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Original article

A COMPREHENSIVE STUDY TO EXAMINE AND CONSERVE A DYED LINEN ARTIFACT

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***Abstract**:*
Due to their organic nature, antique textile artifacts are extremely vulnerable to numerous types of damage. Whether they are made of plants as cotton and linen or of fibers from animal origin such as wool and silk. The holdings of archaeological textiles must undergo various investigations and analyses in order to determine their material components, the process and method of their manufacturing, and the various types of damage to select the proper conservation techniques and materials. This study focuses on repairing and maintaining one of the textile collections, which was in the Textile Museum - now transferred to the National Museum of Egyptian Civilization: NMEC, that exhibit extensive damage. Various conservation techniques and supplies were used to address the damage. This piece of cloth was a linen fabric, according to infrared investigations and analyses. It was also discovered that there were numerous signs of damage, including weakness, fragility, inappropriate previous conservations, and erosion of the linen fibers. After that, various conservation steps were performed, such as mechanical cleaning, removal of previous conservation, and reinforcement.

1. Introduction

The study of archaeological textiles has attracted the attention of many scientists because of their historical significance, the information it gives about the civilization and man development, and the extent of industrial development it has reached. Presenting numerous studies on archaeological textiles and ways to preserve these textiles shows that some authors dealt with the treatment, conservation, and maintenance of textiles in general, and others handled them in some detail [1]. Historical textiles are precious and subjected to many challenges, including temperature, air pollution, humidity, light, and unconventional storage techniques [2, 3]. All of these elements can lead to fiber and dye deterioration and damage, which weaken colors and fibers and cause portion loss [4]. Linen is one of the oldest fibers humans used in manufacturing textiles, as traces of linen fibers were found in textiles thousands of years ago. The first people to know about linen in the world were the inhabitants of the caves of the lakes of Switzerland, where the architectural monuments in the prehistoric era showed inscriptions of linen bundles, as well as the method of spinning and weaving threads, as mentioned by Al-Gaoudi [5]. Linen was used in the Pharaonic era; and linen fibers were prepared from the linen plant by maceration, which is still used today. Linen fibers are characterized by high strength and durability. The chemical com-position of linen is 70-90% cellulose + 6-8% water + a few pectin and waxy substances, and its fibers are tightly bound together by pectin substances [6]. By microscopic examination of the cross-section, cells appear with a round or polygonal section with pointed ends, and linen fibers are in the form of bundles consisting of cylindrical cells stacked in the form of reed cuttings [7]. Examining and analyzing methods of archaeological textiles include scanning electron microscope the infrared spectrophotometer (FT-IR), the, and the optical microscope to make it possible to identify fibers, differentiate between their various types, and determine the existing damage and the extent of their impact and interaction with the textile [8]. In this study, one of the historical linen textiles was examined and conserved using a variety of tests and analyses to discover the manufacturing processes and materials and examine the aspects of damage to choose the best materials for the conservation process.

2. Technical Description and Historical Study of the Textile

The study was conducted on an antique piece of textile dating back to the late period (644-332 BC), which was preserved in the Textile Museum under No. (tm 84), Hall No. (3), before its transfer to the National Museum of Egyptian Civilization: NMEC. It is a rectangular piece of part of a shroud decorated in red and yellow with a length of 64 cm and a width of 50 cm. It was found in Deir al-Madina in Luxor, fig. (1).

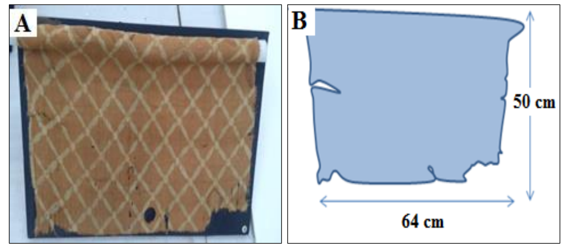

Figure (1) Shows **a.** the artifact, **b.** its dimensions

3. Materials and Methods

Some methods were used to identify the materials for manufacturing the textile piece and the manufacturing technology. The most important manifestations and factors of damage to the textile piece are as follows:

3.1. *Visual appearances*

Visual examination with the naked eye is one of the methods used to identify the decoration method and to determine some of the different manifestations of damage, as well as the histological structure of the piece, the number of warp and weft threads per centimeter, and the direction of twisting of the warp and weft threads [9].

