm and a magnification ratio of 20-200x) equipped with Axio Cam MRC5 in transmitted light using OPTKA MICR- OSCOPY (Italy) equipped with OPTIKA B 9 Digital Camera was used to identify the wood species. Thin sections were obtained in the three principal anatomical directions, transverse (TS), tangential (TLS), and Radial (RLS).

2.4. *X-ray diffraction analysis*

To identify the main components of the samples, fragments from the ground layer underwent X-ray analysis using a device with the following specifications: (a Cu ($K\alpha1/K\alpha2$) radiation source energized at 45 kV and a Philips X-ray diffractometer (PW 1930 generator, PW 1820 goniometer). The XRD patterns were recorded in a 2θ diffraction angle range from 10° to 80°).

2.5. *Infrared spectroscopy*

IRPrestige-21 (FTIR spectrophotometer) and the IRsolution software in the 400-4000 cm^{-1} range with a resolution of 8 cm^{-1} were used for identifying the medium used in the painted gesso layers.

3. Results

The coffin under the study was kept in inappropriate environmental conditions. So, deterioration phenomena became integral. The lid has experienced loss, thermal degradation, color change, loss in the painting layer, and warping. The box showed many deterioration manifestations, including dust, dirt, stain, breaking, loss of some wooden parts, color change of the right side, and detachment of the panels, fig. (2). Therefore, conservation and treatment shall be conducted appropriately.

3.1. *Deterioration aspects*

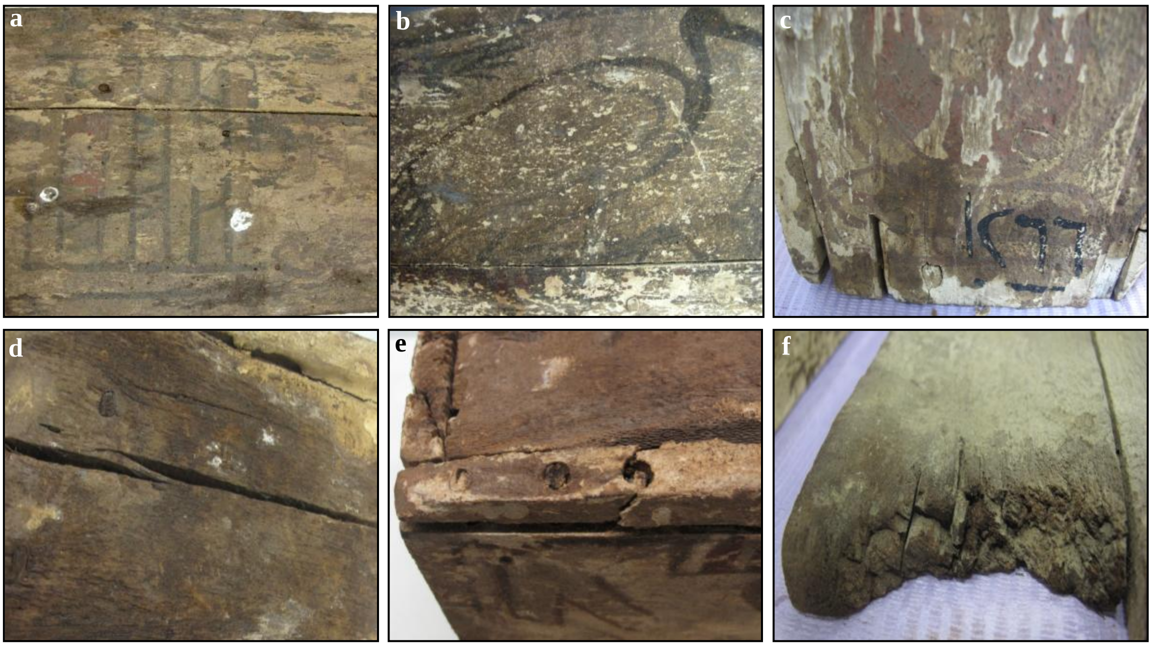
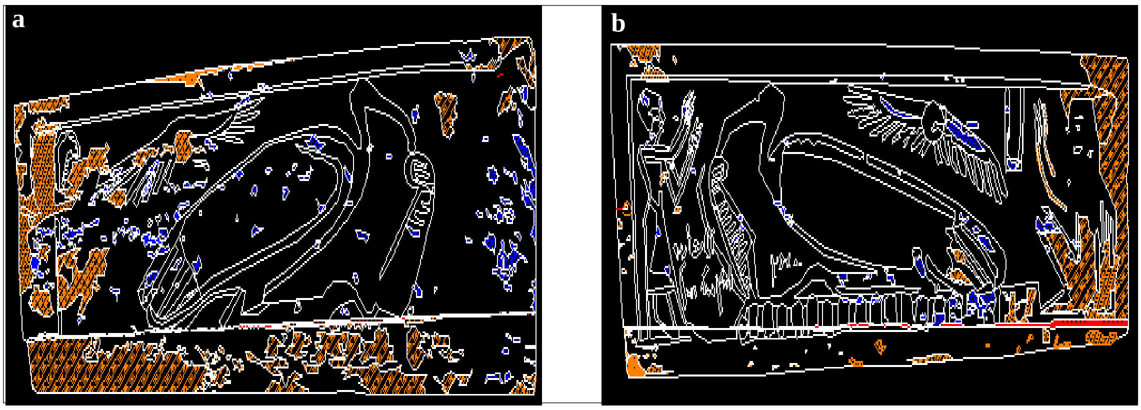


Figure (2) Shows aspects of deterioration found on the coffin; **a**., **b**., **c**. dust, dirt, stain, powdering, and discoloration; **d**., **e**., **f**. cracks, missing parts, separations of wooden panels, breaking and loss of some wooden parts,

3.2. *Documentation of the deterioration aspects by 2D program*

This program is used in documenting the deterioration aspects of the coffin, as well as its real dimensions and details. It illustrates the manifestations of deterioration, including loss, cracks, dirt, breaking, and warping. A color is dedicated to each deterioration form. Moreover, the dimensions are accurately defined. In terms of the coffin under study, the status was totally documented using AutoCAD (2D). A general picture showing the deterioration manifestations was obtained in a scientific and accurate method. It is used as a reference to define the monument's status before and after completing the stages of conservation, fig. (3).



