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The Effect of Uncontrolled Museum Condition on the Properties of Historical Dyed Linen Fabric with Natural Dyes

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THE Ancient Egyptian Textiles in uncontrolled museum conditions are exposed to many challenges such as oscillate relative humidity (RH), changing temperature. This paper aim to study the effect of thermal aging procedures on dyed linen with natural dyes such as Madder dye, Turmeric dye mordanted with different mordents such as Alum, Iron III chloride FeCl3 and Copper sulfate CuSO4.5H2O. The main goal in thermally accelerated ageing is to increase the rate of degradation by making use of the fact that the reaction rate is increased with increasing. The dyed linen fabrics after and before ageing were investigated for their mechanical, chemical, and optical properties such as surface morphology, color parameters (CIELab). Interesting results were obtained. These results will help in establishing standard conditions of light and temperature at which the archeological textile objects can be maintained to minimize deterioration.

Keywords: Ancient, Linen, Dyes, Ageing, SEM, FTIR, Strength, Color change.

Introduction

From ancient till now the textiles are a great part of our daily life. People were created textiles not only for warm, but also as a means of demonstrating social status and signifying personal individuality. Ageing of historical textiles can be conceder as the irreversible changes that occur slowly over time, and in the case of textiles result in the deterioration of mechanical, chemical, and optical properties [1-4]. Many authors have been studied the effect of light, thermal, humidity, washing on some natural dyes including the cochineal dyes. David studied the effect of light from fadometer lamp and he found that fustic dye the most weaker yellow dye and indigo and cochineal dyes have a moderate fastness to the light while madder and logwood dyes the most stable dyes [5-10]. The main consideration of establishing an accelerated ageing are to increase the rate of degradation to measurable levels and to isolate participating reactions. A careful choice of experimental temperature allows degradation conditions to be controlled [11-14].

Different deterioration factors are effect on the historical textiles such as environmental conditions, handling and natural decay. Museums are practice proper conservation methods in order to preserve the historical textiles. A significant number of years can be added to the life of the objects just by knowing how to handle, display and store the artifacts in the museum's collection [15-17]

Therefore, this article is aim to show the effect of uncontrolled thermal museum condition on the historical textiles. This knowledge will lead to create a good and safety museum conditions in order to preserve the historical textiles.

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Materials and Methods

Materials

- Egyptian Linen fabrics, was supplied by Eglan Co., Egypt.
- Alum ($Al_2(SO_4)_3 \cdot nH_2O$), $FeCl_3$ and $CuSO_4.5H_2O$ were purchased from Fluka.
- Madder dye, Turmeric dye ware obtained from Wild Colours, Birmingham, UK. www.wildcolours.co.uk.
- Pomegranate dye was supplied from local Egyptian market.

Methods

Dyeing Process

Extraction of dye by soaking the dyestuff in the water, heating for 1.5 hour and sieve and separating the solid parts from the dye solution. Place the linen fabric in the dye solution with gently stir at 80 ^oC for 1.5 hours. The mordant added to the water bath then stirring and heated until the mordant completely dissolved in the water. Put the dyed linen fabric from the previous stage and heat up to 60 for 45 minutes. The mordant is used to increase the bonding of the dye with the cloth and to affect the degree of color output [18-20].

Thermal Aging

The samples were aged separately at a temperature of 100 ^OC for 72 hours and 144 hours in a temperature-controlled oven "Herous-Germany" [11].

Examinations and Analysis

Morphological Study

HITACHI-SU-1500 Scanning Electron Microscope (SEM) used to assess fiber fracture patterns and the damaged aspects on these fibers [21, 22].

Color Measurement

The CIE Lab values of aged Linen fabrics measured using a double beam Optimatch spectrophotometer (Datacolor international Spectraflash SF450-UK) [23, 24].

Fourier Transform Infra Red Spectroscopy (FTIR)

BRUKER'S VERTEX 70—Fourier Transform Infra Red Spectroscopy with Attenuation Total Reflection (FTIR-ATR) with resolution of 4 cm^{-1} was used. [25, 26].