3.2. *Optical microscope examination (OM)*

HD color CMOS optical microscope was used to identify the type of fibers of the artifact, in addition to the possibility of studying the manifestations of damage that are not visible to the naked eye, with a magnification power of 350-1000-x.

3.3. *Scanning electron microscope attaché to Energy dispersive X-Ray (SEM-EDX)*

A JEOL JSM 5400LV EDX Link ISIS-Oxford "High Vacuum" was used for EDX analysis to identify the type of mordant used in the dyeing process. Furthermore, SEM was used to identify the type of textile fibers and the most important aspects of fiber damage with magnifications of 50-x, 400-x, and 500-x.

3.4. *Color stability test*

A color stability test was performed to assess the sensitivity of the dyes to different materials, and to determine the appropriate material for preparing a suitable washbasin. Small pieces of cotton were wrapped around small wooden sticks, moistened with water, and gently rubbed onto the dyed areas of the artifact in inconspicuous locations. This test was conducted on multiple areas to ensure the stability of the colors.

3.5. *Infrared spectroscopy*

Infrared spectroscopy FTIR-ATR type Nicolet 380 FTIR was used to identify the type of dyes in the tissue piece and to study the chemical changes of textile fibers.

4. Results

4.1. *Visual inspection*

The visual examination revealed various manifestations of deterioration, including total damage. Figure (2-a) shows loss in some parts. Additionally, previous conservations of damaged parts and some stains and dirt were observed, fig. (2-b, c & d).

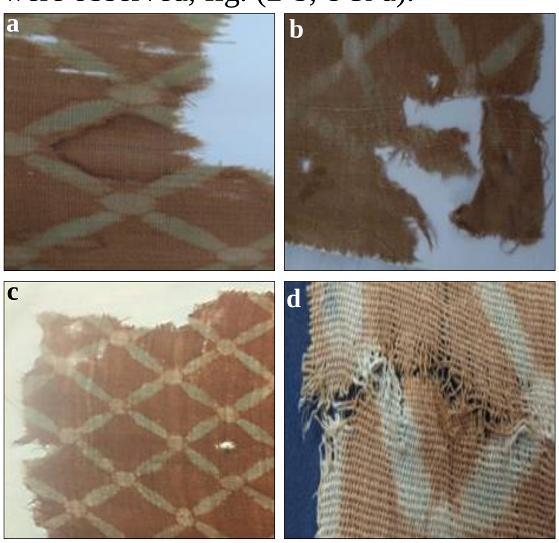

Figure (2) Shows the manifestations of tissue damage, such as **a.** total loss, **b.** & **c.** partial loss, **d.** previous conservations.

4.2. *Optical microscope*

Digital microscope examination revealed that the weaving structure of the artifact was plain 1/1, fig. (3-a). The fibers were identified as linen, fig. (3-b), after comparing with other photos of linen (standard) as shown in fig. (3-c). Additionally, Figure. (3-d) displays the damage in fibers caused by erosion and splitting.

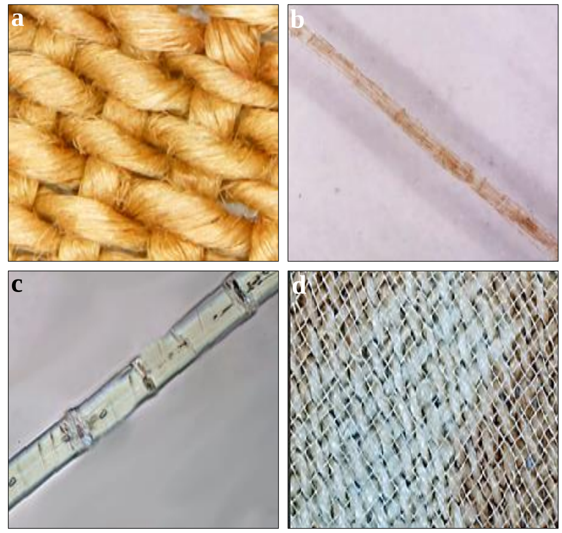

Figure (3) Shows **a.** histological structure of the artifact, **b.** historical linen fibers, **c.** linen fibers from a standard sample, **d.** dyed parts in specified areas; 10-x

4.3. *SEM-EDX*

Scanning electron microscope (SEM) examination revealed that the textile piece was made of linen fibers. Flury-Lemberg [10] addressed the importance of identifying the quality of textile fibers to determine the treatment method and the state of damage to the linen, fig. (4-a & b). EDAX results of dyed sample unit, fig. (4-c) showed the presence of aluminum, (Al), sulfur (S) and potassium (K), which may indicate the use of alu-minum salts or potassium and aluminum sulfate as a mordant in the dyeing process [11].