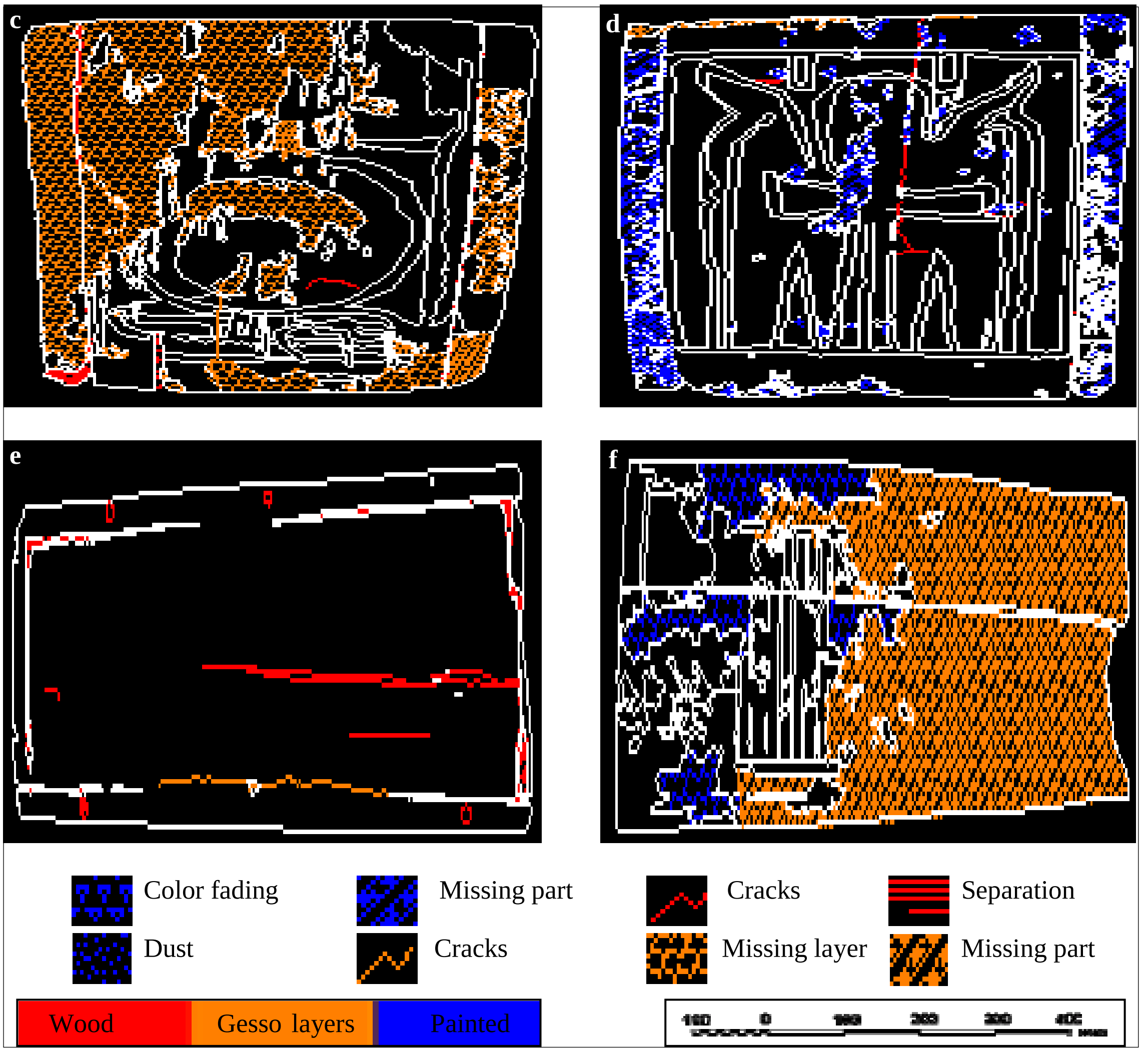


Figure (3) Shows schematic diagrams of the coffin showing the deterioration aspects by 2 D program; **a.** schematic diagram of the coffin left side, **b.** schematic diagram of the coffin right side, **c.** schematic diagram of the coffin head area, **d.** schematic diagram of the coffin foot area, **e.** & **f.** schematic diagram of the coffin lid

3.3. *Identification of wood species*

An optical microscope was utilized to define the type of wood using micro-samples of the cross, longitudinal, and radial sections. Each section reveals some features that help identify the type of wood. This is the most effective method in the examination of wood samples. The structure of the wood of the three sections was examined and compared with standard samples. They showed the basic cells, growth rings, and some distinctive features to help confirm the type of wood [13]. The cross-section was characterized by large round capillary, either individual or double groups arranged in longitudinal rows that alternate with ranges of fibrous cells. The longitudinal section had a large, ladder-like wooden capillary with mesh netting. Moreover, there were clusters of fibers with slanting cross-section alternate lenticular stratified parenchymatic clusters. The radial section had numerous parenchymatic cells, which coat the alternate vessels and fibers. Comparing the anatomical features of the sample with standard samples revealed that the coffin was made of (Ficus sycomorus) [14], fig. (4)