Mechanical Measurements

Tensile strength and elongation of samples were measured using Shimadzu Universal Tester of type S-500 Japan, according to ASTM 2000, D 3822-96 [27, 28]

Results and Discussions

Effect of thermally accelerated ageing on fiber morphological

The morphology of the surface of the dyed linen fabric before and after thermally accelerated ageing was investigated using Scanning Electron Microscope (SEM). Thermally accelerated ageing cause damage and deformation morphology of the surface of the dyed linen fabric. The surfaces of the unaged linen fibers were smooth with homogeneous appearances. Some types of fiber fracture patterns and damage were identified in the aged linen fiber with examples shown in Fig. 2. One can see different deterioration aspects of thermally accelerated aged fiber such as shrinking, breaking due to severe drought caused by the effect of heat ageing. This finding is agreement with previous attempts that aimed to study of the effect of heat ageing of historical textiles [7, 29].

Effect of thermally accelerated ageing on fiber mechanical properties

Dyed linen fabric were prepared according to the warp test specimen's standard with the dimensions 25× 5 (length × width). The warp strips were produced by raveling away yarns on each side. Five samples were used for each test [14, 30, 31] Study the mechanical properties changes of the thermally accelerated aged fabric is important step. It is reflect to the changes in crystalline orientation, the chemical structure of the fiber polymer system and the fiber morphology. It is appear for the reader that the thermally accelerated aged fabric showed decreases in tensile strength and elongation properties over unaged dyed linen fabric. This result present a clear image about the thermally tends to accelerate the decomposition of dyed linen fabric. By other words, it is turn leads to loss of the mechanical properties. The decreases in tensile strength and elongation of aged linen fabric can be correlated with the change in chemical groups of fiber as showing in Table.1 and Fig.3 (A and B). The results showed that after thermally accelerated ageing, the dyed linen fabric showed significant reduction in tensile strength and elongation over unaged dyed linen fabric

Fig.1 show Historical textiles date back to different Egyptian period The Ismaili Museum, Egypt as examples of textiles that have exposure to uncontrolled conditions in museums

