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A RECENTLY DISCOVERED CORN MUMMY IN IBIS, SOUTH OF ABU SIR, NORTH OF SAQQARA 2018: A CASE STUDY

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Abstract

The present study mainly aimed to document the newly discovered grain mummy and to disclose some scientific information about this type of mummies. It also aimed to identify degradation. Thus, it utilized many non-destructive analyses, such as the digital microscope, SEM, FTIR, XRD, and microbial isolation. The study concluded that the discovered mummy is a type of "Osiris bed" that contained papyrus rolls, unlike the common corn mummies. The microscopic examination confirmed that the used papyrus was uniquely constructed with a single thick layer. The infrared results revealed that the black resin that covered the mummy might be Frankincense resin, which was subjected to oxidation processes giving the black color. Moreover, the S-twist pattern was used in linen spinning with simple weave (1/1), the linen bandages had advanced decay by Aspergillus Flavus- Link and complete destruction of barley grains by Alternaria arborescens E.G Simmons. XRD revealed that the resin minimized the crystallinity index of linen bandages notably compared to the uncovered linen bandages with resin.

Keywords*: Ptolemy IV; Papyrus; Crystallized cellulose; Egyptian textiles; The parenchyma cells.*

Introduction

Ancient Egyptian civilization has revealed many secrets. However, there is much mystery about many discoveries. One of the most famous achievements of Egyptian civilization is mummies, where the ancient Egyptians believed that the steppingstone to immortality is mummification [1, 2].

However, it is widely known that the Egyptians mummified their humans and animals, such as birds and monkeys for ceremonial and religious reasons. Four main categories are detected. They are (i) household pets, (ii) victual mummies, (iii) sacred animals, and (iv) votive mummies. This is alongside what is known as 'falcon mummies' or 'corn mummies'; the oldest reference in funerary texts to the use of the corn dates back to the coffin texts during the Middle Kingdom. Some archaeologists believe that the corn mummies were fake mummies. There was a large confusion about the time of their discovery, where they were thought to be the mummies for falcons or infants because of their small size that did not exceed half a meter. The history of that distinctive category of mummies dates back to the early first millennium BC at least [3].

These pseudo-mummies contain grain without any animal remains or mummified humans [4]. They were closely associated with Osiris and regeneration. Thus, they were sometimes called "Osiris mummies". They were a class of religious artifacts consisting of a three-dimensional human-like artifact kept in a wooden sarcophagus embellished with holy

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images of a falcon which were manufactured during "the Khoiak Festival" associated with resurrection and rebirth [5, 6].

The first real study of the technique of those mummies was by *M. Raven 1982* [7] that, with subsequent studies, indicated that corn mummies were made from grains (e.g. wheat or barley) and Nile mud and wrapped with linen bandages. Their final shape roughly resembled a mummified human. In 2008, the Walters Art Museum examined an Egyptian corn mummy that dates back to 685-520 B.C. (the Late Period). It revealed that the corn mummy composited of a bundle in the shape of a human mummy but made of clay or sand and grains, then wrapped in linen bandages with a black resin applied over the body of the mummy. In 2014, *J. Walthew and E. Mayberger* [8] carry out an examination study on three corn mummies stored in the Metropolitan Museum of Art. The results confirmed using the sand, soil, and barley in filling the grain mummies [9-11]. There were also dark resin-coated wrappings covered with a finer textile fragment that was tied at the head and foot [12-14]. Despite these painstaking attempts to understand the nature of grain mummies, their nature is still vague and requires further studies.

This paper attempts to unveil the components and nature of the corn mummy that dates back to the late period (Fig. 1), using microscopic examination of all layers of the mummy, as well as FTIR and XRD. Will we obtain new information about the components of these distinctive mummies? What is the nature, type, and characteristics of linen textiles used in covering the grain and the mud? What is the nature of the grain, wheat or barley? What is the nature of the black coating? The scientific analysis of the study tries to answer these questions, as possible.

Fig. 1. Shows outline the condition of discovered corn mummy in Saqqara:
(A) Shows the whole set inside the broken box where the mummy, canopic jars, amulets and beads can be seen;
(B) discovered Collection after lifting the top cover of the wooden box;
(C) & (D) Fractures and fissures are shown in the mummy outer layer