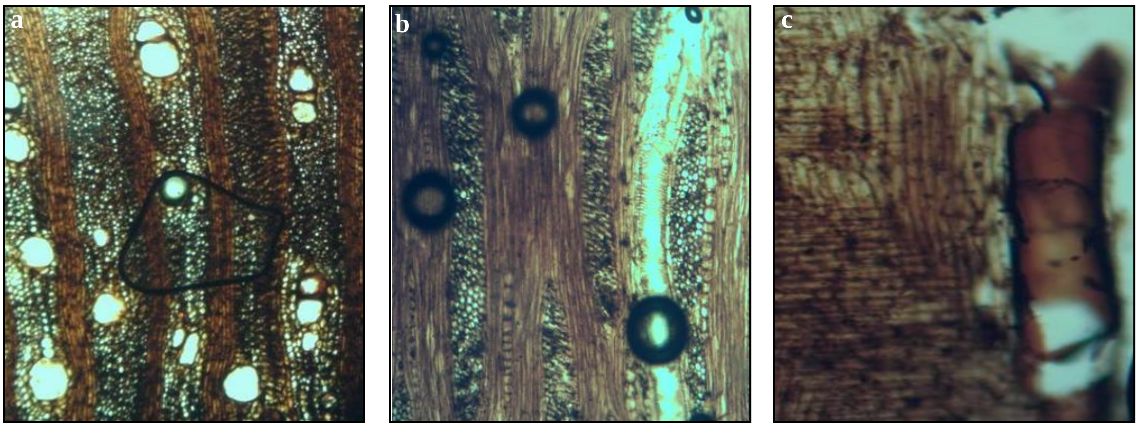


Figure (4) Shows ficus sycomorus; **a.** Transverse section (TS) vessels solitary or in radial multiples of 2 to 4 and axial parenchyma vasicentric in bands more than three cells wide (40 x), **b.** tangential section (TLS) rays of two distinct sizes, larger rays commonly 4 to 12 seriate (40 x), **c.** laticifers were observed in rays (arrowhead) (200 x)

3.4. *Identification of ground gesso layers*

The ancient Egyptians realized the importance of the good preparation of the wood surfaces before applying the paint layer [15]. Therefore, the paint layer was applied on a ground gesso layer [11]. It was commonly used and made of limestone powder, glue, and water that were mixed well to form a paste with a heavy or light texture, when necessary [16]. Analyzing a sample of the coffin's gesso layer showed that it mainly consisted of a smooth layer of calcite ($CaCO_3$), fig. (5).

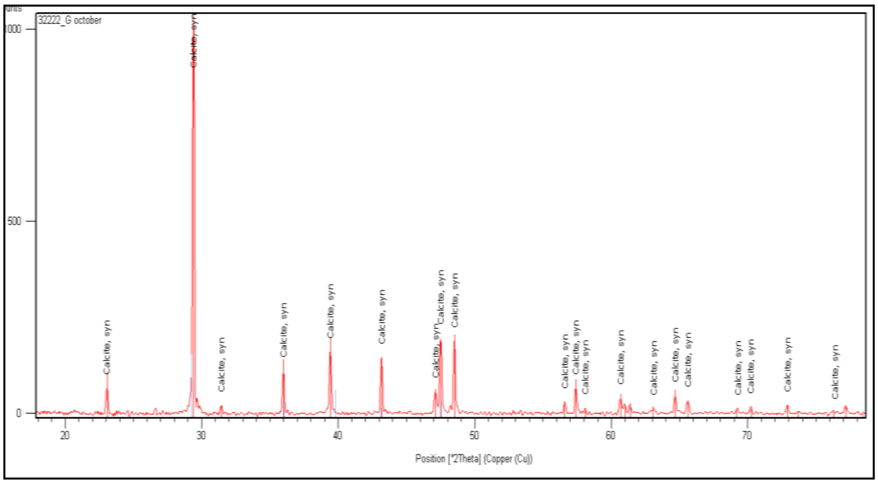


Figure (5) Shows a sample of the preparation layer showing calcite ($CaCo_3$) as the main component

3.5. *Identification of binding media*

This is a basic analysis before the beginning of conservation. In other words, the identification of the binder in the preparation layer helps select the cleaning and consolidation materials that do not negatively affect the preparation layer. The infrared analysis of a sample of the gesso layer showed that the binder could be animal glue because it was one of the oldest materials used by the ancient Egyptians [17]. It is made of animal tissue containing gelatin (e.g. bone, leather, cartilage, hooves, sinews, and horns) [18]. It is put in boiling water and the liquid becomes concentrated by evaporation. Then, it is poured into molds for cooling. When used, it is broken into small pieces in pots containing water. After that, the pieces are heated to be used in the sticky form [19]. Comparing the functional groups of the sample under study with standard samples showed that the functional groups of the sample matched those of the glue, fig. (6). That is, the comparison revealed the functional group of (N-H 1500-1565 cm-^{1}. It was confirmed by the N-H stretching band at 3200-3500 cm-^{1} and bands corresponding to the stretching frequencies of carbonate (1490-1370cm-^{1}, 910-870 cm-^{1}).

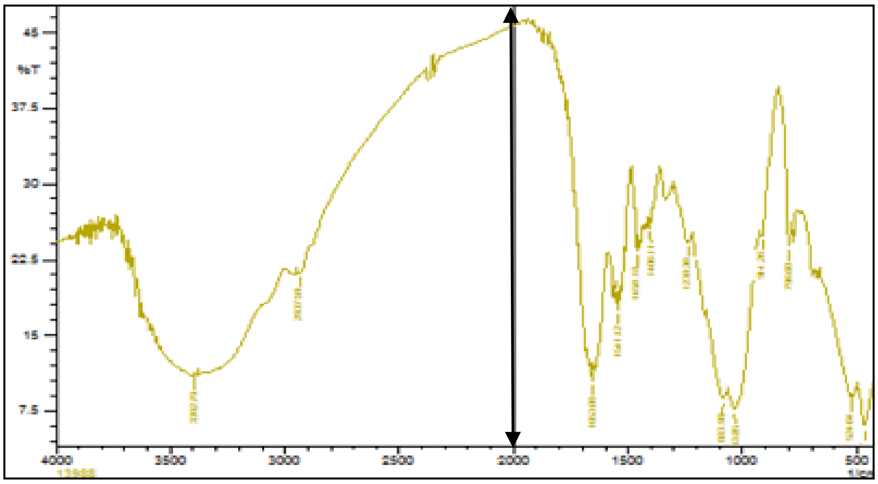


Figure (6) Shows a sample of the binder in the preparation layer using infrared spectroscopy

4. Discussion

Comparing the results of some studies on coffins dating back to the Roman period showed that the ancient Egyptian made some coffins for sacred birds in the same manner as the style and technique of the human coffins [9], including the assembly using various wood interleaves. This was clear in the reassembly of the cover and the body. The appropriate gesso layers were prepared to fit the different decorative styles. Therefore, calcium carbonate and glue were used as a gesso layer, which was common in human coffins [10], for the coffin under study. Identifying the wood type showed using sycamore that dominated the human coffins in ancient Egypt because of its easiness of carving and manufacturing [11], as well as sacredness. It could be concluded that the ancient Egyptian paid great attention to these coffins dedicated to sacred birds and animals and applying the same materials of human coffins [10]. Furthermore, the features of the wooden coffins of the Roman era were clear in the decorative style on both sides of the coffin, illustrating the integration of the Roman-Egyptian depiction, especially in the representation of human faces, clothes, and wig [5].