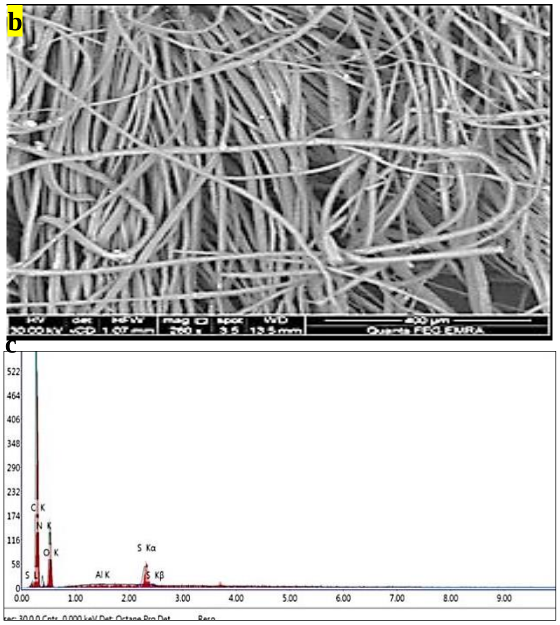

Figure (4) Shows a. & b. SEM photomicrographs results of the archaeological sample, c. EDX analytical results of dyed samples

4.4. *Color stability test*

The stability of the colors was confirmed; therefore, it showed good stability during the conservation process with the washing solution.

4.5. *FT-IR*

FT-IR spectra of linen fiber, fig. (5) indicate that the dyes used in the textile were turmeric and madder. For turmeric, a broad peak around 3400-3200 cm^{-1} was observed, which suggests the presence of O-H stretching vibrations in the hydroxyl (-OH) functional groups of curcumin, the main component of turmeric dye. A peak at around 1600-1500 cm^{-1} was also observed, indicating the presence of C=C stretching vibrations in the aromatic ring of curcumin, and a peak at around 1300-1200 cm^{-1} indicated the presence of C-O stretching vibrations in the ether and ester functional groups of curcumin [12,13]. For madder, a peak around 3600-3200 cm^{-1} was observed, indicating the presence of O-H stretching vibrations in the hydroxyl (-OH) functional groups of alizarin, the main component of madder dye. A peak at around 1640-1620 cm^{-1} was also observed, indicating the presence of C=O stretching vibrations in the carbonyl functional groups of alizarin and related compounds, and a peak at around 1590-1570 cm^{-1} suggested the presence of C=C stretching vibrations in the aromatic ring of alizarin [14,15]. Moreover, there is a characteristic peak in the range of 1500-1900 cm^{-1} related to the carbonyl groups produced from the degradation of cellulose fibers. The absorption increase in this range is due to the oxidation of cellulose [16]. Also, there is a characteristic peak in the range of 3600-3900 cm^{-1} related to the hydroxyl group (OH) found in linen fibers [17, 18].

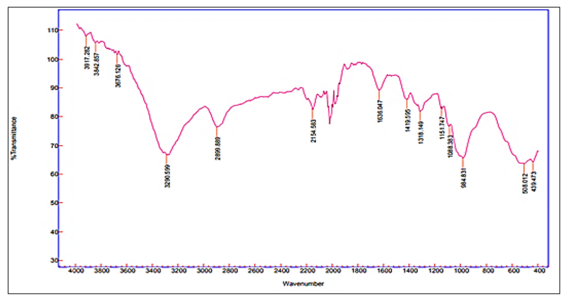

Figure (5) Shows the results of the FT-IR spectrum of a sample taken from the artifact fibers, indicating the cellulose and hemicellulose functional groups.