The Discovered Corn Mummy

The mummy was discovered in the excavations of the Ibis - south of Abu Sir, north of Saqqara, in April 2018. It is one of a whole collection containing symbolic Canopic jars and a number of amulets and beads. It was inside a wooden box. Studying the royal cartouche on the box proved that the collection dates back to the period of King Ptolemy IV who ruled Egypt from 221 to 204 B.C. The figures 1 and 2 illustrate that the Canopic jars and amulets made of white faience are in a good condition. However, the wooden box had advanced decomposition and damage, where most of the sides were decayed. There were only wooden planks in the upper right sides and the left wooden planks filled with burial sand, which overlapped with the fibers of the wooden box and layers of the mummy. It could be easily observed that the wooden planks were joined together by "tenons", in addition to wooden pegs in some areas (Fig. 1B). It was the same style of the carpenters in Pharaonic period. The lateral part also appeared to be decomposed and fractured as many of the component layers of the mummy were separated as scattered fragments (Fig. 1C). Furthermore, figure 2 shows decomposing planks, where the breakdown of the wood structure with many holes scattered in the wood. The visual examination confirmed that the mummy consists of a number of successive layers, as shown in figure 3. The composited bundle of the mummy is arranged in the following order from inside to outside: Barley grains, papyrus rolls, linen bandages, and black resin. There are no remnants of the Nile silt or sand similar to what is known about corn mummies. Another important point is the presence of a layer of papyrus coils. A papyrus layer existed in a specific type of mummies called the "bed of Osiris" referred to by the travelers and ancient historians to help the resurrection of deceased. In other words, the present mummy is a unique grain mummy. "Osiris-bed" was known in the Eighteenth Dynasty according to texts in Neferhotep tomb in Thebes. However, there has been no real evidence for this type of grain mummy, except for the current one.

Fig. 2. Shows the details of the mummy and the condition of the wooden box:
(A) Indicating that the box is incomplete, where there are a lot of missing sides,
and the wood is covered with dust and sand, the structure of the wood is completely worn
and a deep crack in the mummy is observed showing the inner layers;
(B) Advanced decomposition occurs in wood, where it is transformed into powder and in addition,
the surface of the outer layer of the mummy is uneven, where the black layer appears somewhat wavy;
(C) The sand is attached to the surface where the yellowing of the outer black layer is added

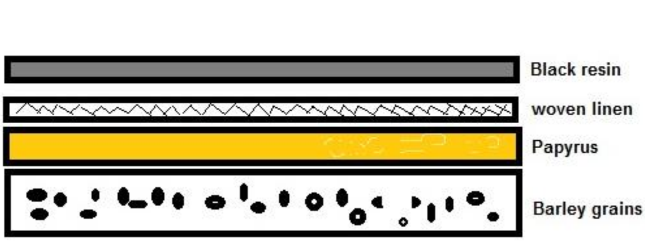

Fig. 3. Shows the anatomical composition of the layers of the corn mummy

Experimental part

Initial examination with a digital microscope

All layers of the mummy were examined using a digital microscope (USB 2.0) with 1000x 8led, California.

Examination of the surface using a scanning electron microscope

The woven linen and papyrus were examined with Philips XL 30; an environmental scanning electron microscope.

Determination of crystallinity index for linen and papyrus

X-ray diffraction was employed to determine the crystallinity degree of papyrus and linen based on the author's previous research [15-18]. The crystallization value was calculated according to the methodology of *Zugenmaier* [19] and *Park et al*. [20]. This analysis was used to determine the effect of burial operations on cellulosic materials, such as the linen wrapping and papyrus.

FTIR of the resin

Infrared spectroscopy with KBr method was used for characterization of resin, with an FTIR spectrometer: Nicolet 380 with range 650-4000cm^{1}. I.R frequencies were recorded with an average of 128 scans and a resolution of approximately 4cm^{1}.

Identification of fungi

Using an enrichment culture technique, the author isolated fungal colonies from the linen, papyrus, and barley. PDA media was chosen for the isolation and growth of fungi according to *Uthayasooriyan et al.* [21].

Results and discussion

Digital microscope

The digital microscopy of the grains proved that it belonged to *Hordeum rulgare L.* These species of barley have been planted in Egypt since the age of the Ancient Kingdom. Despite the hot desert environment of Egypt, the flood of the great Nile River made the land fertile to grow crops, such as wheat and barley. When I followed the damage in the barley grain, I found out that it was very decomposed where the endosperm layer and aleurone cells were destroyed and decomposed completely. The previous cells served as a store for starch grains. The starch could be degraded by fungi and anaerobic bacteria, where polysaccharide polymers (e.g. starch) are the favorite for microorganism. Recent studies reveal that beta-amylase hydrolyzed Glucans (starch granules) to maltose. Furthermore, enzymes, such as Glucosidases hydrolyze and Exo-D-1.4 gluconasses, decomposed the cellulose into smaller chains, then into the cellobiose, and finally to glucose [22].

Figure 4A-C illustrates that the hair of the brush, bracts (chaff), and bran layers (epidermis, hypodermis, cross cells, and tube cells) were in a good condition and did not undergo any form of decay. This might be due to the barley husk composition containing lignin, cellulose, insoluble arabinoxylans, polyphenol, and a quantity of minerals [23]. It was scientifically proven that Polyphenolic compounds could control fungal pathogens, e.g. *Aspergillus fumigatus* and *Aspergillus flavus* [24, 25].