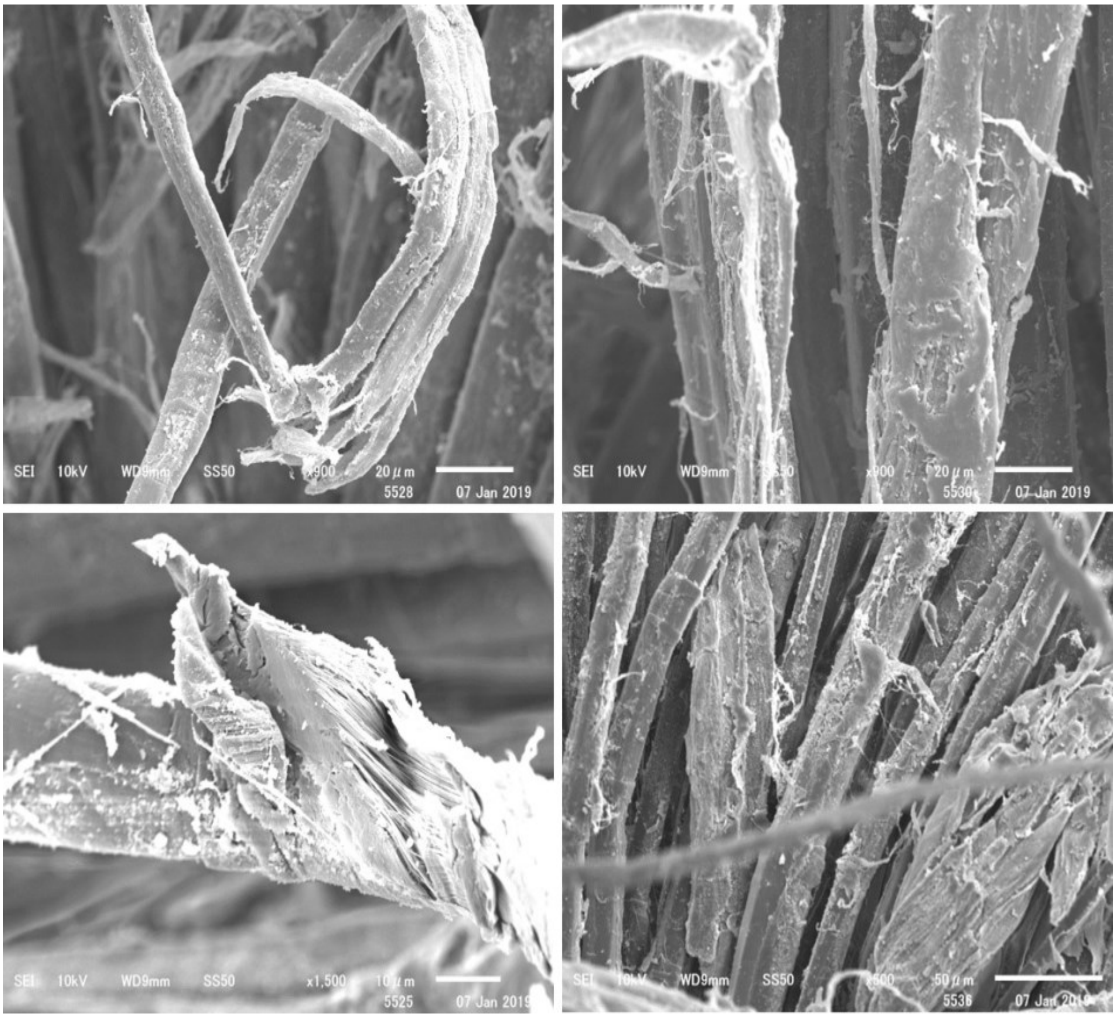

Fig.2. show the effect of thermally accelerated ageing on linen fibers. One can see deformation of the fibers, different deterioration aspects on the fiber.