5. Applied Conservation Works

Based on the previous results applied conservation procedures were carried out to maintain the coffin under study. Thus, the following stages were conducted

5.1. *Primary insurance of the surface crusts*

Because some crusts were prone to loss, they were secured before conservation using tissue paper with Klucel G (0.5%); an organic polymer that is largely used in the conservation of antiquities [20]. Hydroxypropyl cellulose (HPC) is a non-ionic cellulose ether that can be dissolved and widely used in the field of book conservation [21]. It is characterized by solubility in organic solvents, thermal plasticity, and surface activity [22]. It is a white powder with neither odor nor taste. Because of the different series lengths, its viscosity, properties, and uses vary [23]. It is soluble in many polar organic solvents and water (with a temperature below 38 °C). However, it is insoluble in water above 45 °C. Moreover, it is extremely active on the surface [24]. This method proved effective in securing the crusts subjected to loss, fig. (7).

Figure (7) Shows securing some crusts using Japanese papers with Klucel G (a concentration of 0.5%)

5.2. *Cleaning*

Cleaning and removing dust and dirt is the most important stage in the treatment process because it helps show the obliterated decorative details. Moreover, the accumulation of dust on the surface causes many fungal and insect infections [15]. Cleaning was carried out using a vacuum cleaner to remove the dust from the box and the scalpel to remove the surface stains that result from bird droppings. Then, a mixture of alcohol and toluene (1:1) was applied to remove surface stains, especially in the lid, fig. (8).

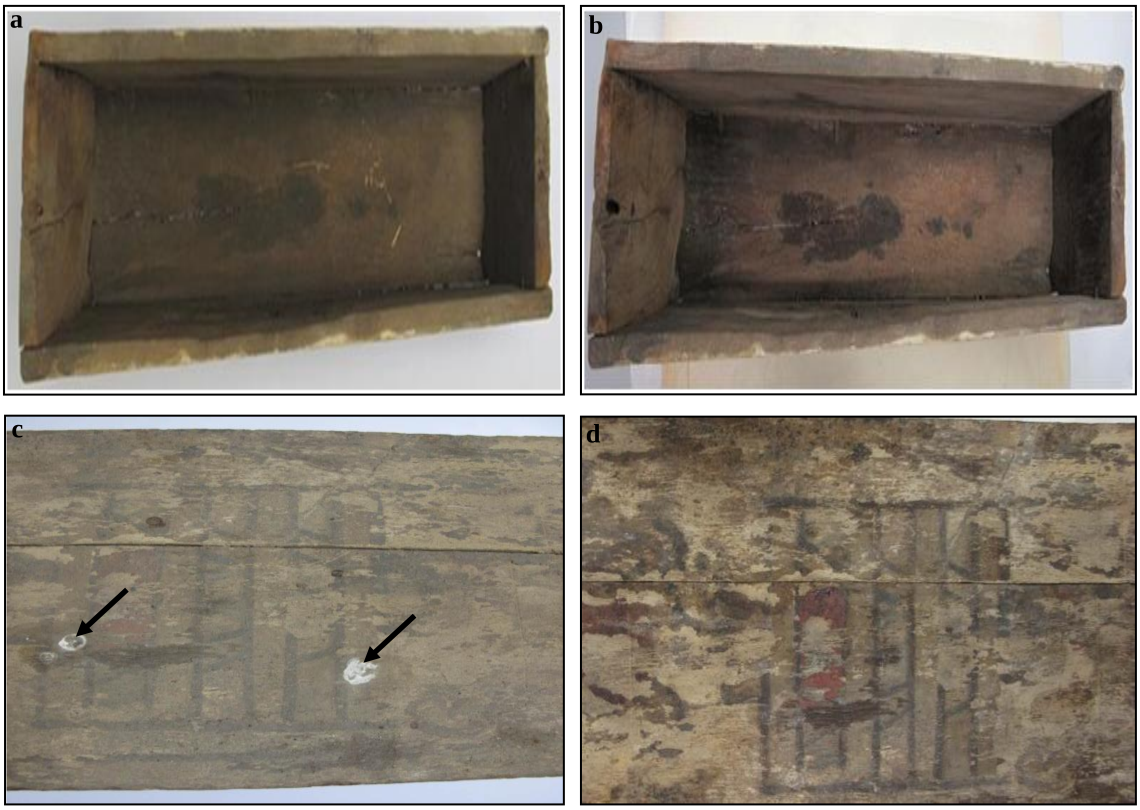


Figure (8) Shows the stages of mechanical and chemical cleaning; **a.** & **b.** pre-cleaning, **c.** & **d.** after cleaning