The surface of the papyrus (Fig. 4D-F) was free from any erosion or surface dust, with a light color and knit fibers. However, dark brown spots (Fig. 4D and E) could be noticed on the surface of the strips resulting from the thermal decomposition of the lignin.

Flax fibers topped the scene in the textile industries over the successive pharaonic times about 5000 BCE when the delta was peppered with fertile soil suitable for the growth of flax. The most important characteristics of flax are its strength compared to cotton and drought speed. These characteristics made linen a textile raw material suitable for all the ages that followed Egyptian civilization such as the Greco-Roman period. Figure 5A-E confirms that the weavers during the reign of Ptolemy IV followed the same classical methods of the Ancient Egyptian civilization. The studied fabric was from plain weave where the warp tied to the weft in the pattern (1/1). Furthermore, I could easily define a spliced thread between the yarns (Fig. 5B). Fundamentally, splicing can be detached into two major types: i) fiber strips added constantly, ii) fiber strips tied end to end, by either twisting and turning back or the twisting only [26, 27].

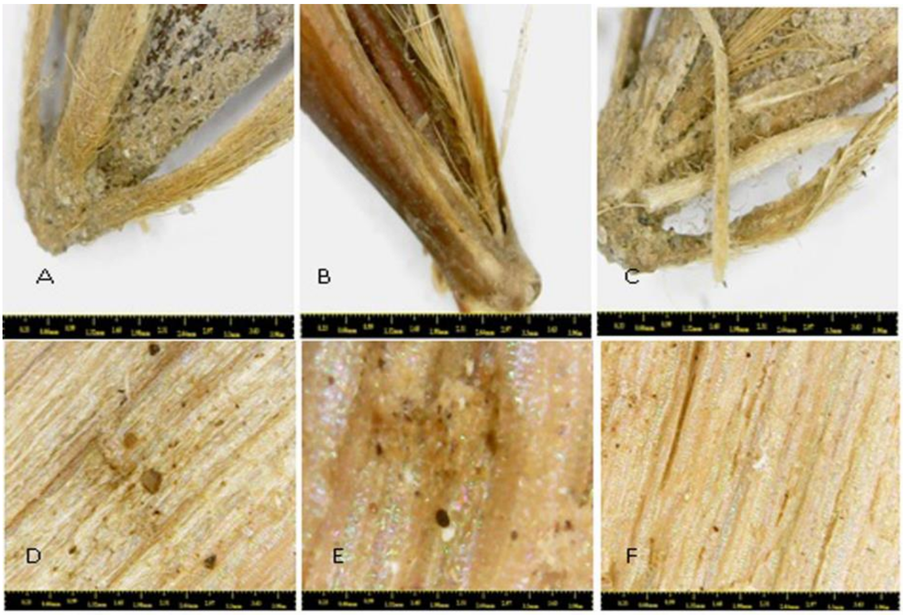

Fig. 4. Showing the grains inside the corn mummy the physical morphology confirmed that the grains belong to the family of *Hordeum rulgareL*. (barley): A, B and C showing the shape of the old barley and the extent of the decomposition of the fiber where the inside starch granules and aleurone cells have decayed completely and only cellulose cover was remained.