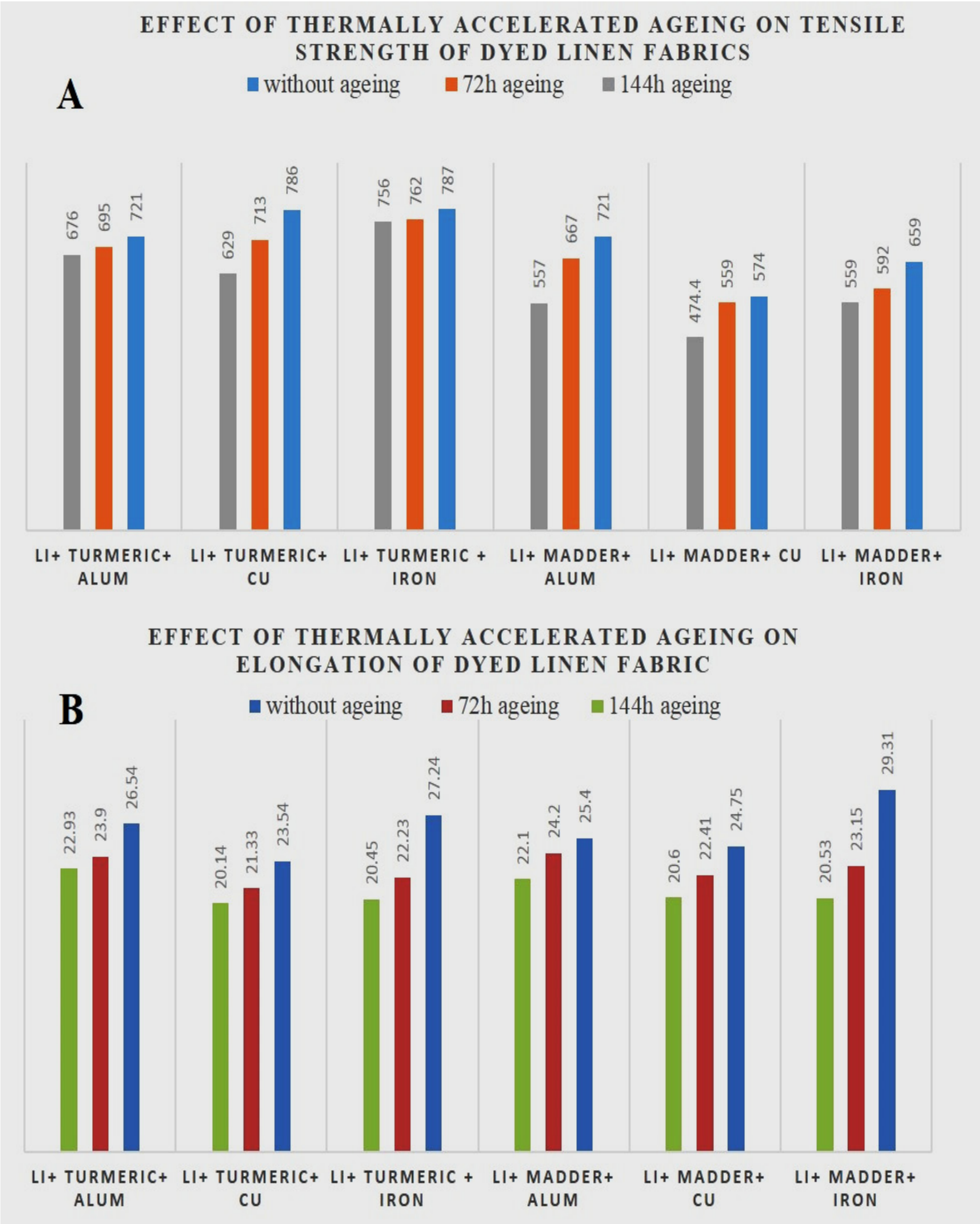

Fig.3. show the effect of thermally accelerated ageing on tensile strength of dyed linen fabric (A). The effect of thermally accelerated ageing on elongation of dyed linen fabric (B).