5.3. *Re-adjustment and re-assembly of the lid*

Due to temperature fluctuation and different effects on the inner and outer layers of wood, warping occurs. The same happened to the lid [25]. The twisting of surface wood mainly results from the weak bond between the fibers. Consequently, the mechanical strength of the wood is affected and its dimensions change, resulting in warping and damage. In other words, the great temperature fluctuations in the surrounding environment cause internal stress and damage to the monument [26]. This effect increases when the wood artifacts consist of different materials due to their different rates of expansion and contraction [27]. In addition to affecting the surface that is void of colors, such fluctuations cause damage to the surface layers [28]. Therefore, the fluctuations of continuous temperature cause different deterioration manifestations, including fiber separation, cracking, and change of dimensions [29]. Wood drying results from high temperatures because wood loses the free water, i.e. water in the cell vacuums. This affects wood shrinking clearly. However, the increasing temperature causes wood dryness due to the loss of formation water, i.e. water in the walls of the cells. The walls are eventually reduced, and wood shrinkage takes place. Wood shrinkage means reducing the wood size that varies based on the direction of wood fibers [30]. Also, the type of wood plays a magnificent role in being affected by temperature. That is, the shrinkage of hardwood is more than that of softwood [31,32]. The re-adjustment of the lid was conducted by spraying a mixture of water and ethyl alcohol at intervals, as well as using metal clamps. The lid of the coffin consisted of two panels of wood assembled by wood joints. During readjustment, the panels were separated. Consequently, they were dismounted and reassembled using Paraloid B72 (a concentration of 60%, as an adhesive), metal clamps, and sandbags to avoid warping. Moreover, wood was insured well with cotton pads coated with Japanese paper to prevent friction with the metal clamps, fig. (9). Over the past few decades, acrylic resin, including Paraloid, has been used as an adhesive (40-60%) because of its relative stability, transparency, and mechanical resistance. It also fits all materials, such as metal, stone, wood, glass, or ceramic, etc. Paraloid (1:5%) is used in mural paintings, while (5:10%) is used in strengthing the gesso layer and colors of oil paintings. It is prepared in either toluene or isopropanol. Moreover, Paraloid (5:20%) is used to strengthen the wood holes that result from insect infestation. While (30%) is used to strengthen plaster ceilings, (20:60% in acetone) is used as an adhesive for glass and ceramic. As an adhesive, the effectiveness of Paraloid depends on the weather conditions on application. For example, it gives bad results in high temperatures. Moreover, the type of dissolvent plays a key role in adhesion. Using a volatile solvent, e.g. acetone hinders the penetration of Paraloid and a less volatile solvent, e.g. Touline improves the penetration of the resin [33].

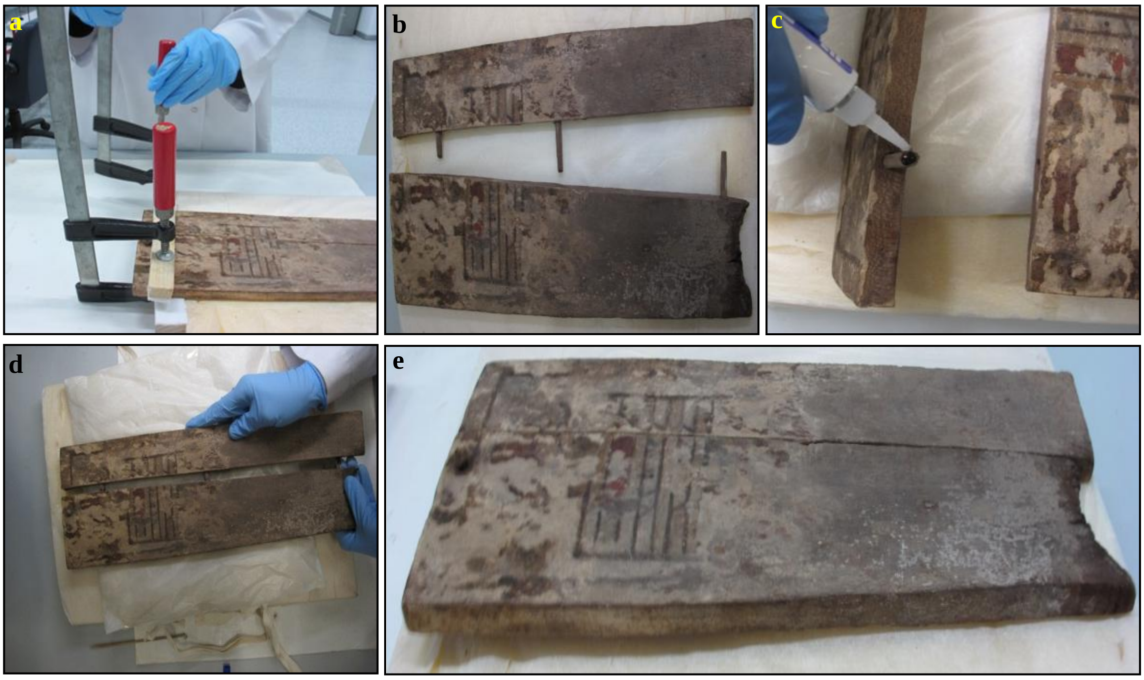


Figure (9) Shows **a.**, **b.** & **c.** the stages of re-adjustment, **d.** re-assembly in the lid, **e.** final stage

5.4. *The assembly of the box*

The box has suffered a separation of the panels because of the expansion and contraction caused by temperature fluctuations. It was assembled in the same manner as the lid. Paraloid B72 (60%) was injected and metal clamps were utilized until the polymer dries, fig. (10).