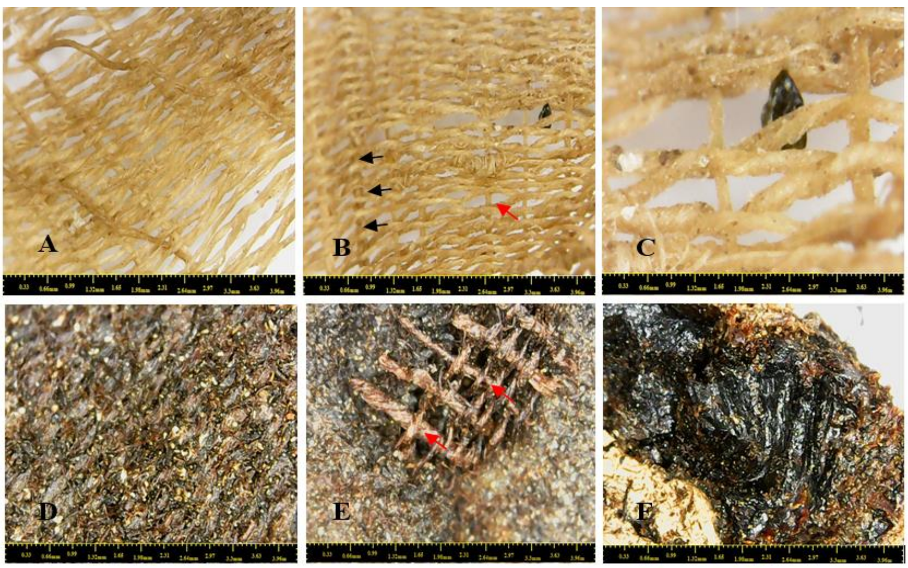

Fig. 5. Shows the surface of the mummy tissue and the resin layer. The black arrows indicted to *Plexus splicing* it is clear that the resin has been mixed with the fabric in the final coating, it appears from (C and E) revealed that the linen fabric from the plain weave where the warp tied to the weft in pattern (1/1) as the arrows indicates; linen fabric mixed with resin is also shown (D-F)

The examination showed that the fabric of the mummy was based on a continuous splicing method. Consequently, it lowered the validity of some previous studies in the field of archaeological textiles, which stated that Egyptian weavers transformed from the continuous link to end-to-end splicing about 3500 BC [28]. Figure 5D and E illustrated that the used fibers were yellowish. Moreover, figure 5 confirmed mixing the linen fabric with resin in the last layer.

Surface of the mummy layers under ESEM

The author utilized SEM for gaining more details on the technical methods and the decay processes of the corn mummy. Figure 6A showed that the S-twist pattern was used in linen spinning. Two or more spun yarns twisted together to form a thicker yarn. Additionally, many mineral particles stuck on linen cuticle walls (Figs. 6b and c), and many of them were interwoven between the folds of linen fibers. I noticed erosion in primary cell walls in some fibers (Figs. 6b and c) and fungal spores covering the walls of the lateral fibers.

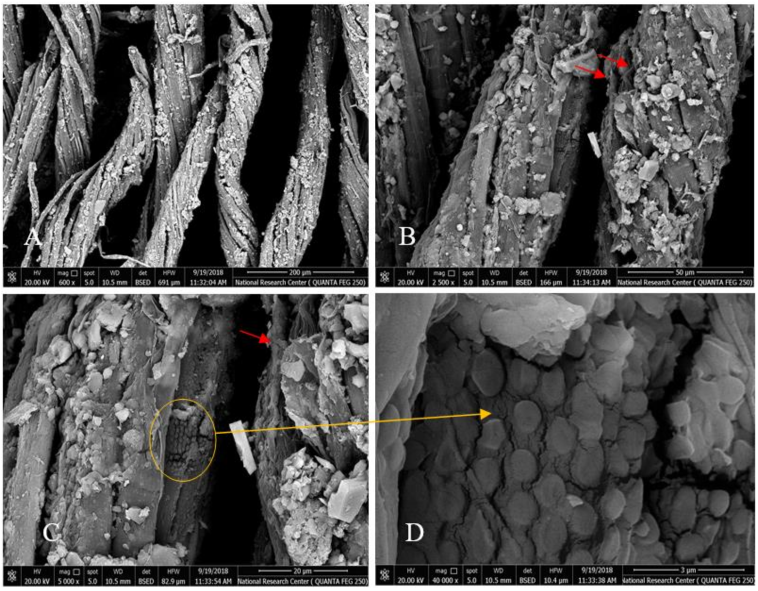

Fig. 6. Showing the layer of linen tissue found on top of the papyrus layer in the mummy, where the twisted linen fibers have appeared. Figure 6B shows the remains of dust and solid adhered particles to the tissue and shows spores on the fibers walls, the red arrows indicted the erosions in primary cell walls also the yellow circle indicted the fungal spores

Although the Egyptians used the papyrus as writing support 5,000 years ago, no single written description has explained its manufacturing process. Therefore, the microscopic examinations of the archeological papyrus samples are important to answer such secrets. For example, were the Ptolemaic papyrus made by the peel or strips method? The manufacturing method is one of the most important questions that could be answered by examining the papyrus used in the mummy, especially because Pliny's (A.D. 22-79) is the classical reference for papyrus manufacture in Egypt. Probably, Pliny never saw papyrus production himself. Microscopy graphs (Fig.7) illustrated that papyrus was made according to the traditional slide method, but it had many differences and characteristics that make this papyrus unique. First, the present papyrus composed of a single layer that the strips were regulated vertically only. Second, the manufacturer used a high thickness of the slides in a way to compensate for the lack of a horizontal layer. Therefore, what is called "a grid pattern" did not appear in this papyrus. Moreover, there is no evidence for the residues of adhesive between the vertical slides where we can note that the parenchyma cells stacked in a honeycomb-like network occupying the length of the stem (Fig. 7A-D). Anatomically, the parenchyma cells were filled with air ducts under the influence of pressure resulting from manufacturing processes, such as compressing and rolling…etc. Ducts collapsed and the hollow spaces were filled forming a dovetail. Thus, the strong bond between the papyrus strips was formed. Fungal spores could be detected on the walls of the fiber, but without the presence of mycelium similar to the linen fibers. It might be interpreted as a recent fungal infection or an old biological injury and did not have the appropriate conditions for growth, especially moisture [29].