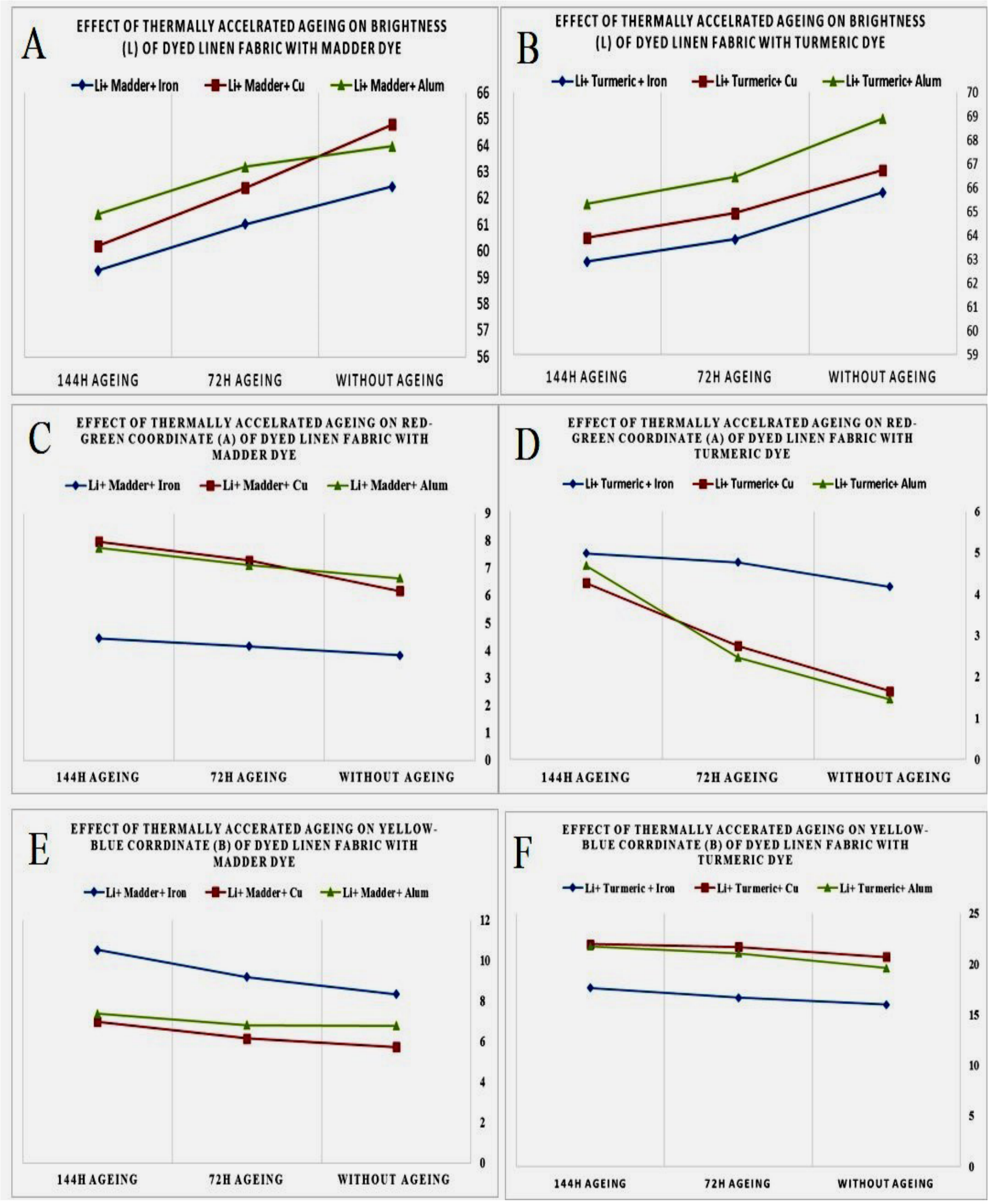

Fig.4. show the effect of thermally accelerated ageing on the L* corresponding to the brightness of dyed linen fabric (A and B). The effect of thermally accelerated ageing on the red–green coordinate of dyed linen fabric (C and D). The effect of thermally accelerated ageing on the yellow–blue coordinate of dyed linen fabric (E and F).