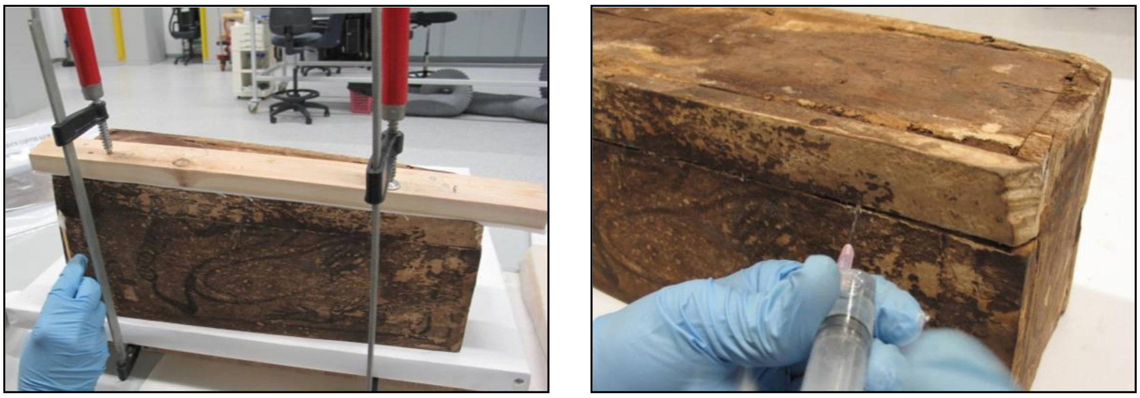


Figure (10) Shows the stages of the coffin box's assembly

5.5. *Consolidation*

Both the wood and the painted gesso layers were consolidated, where, the wood of the lid was consolidated using Paraloid B72 (5%) that was increased to 7% in weak areas. The using of Paraloid B72 in our case is attributed to its durable index [34] especially as a final protective layer [35]. Where, it protects the surface of the monument against acid pollutants. However, it suffers a color change in case of improper application fig. (11-a,b). The decorative colorful layers were consolidated using Klucel G (1%) along with using magnifying lenses. It was carried out in a drawing-like manner, fig. (11-c,d).

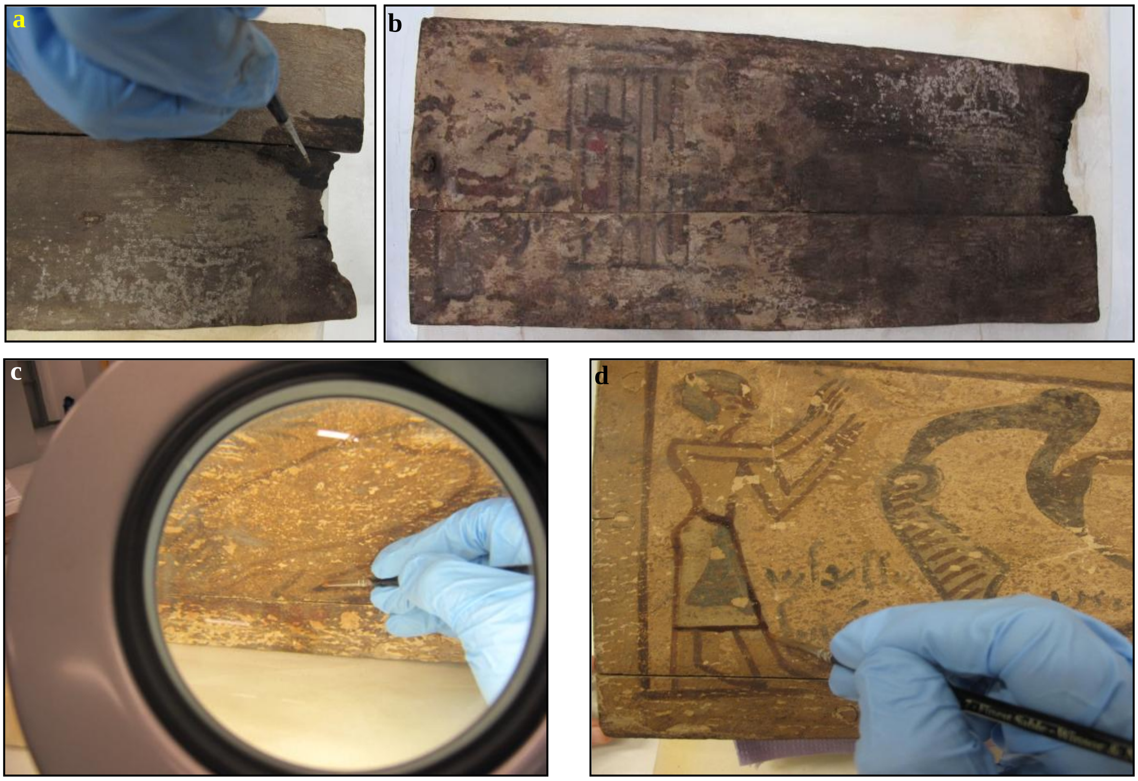


Figure (11) Shows surface consolidation of the lid from back and front, **a**. during consolidation, **b**. after consolidation, **c**. & **d**. surface consolidation of color motifs

5.6. *Completion*

The coffin had cracks, loss, and gaps in the wood. These are weak and attractive positions for the insects. A mixture of glass microballoon, Paraloid B72 (15%), and color oxides was used to fill the fine cracks. Moreover, wrapped cotton was used to fill the deep cracks along with the injection of Paraloid B72 (15%) until the polymer dries. Then, the aforementioned microballoon mixture was applied as a thin surface layer on the cotton, while lowering the level of completion to illustrate the difference between the completed and the old parts. Completion was very accurate, as shown in fig. (12-a,b,c,d,e). Finally, fig. (13) shows the coffin after conservation from all directions.