The destruction and collapse of the cell’s walls (Figs. 7E and F) might be attributed to stresses and loads during the circumstances of the burial. In addition, the wooden box was found to be rickety that did not provide protection for the layers of the internal mummy that appeared to be crumbled, especially the resin layer as shown in the previous graphs.

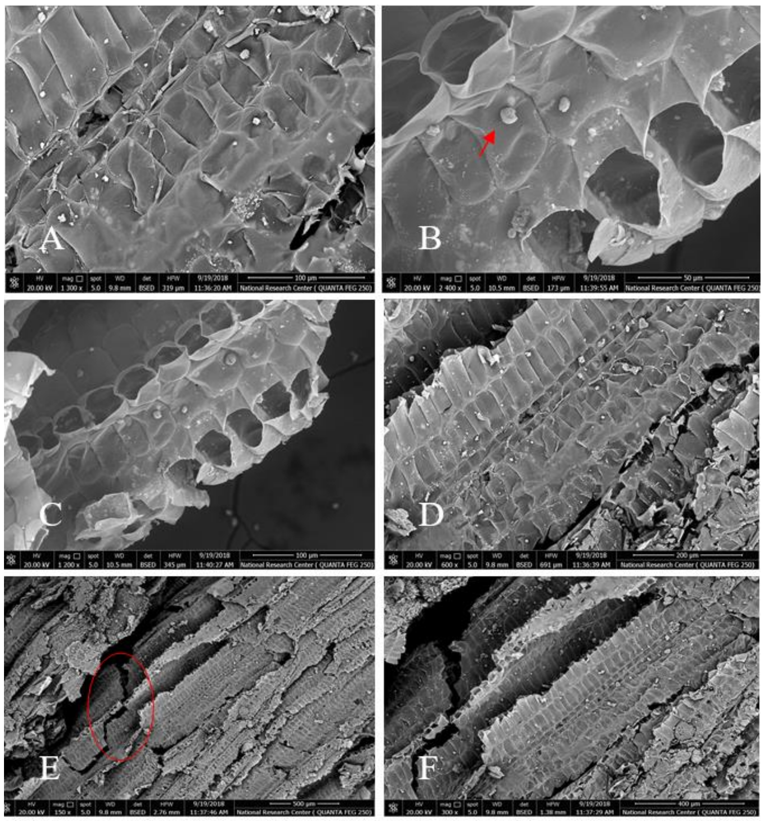

Fig. 7. shows clearly the characteristics of the used papyrus, showing the parenchyma cells which Spores Spread on its walls furthermore (A-D) the physical destruction and collapse of the fibers (E and F)

XRD analysis

Papyrus consists of hemicelluloses (33%), holocellulose (68%), alpha-cellulose (35%), and lignin (≤ 25%) [30]. Some of these components are characterized by a crystalline structure and the others are arranged randomly. Thus, the crystallinity of α cellulose can be calculated by typical three peaks 002, 101 and 101; calculation of the crystallinity index through the Segal equation [31, 32]. In figure 8, the papyrus crystallinity decreased to 42%, while the crystallinity of modern papyri records 57.3% according to some studies [33].

This decline may be due to the exposure of papyrus to temperature variation over thousands of years of burial in the desert sands of Saqqara. Higher heat means more stored energy and agitation where the electrons vibrate chaotically and begin to jump to higher orbits than their ground state. The agitated state makes electrons more prone to grab other molecules or atoms by "exchange electrons". However, it should be noted that the Sand soil surrounding the mummy is known to contain a high percentage of oxygen because it is unfastened. Under these conditions, most oxygen reacts, and bonds with organic molecules cause oxidation. Paths of oxidative effects include de-polymerization and recrystallization, where many areas of crystalline cellulose lose their organization.