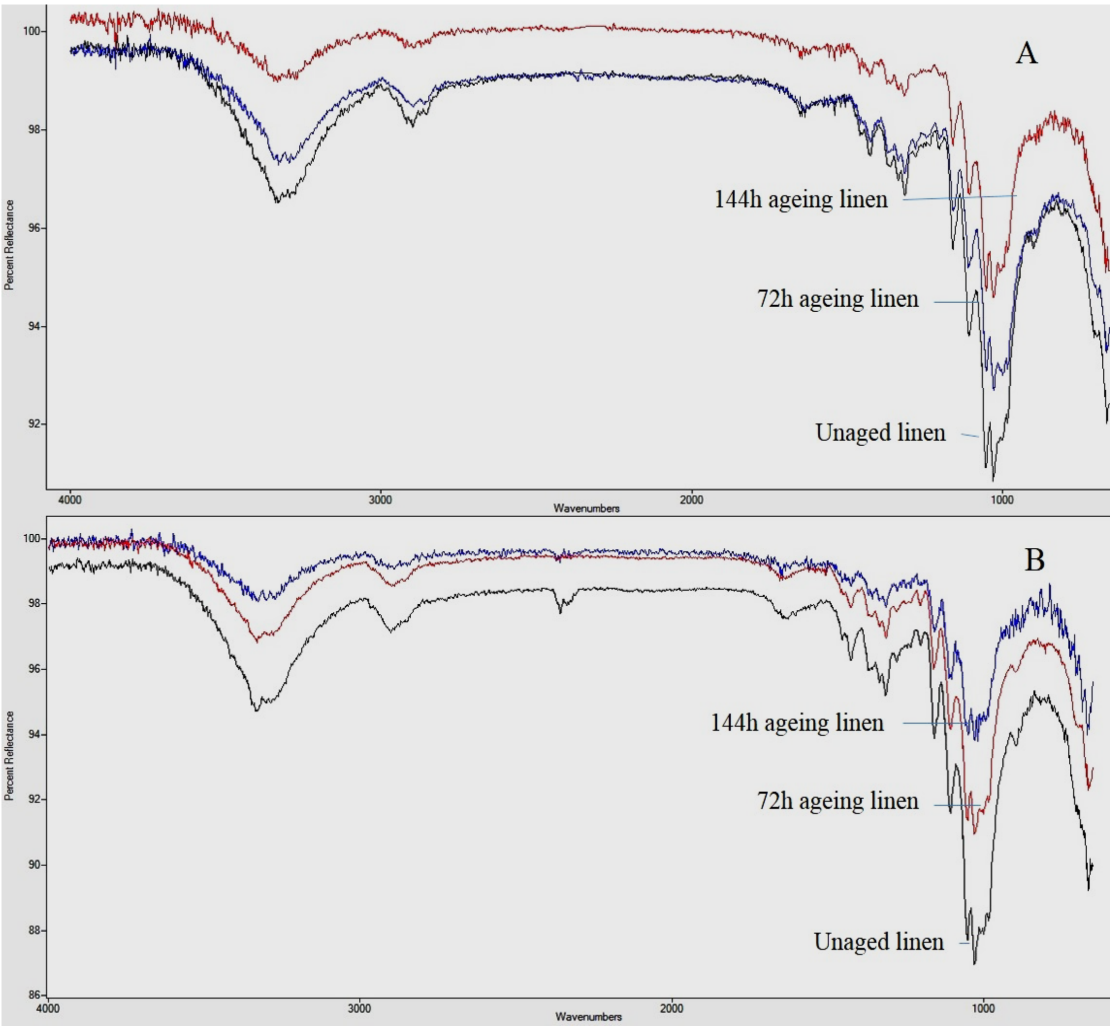

Fig.5. show the effect of thermally accelerated ageing on chemical structure of dyed linen fabric with Madder dye (A). The effect of thermally accelerated ageing on chemical structure of dyed linen fabric with Turmeric dye (B).

Effect of thermally accelerated ageing on color change

The results of the change in optical parameters of dyed linen fabric before and after thermally accelerated ageing are demonstrated on Table 1 and Fig.4. It is appear for the reader that the dyed linen fabric after thermally accelerated ageing become less in brightness as shown in Fig 4(A and B). For example, it noticed that the ΔL of dyed linen fabric dyed with madder dye mordented with Iron is -1.43 after 72h ageing and -3.17CIELab unit after 144h ageing. While the -ΔL of dyed linen fabric dyed with Turmeric dye mordented with Iron is -1.96 after 72h ageing and -2.89 CIELab unit after 144h ageing. The results show a noticeable color change in dyed linen fabric after thermally accelerated ageing as most of the unaged linen fabric became darker than unaged ones. These findings are in agreement with other literatures; found that the thermally accelerated ageing cause darkening of dyed fabrics.

In addition, Table 1 and Fig.4 (C and D) show the effect of thermally accelerated ageing on the red–green coordinate (a) of dyed linen fabric. Generally, it noticed that the sample after ageing become slightly redness. For example, it noticed that the Δa of dyed linen fabric dyed with madder dye mordented with Iron is 0.33 after 72h ageing and 0.62 CIELab unit after 144h ageing. While the Δa of dyed linen fabric dyed with Turmeric dye mordented with Iron is 0.59 after 72h ageing and 0.81 CIELab unit after 144h ageing.

On the other side, Table 1 and Fig.4 (E and F) show the effect of thermally accelerated ageing on ageing on the yellow–blue coordinate (b) of dyed linen fabric. One can see that the samples after ageing become slightly yellowness. For example, it noticed that the Δb of dyed linen fabric dyed with madder dye mordented with Iron is 0.85 after 72h ageing and 2.19 CIELab unit after 144h ageing. While the Δb of dyed linen fabric dyed with Turmeric dye mordented with Iron is 0.67 after 72h ageing and 1.63 CIELab unit after 144h ageing. The results show after of thermally accelerated ageing, the dyed linen fabric became darker (-ΔL), more red (+Δa), and more yellow (+Δb) in character.

Effect of thermally ageing on chemical structure of dyed linen fabric

FTIR-ATR spectra present interesting results of the secondary structure of dyed Linen fabrics before and after thermally accelerated ageing. It is appear for the reader, which this data leads to a general characterization of the material or the identification of specific compounds. Fig 5A, three spectra of dyed linen fabrics dyed with Madder dye before and after thermally accelerated ageing. Fig 5B, three spectra of dyed linen fabrics dyed with Turmeric dye before and after thermally accelerated ageing [32]. Fig 5, three spectra of dyed linen before and after thermally accelerated ageing.