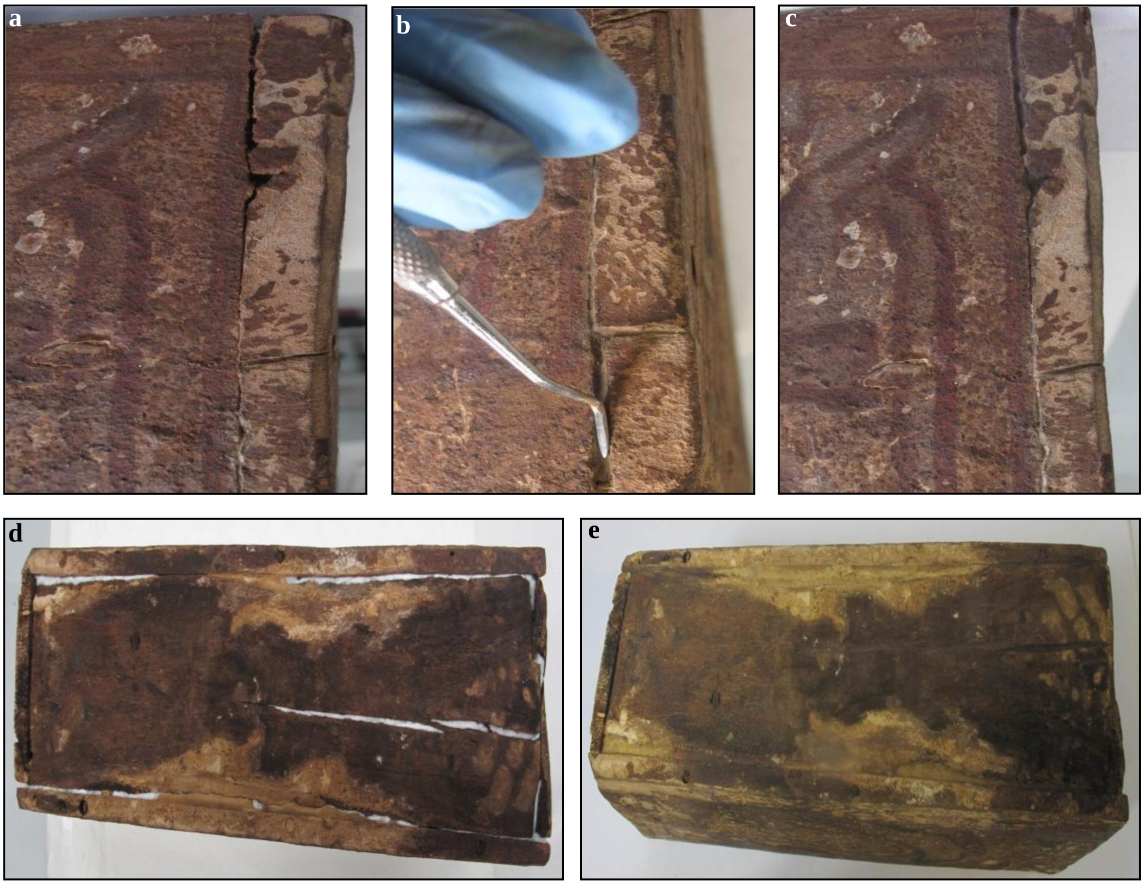


Figure (12) Shows the stages of completion of fine cracks **a.** before completion, **b.** during completion, **c.** after completion, **d.** & **d.** the stages of completion of deep cracks

Figure (13) Shows the coffin after conservation

6. Conclusion

A wooden painted anthropoid coffin dating back to the Graeco-Roman period from El-minia storage, consisting of lid and box, was analyzed and subjected to deep conservation. The ancient Egyptians were interested in the mummification of sacred birds and protecting the mummies in specially prepared coffins. The wood species identification indicates that ancient Egyptian carpenter made the coffin with local woods, such as sycamore. This coffin suffers from deterioration caused by exposure to unstable environmental conditions. Visual assessment and investigation of the surface morphology revealed many aspects of deterioration of the surface conditions of the coffin, such as cracks, missing parts, and separation between the wood layer that require conservation. The analysis using OM, XRD, and FTIR allowed characterizing the original materials to choose the most appropriate cleaning and consolidation measures and to decide the removal of previous materials that disturbed the authenticity of the object. OM identification indicated that the wood used in the coffin boards was Sycamore. Analyzing a sample of the coffin's gesso layer showed that it mainly consisted of a smooth layer of calcite ($CaCo_3$), and FTIR spectra revealed that the binding medium used in the fine gesso layer was animal glue. Documentation using AutoCad (2D) is significant in creating a detailed map of the monument before conservation. The materials and methods that had been applied were extremely effective for stability and reinforcement to the coffin without harmfulness on the original materials. To put it differently, identifying the type of wood, binder, and components of the preparation layer helped select the most appropriate materials for conservation. Paraloid B72 (5:7%) proved successful in the consolidation of the thermally degraded wood. Moreover, it gave good results in the assembly of the box (60%). The primary insurance of the falling crusts is necessary. Klucel G (0.5% concentration) gave good results. Moreover, it (1% concentration) was used for the consolidation of color motifs' layers. The coffin was successfully conserved and ready to display or storage.

References

[1] Ikram, S., (2005). *Divine creatures: Animal mummies in ancient Egypt*, AUC Press, Cairo.

[2] Armitage, P. & Clutton-Brock, J., (1981). A radiological and histological investigation into the mummification of cats from ancient Egypt, *J. of Archaeological Science*, Vol. 8, pp: 96-185.

[3] Abdel-Maksoud, G., (2001). Conservation of Egyptian mummies, part I: Experimental study on the ancient Egyptian technique of mummification, in: Szymanska, H (ed.) *Mummy Result of Interdisciplinary Examination of the Egyptian Mummies of Aset-iri-khet-es from the Archaeological Museum in Cracow*, Cracow, Polish Academy of Arts and Sciences, Poland, pp. 225-234.

[4] Cheng, S., Liu, J., Huang, C., et al., (2009). Insecticidal activities of leaf essential oils from Cinnamomum osmophloeum against three mosquito species, *Bio-resource Technology*, Vol. 100, pp: 457-464.

[5] Colombini, M., Modugno, F., Silvano, F., et al., (2000). Characterization of the balm of an Egyptian mummy from the seventh century B.C., *Studies in Conservation*, Vol. 45 (1), pp: 19-29.

[6] Cordeiro, L., De Oliveirab, S., Buchi, D., et al., (2008). Galactofuranose-rich heteropolysaccharide from Trebo-uxia sp., photobiont of the lichen Ramalina gracilis and its effect on macrophage activation, *Int. J. of Biological Macromolecules*, Vol. 42, pp: 436-440.

[7] Cosmacini, P. & Piacentini, P., (2008). Notes on the history of the radiological study of Egyptian mummies: From X-rays to new imaging techniques, *La Radiologia Medica*, Vol. 113, pp: 615-626.

[8] David, A., (2001). Mummification, in: Redford, D. (ed.) *The Oxford Encyclopedia of Ancient Egypt*, Vol. 2, Oxford Univ. Press, pp.439-444.

[9] Edwards, H., Currie, K., Ali, H., et al., (2007). Raman Spectroscopy of natron: Shedding light on ancient Egyptian mummification, *Anal Bioanal Chem*, Vol. 388 (3), pp: 683-689.