The values of crystallinity recorded 45 and 44% for linen and linen mixed with resin, respectively (Fig. 9), while the crystallinity index of modern linen records 70 to 80% according to the literature [34, 35]. This result demonstrates radical changes in the structure of crystalline regions of the linen fabric, especially linen mixed with resin. The deterioration of crystallized cellulose in the linen was much higher than that of the papyrus, despite the similarities in the damage conditions. Therefore, heat and oxidation are not the only factors responsible for linen damage. It may be due to fungal growth that causes enzymatic hydrolysis during this process. The enzymes destroy the cellulose chains, and the crystallinity decrees successively. The degree of crystallization is a controversial phenomenon, especially during enzymatic degradation, where the enzymes begin to break down the non-crystalline areas firstly leaving crystalline regions to be decayed at the end [36]. Thus, the degree of crystallization rises in the initial stages, then decreases in the advanced stages of enzymatic degradation as was the case in the linen wrappings indicating its advanced stage of damage. Moreover, linen mixed with resin was the most affected and might be the result of resin. Egyptology studies report that the Egyptians used resin from pine trees imported from Syria, and then it was mixed with beeswax or bitumen [37]. Various studies report that autoxidation is one of the most degradation pathways of natural resins. It takes five stages, as follows: i) formation of a radical by the chain; ii) radical reacts with air oxygen and products of peroxide; iii) the latter abstracts a hydrogen atom from another molecule forming hydroperoxide beside a new radical; iv) two radicals re-assembled and break the chain; v) the homolytic splitting of peroxide bonds generate two new radicals as branching of the chain allowing autoxidation to proceed especially under high temperatures and exposure to light [38-40]. To conclude, the resin has greatly increased the damage and destroyed the crystal structure severely.

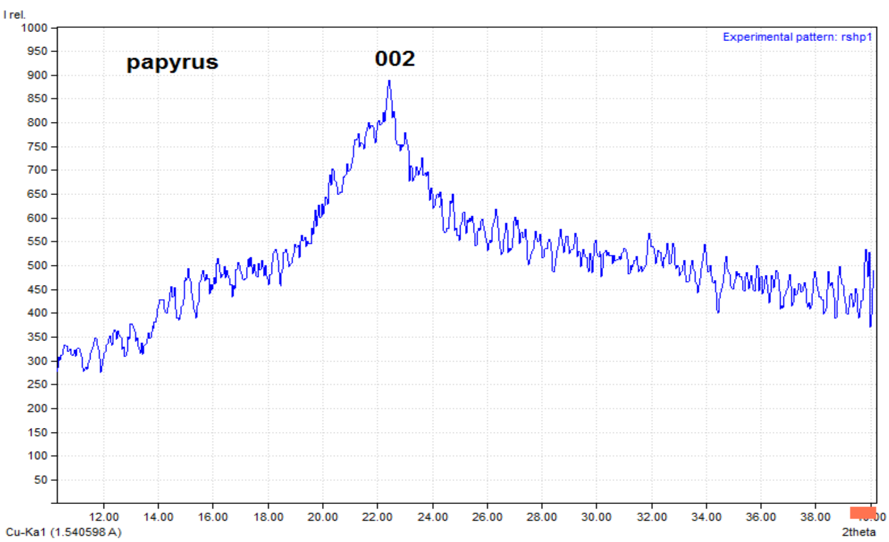

Fig. 8. Shows XRD measurement of papyrus the width at half maximum of (002) peak of archaeological papyrus is pointy low which indicts the decrease of crystallinity index of papyrus