5. Discussion

Due to the historical importance of antique textiles, they have attracted the attention of many scholars to reveal what our ancestors were like [19]. One of these textiles is linen which is one of the oldest textiles used by humans, because of climatic and weather factors, use in daily life, and ways of display, these textiles are exposed to a lot of damage and dirt [20]. The visual examination of the aforementioned textile showed that the fabric piece was executed in a style similar to the style of batik decoration with the presence of different colors [21]. The textile piece was exposed at some point to inappropriate conditions, which led to the damage to some edges and stresses to the piece. This may be due to inappropriate gallery display of the piece using staples in the installation, which put a strain on these areas and resulted in cuts and tears [22]. It was also noted that there were many stains on the textile piece. Additionally, it was noticed that the dye had run to other parts unintentionally reaching the final end product after dyeing with the type of method required, which was not clear by visual examination. This examination also illustrated how much the fibers were damaged due to erosion and splitting. Also, the infrared spectroscopy analysis demonstrated that the fiber was formed from linen, the type of dye used in the yellow color was turmeric, and the dye used in the red color fiber was madder [23].

6. Conservation Procedures

Based on the above mentioned results, some treatment and maintenance procedures were done as follow:

5.1. *Mechanical cleaning*

Dust on the surface of the piece, insect residues, and dirt between the threads and fabric folds were removed using a vacuum cleaner, an air blower, some brushes, and manual tools [24].

5.2. *Removing the previous conservation*

The previous conservations that led to the damage of the piece were removed, which were parts of the Karpelin cloth attached to the thread by stitching in the places of loss. Additionally, the textile suffered from acidity and stains and its separation and removal from the artifact was necessary.

5.3. *Wet cleaning*

Due to the presence of stains and dirt, mechanical cleaning was ineffective, and the detergent used had to be carefully selected to avoid damage to the textile fibers. To determine the appropriate washing solution, a pH indicator was used to test the solution's acidity. A wash basin was then prepared using a solution of water and sodium bicarbonate in a 1:1 ratio for 15 minutes [22,25], which was used to remove stains and excess acidity and neutralize the pH value. The washing solution was changed five times after making a test for each wash basin and the purity of the water for each of the five stages. During washing, the piece had to be reinforced with gauze and this step was repeated until the washing water reached the desired color. After washing, the piece was rinsed and dried thoroughly, and then reinforced from the back with Karpelin cloth using silk threads in colors that matched the piece. Methyl cellulose was also used to reinforce and repair some areas of the piece. Finally, the piece was appropriately displayed inside a showcase after adjusting the RH levels using silica gel to absorb excess moisture and provide suitable, non-destructive lighting for display [26].

5.4. *Drying process*

The textile piece was dried using cotton towels and blotting paper that had been placed on top of after the wet cleaning process and pressed by hand, placing it on a flat surface, and placing a sheet of polyethylene on the bottom of the artifact with blotting paper to remove the excess water by tamping with pressure gently and leaving it to dry at room temperature.

5.5. *Final support*

The piece was completely reinforced from the back using Karpelin cloth to reinforce the artifact with stitches using silk threads in appropriate colors for the piece, fig. (6-a & b).

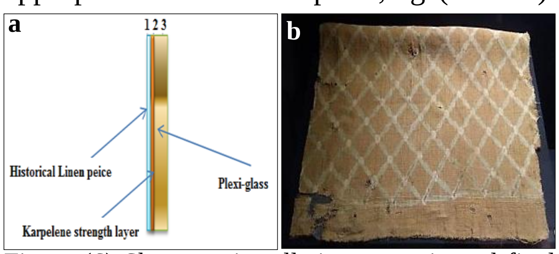

Figure (6) Shows **a.** installation scenario and final presentation of the historical linen piece by drawing a sketch profile, **b.** installation and final presentation of the historical piece of linen.

7. Conclusion

This study aimed to conserve and preserve a rare and historically significant piece of art that had been kept for several years in the Textile Museum prior to its transfer to another museum. Various tests and analyses, including optical microscope, SEM, and FTIR spectroscopy, were carried out to identify the dyes used in the artifact, as well as to study the damage manifestations. Infrared spectroscopy revealed that the red color was madder, and the yellow color was turmeric. The textile piece was found to be severely deteriorated due to weakness, fragility, erosion of the fibers, spread of dirt and dust, and many missing parts and cuts. The conservation procedures included mechanical cleaning, reinforcement, consolidation, and completion of missing areas, which were carried out to preserve the artifact. Finally, the artifact was appropriately displayed inside a showcase. The study contributes to a better understanding of ancient Egyptian dyes and technology, as well as to the preservation of valuable historical artifacts for future generations.

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