[10] Harrell, J., (2002). *Archaeological geology in Egypt: Ancient oil wells and* *mummy bitumen, earliest geological map, first paved road, pyramid temple pavements, and the Sphinx age controversy*, NCGS Newsletter, Northern California Geological Society.

[11] Abdrabou, A., Abdallah, M. & Abd Elkader, M., (2015). Analytical study and conservation processes of a painted wooden Graeco-Roman coffin, *IJCS*, Vol. 6 (4), pp: 573-586

[12] Abdrabou, A., Abdallah, M., Nabil, E., Matsuda, Y. & M. Kamal, H., (2019). Preliminary investigation of the materials and techniques used in a decorated wooden stick of king Tutankhamun, *Conservar Património*, Vol. 30, pp: 9-19

[13] Crivellaro, A. & Schweingruber, F. (2013) *Atlas of Wood, Bark and Pith Anatomy of Eastern Mediterranean Trees and Shrubs with Special Focus on Cyprus*, Springer-Verlag Berlin Heidelberg.

[14] Cartwright, C. (2001). Cedrus Libani under the microscope; the anatomy of modern and ancient cedar of Lebanon wood, *Archaeology and History in Lebanon*, Vol. 14, pp: 107-113.

[15] Fahn, A., Werker, E. & Bass, P. (1986). *Wood Anatomy and identification of trees and shrubs from Israel and adjacent regions*, Israel Academy of Sciences and Humanities, Jerusalem.

[16] Ismail, Y., Abdrabou, A. & Abdallah, M., (2016). A non-destructive analytical study and the conservation processes of Pharaoh Tutankhamun´s painted boat model, *IJCS*, Vol. 7 (1), pp: 15-28.

[17] Nabil, E., Ali, M. & Kamel, S., (2017). Investigation and analysis study of an old kingdom Cheops first boat oar blade, *J. of Ancient Egyptian Interconnections*, Vol. 16, pp: 87-98.

[18] Akhtari, M. & Nicholas, D., (2013). Evaluation of particulate zinc and copper as wood preservatives for termite control, *Eur. J. Wood and Wood Prod.*, Vol. 71, pp. 395-396.

[19] Christensen, M., Kutzke, H., & Hansen, F. (2012). New materials used for the consolidation of archaeological wood-past attempts, present struggles, and future requirements, *J. Cult Herit.*, Vol. 13, pp.183-190.

[20] Crivellaro, A. & Schweingruber, F., (2013). *Atlas of wood, bark and pith anatomy of eastern Mediterranean trees and shrubs with special focus on Cyprus*, Springer-Verlag, Berlin

[21] Kate, G. & Foekje, B. (1997). Solvent reactivation of hydroxypropyl cellulose (Klucel G®) in textile conservation: Recent developments, *The Conservator*, Vol. 21 (1), pp: 12-20

[22] Horie, V. (2010). *Acrylic polymers, Materials for Conservation*, 2nd ed., Elsevier, UK.

[23] Gordobil, O., Egües, I., Urruzola, I., et al., (2014). Xylan-cellulose films: Improvement of hydrophobicity, thermal and mechanical properties, *Carbohydrate Polymers*, Vol. 112, pp: 56-62.

[24] Pareo, P., De Gregorio, G., Manca, M., et al., (2011).Ultra lightweight PMMA-based composite plates with robust super-hydrophobic surfaces, *J. of Colloid and Interface Science*, Vol. 363 (2), pp: 668-675.

[25] Nabil, E., Mahmoud, N., Youssef, A., et al., (2018). Evaluation of physical, mechanical and chemical properties of Cedar and Sycamore woods after heat treatment, *Egyptian, J. of Chemistry*, Vol. 61, no. 4, pp: 1131-1149.

[26] Eylem, D., Tomak, E., & Huseyin. P. (2012). The effect of some wood preservatives on the thermal degradation of Scots pine, *Thermo Chimica Acta*, Vol. 547, pp: 223-231.

[27] Chew, N., (2011). Pyrolysis of tropical hardwood under long-term and low temperature conditions, *Int. J. on Architectural Science*, Vol. 8, pp: 17-27.

[28] Kocaefe, D., Poncsak, S., Tang, J., et al., (2010). Effect of heat treatment on the mechanical properties of North American jack pine: Thermo gravimetric study, *J. Mater Sci.*, Vol. 45, pp. 681-687.

[29] Blasi, C. (2008). Modeling chemical and physical processes of wood and biomass pyrolysis, *Progress in Energy and Combustion Science*, Vol. 34, pp: 47-90.

[30] Jamsa, S. & Viitaniemi, P., (2001). Heat treatment of wood better durability without chemicals, in: Rapp A. (ed.) *Review on heat treatments of wood. Cost action E22. Proceedings of Special Seminar*, Antibes, France, pp.17-22

[31] Bekhta, P. & Niemz, P. (2003). Effect of high temperature on the change in color, dimensional stability and mechanical properties of spruce wood, *Holzforschung*, Vol. 57, pp: 539-546.

[32] Podany, J., Garland, K., Freeman, W., et al., (2001). Paraloid B-72 as a structural adhesive and as a barrier within structural adhesive bonds: Evaluations of strength and reversibility, *JAIC*, Vol. 40 (1), pp: 15-33.

[33] Pandey, K. & Vuorinen, T. (2008). UV resonance Raman spectroscopic study of photo degradation of hardwood and softwood lignins by UV laser, *Holzforschung*, Vol. 62 (2), pp: 183-188.

[34] Traistaru, A., Timar, M. & Campean, M. (2011). Studies upon penetration of Paraloid B72 into poplar wood by cold immersion treatments, *Bull. of the Transilvania Univ. of Braşov*, Vol. 4 (53), pp: 81-88.

[35] Traistaru, A., Timar, M., Campean, M., et al., (2012). Paraloid B72 versus Paraloid B72 with nano-ZnO additive as consolidants for wooden artifacts, *Mater Plast*, Vol. 49 (4), pp: 293-300