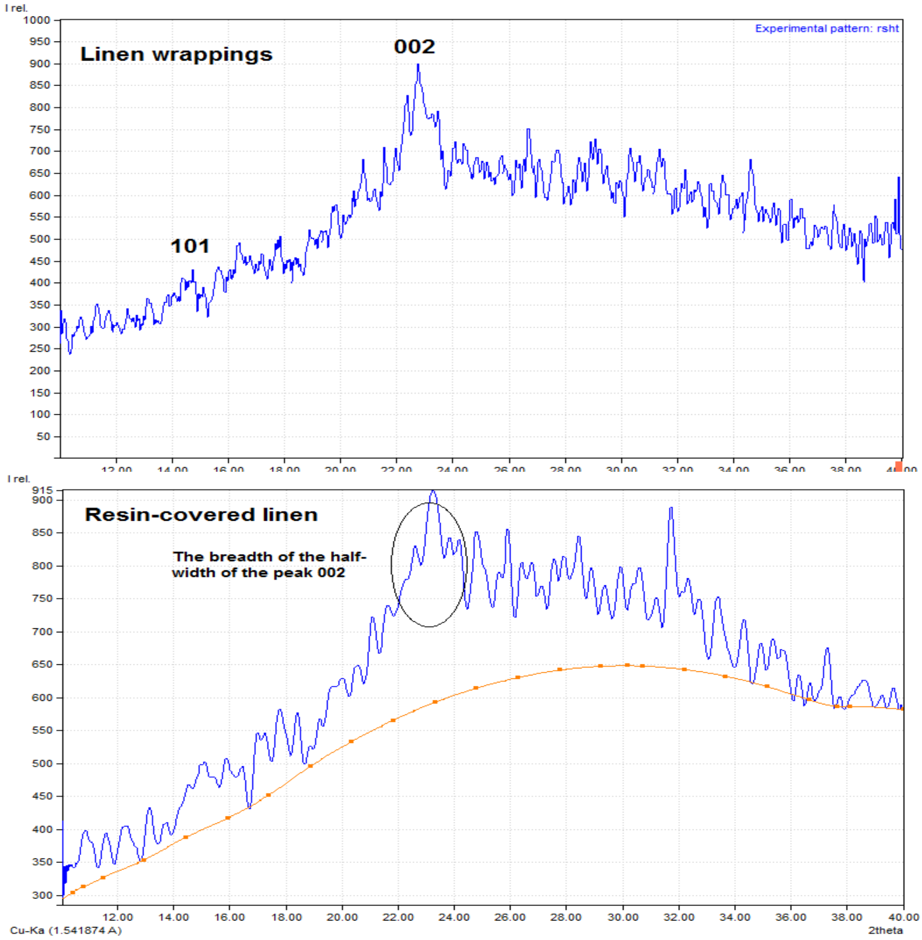

Fig. 9. XRD diagrams of linen wrappings (upper) and the linen in final layer of mummy which covered with resin (lower), Although the same linen is used and exposed to the same conditions, the degree of crystallinity of flax covered with resin is very low when compared to linen wrappings

FTIR

IR spectra (Fig.10) shows weak bending bands of Si-O at 653, 843, and 761cm^{-1}. Furthermore, Si-O stretched at 1087 and 1137cm^{-1} [41, 42]. Most probably, the sand grains in the burial environment were mixed with the resin particles producing those vibrations characteristic of silica, OH stretch bands of carboxylic acids and alcohols at the region 3500-3000cm^{-1} produced by oxidation or may be partial hydrolysis of resin. At the region of 2921-2840cm^{-1}, C-H stretching vibrations were detected [43, 44]. Furthermore, the characteristic bands of alkyl fragments at 730cm^{-1} (C-H wagging) and the strong C=O stretch of (ketones, aldehydes, and esters) in 1712cm^{-1} were observed. The literature reports that the frequency at 1700cm^{-1} was chosen as a criterion for the classification of the different resins, where the lower wave numbers from 1690 to 1710cm^{-1} (due to carboxylic acids) characterized black copal, dammar, mastic, and pitch, while the bands from 1713 to 1727cm^{-1} (due to aliphatic ketones) characterized tragacanth [45-47], white copal, and frankincense, confirming that the resin may be white copal or frankincense. In this context, the copal was rarely used in the Ancient

Egyptian and the Greek-Roman periods. It can be summarized, as follows: In the double wooden naos of Tutankhamun, the copal was detected by chemical analysis. The explorers speculated that the copal was imported from Sudan. In addition, copal was found in a big scarab of the wooden, gilded pectoral of a scribe named "bay". According to the texts in the temples of Kom Ombo and Edfu, copal was used in religious rites [48, 49]. On the other hand, Frankincense resin was commonly used as a filler material in the Twentieth Dynasty. It was also detected as a binder in mummy cartonnage in the Late Period [50]. Although it is difficult to determine the type of studied resin, the results highly suggest the Frankincense resin because of the intensive presence of monosaccharide groups in the results of IR.

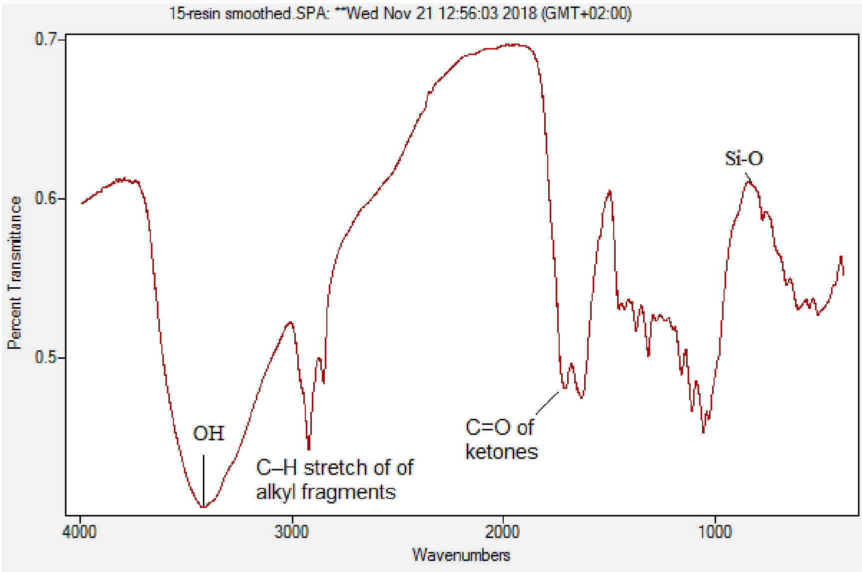

Fig. 10. Shows the characteristic bands of alkyl fragments at 730cm^{-1} (C-H wagging) and the strong C=O stretch in the resin of the mummy

Isolated fungus

Figure 11 shows that the *Aspergillus Flavus- Link* was the most dominant fungus from the linen. It is one of the most found fungi in the Ancient Egyptian textiles. *Abdel-Kareem* [51] reports that *Aspergillus Flavus- Link* clearly spread in flax textiles at the Egyptian and Coptic Museum in Cairo. The presence of this genus reflects the poor ventilation in the burial environment. In most cases, *Aspergillus* produce cellulase that hydrolyzes cellulose via reacting with the β-1-4-glycosidic bonding, especially in the amorphous region. Sugar is then liberated from the cellulose molecules and increases the degree of agitation, breaking the internal cellulose molecules and reaching the so-called hydrolysis 2,4,1-2,4,4 [51]. This finding explains the weakness and degradation of linen fibers as demonstrated by the microscopic examination. While *Alternaria arborescens E.G Simmons* were isolated from the barley sample, *Alternaria arborescens* caused many diseases to crop, especially wheat and barley seeds, suggesting the complete destruction of barley grains. However, it cannot be determined whether the contamination occurred in the pre-harvest or post-harvest stage, while isolates of papyrus did not record any fungal growth.

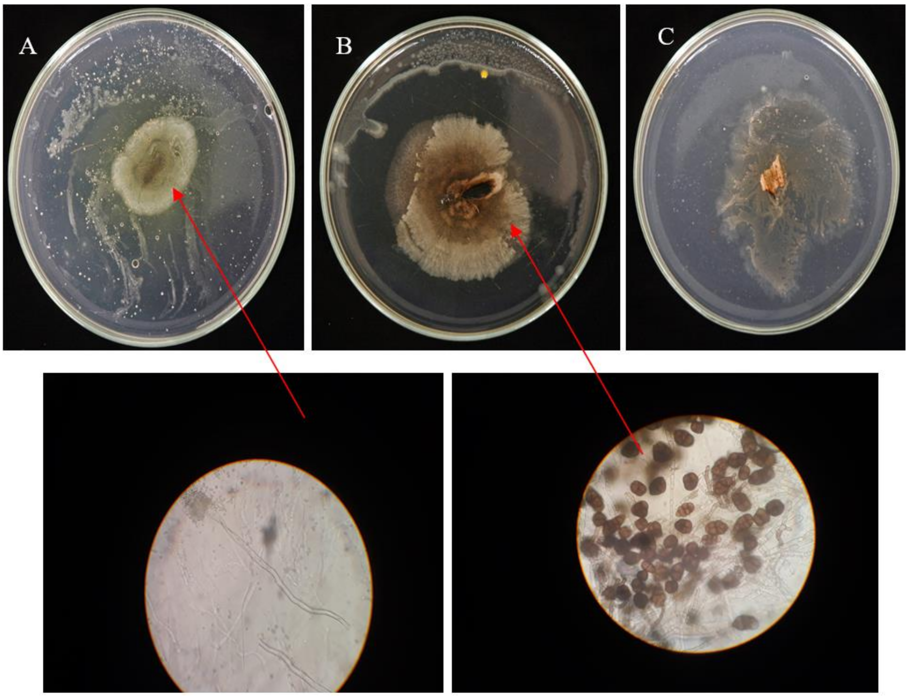

Fig. 11. Shows the isolated fungi from linen and burley:
(A) linen, (B) burley and (C) papyrus, from investigation under light microscope
the *Aspergillus Flavus-Link* was identified in linen while while
Alternaria arborescens E.G Simmons were isolated from the barley sample also,
there is no growth of fungi for papyrus sample

Conclusions

The discovered grain mummy in Abu Sir is not an ordinary symbolic mummy. It is a kind of "Osiris -bed" as mentioned in the old texts from the 18th Dynasty. The papyrus and barley are the basic components of this type of fake mummies. However, the other ordinary grain mummies are free from papyrus. The digital examination illustrated that the starchy substances in barley had been decayed totally, while the chaff remained unaffected due to the polyphenolic compounds in the barley chaff. It also revealed a fantastic historical correction in the textile industry in Ancient Egypt where continuous splicing method in the linen with warp tied to the weft in the pattern (1/1) was used in linen bandages although the historical sources report the end of continuous splicing, replacing it with "end-to-end splicing" around 3500 BC. SEM examination revealed that the papyrus was made with a slide method, but a vertical single layer was used only. The vertical stripes were thick enough to have a flat and cohesive surface for writing. But was a single layer of strips an industrial technique or just a coincidence due to the thickening of papyrus fibers? We can answer this point only if we study many papyrus fragments in that era. Furthermore, the IR result reported that copal or frankincense could be the main component of the black resin.

Acknowledgements

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