The IR bands at 3370 and 3406 cm−1 refer to presence of hydroxyl groups and is assigned to the stretching ν(OH) vibrations. This data is proof of existence inter and intramolecular hydrogen bonds. Other band at 2900 cm−1 is refer to stretching vibrations of methyl and ethyl groups ν(CH3) and ν(CH2) that conceder as (cellulose compounds). In addition, at 1639 cm−1 is refer to vibrations of ν(C=C) (lignin compounds), δ (OH), and ν(CO) bonds (derived from carbonyl, or aldehydic, or carboxyl groups). In the other side, at 1112 and 1060 cm−1 is proof of existence the C–O bridge stretching and C–O–C pyranose ring skeletal vibration (β-glycoside linkages, cellulose compounds).

It is noticed in FTIR-ATR spectra absorbance slightly decreases with thermally accelerated ageing for 72h of dyed linen fabrics dyed with Madder. While marked decreases with thermally accelerated ageing for 144h of dyed linen fabrics dyed with Madder as shown in Fig.5A. On the other side, It is noticed in FTIR-ATR spectra absorbance marked decreases with thermally accelerated ageing for 72h and 144h of dyed linen fabrics dyed with turmeric dye as shown in Fig.5B. One can see, IR analysis showed significant absorbance decrease in the spectra of dyed linen fabric after thermally ageing at the range from 1620 to 1640 cm-1 related to carbonyl groups, as well as at 3250 cm-1 (peak related to OH groups) in comparison with the spectra of the unaged dyed linen fabric as shown in Fig.5 (A and B). This findings are agreement with El-Gaoudy et at., This findings are agreement with El-Gaoudy et at. (2011), and (2013) [33] [34]. This result lead and reconfirms to the dehydration hypothesis and oxidation of thermally accelerated aged linen fabric. In addition, this hypothesis confirmed by SEM image that show deterioration aspect such as shrinking, breaking as shown in Fig.2.

Conclusion

The results would lead in establishing the standard conditions of display and storage of

TABLE 1. The color parameters and mechanical properties of dyed linen fabric before and after thermal ageing.

Linen Fabrics dyed with natural dyes before ageing						
No	Samples	Color parameters			Mechanical Properties	
		L	a	b	Tensile St	Elongation
1	Li+ Madder+ Iron	62.45	3.83	8.34	659	29.31
2	Li+ Madder+ Cu	64.80	6.18	5.73	574	24.75
3	Li+ Madder+ Alum	63.98	6.64	6.78	721	25.4
4	Li+ Turmeric + Iron	65.8	4.18	16.02	787	27.24
5	Li+ Turmeric+ Cu	66.74	1.65	20.7	786	23.54
6	Li+ Turmeric+ Alum	68.9	1.46	19.61	721	26.54
Linen Fabrics dyed with natural dyes after thermal ageing for 100C at 72 h						
7	Li+ Madder+ Iron	61.02	4.16	9.19	592	23.15
8	Li+ Madder+ Cu	62.4	7.29	6.15	559	22.41
9	Li+ Madder+ Alum	63.2	7.12	6.82	667	24.2
10	Li+ Turmeric + Iron	63.84	4.77	16.69	762	22.23
11	Li+ Turmeric+ Cu	64.93	2.75	21.71	713	21.33
12	Li+ Turmeric+ Alum	66.45	2.47	21.10	695	23.9
Linen Fabrics dyed with natural dyes after thermal ageing for 100C at 144 h						
13	Li+ Madder+ Iron	59.91	4.45	10.53	559	20.53
14	Li+ Madder+ Cu	60.2	7.98	6.98	474.4	20.6
15	Li+ Madder+ Alum	61.4	7.75	7.38	557	22.1
16	Li+ Turmeric + Iron	62.91	4.99	17.65	756	20.45
17	Li+ Turmeric+ Cu	63.91	4.27	21.99	629	20.14
18	Li+ Turmeric+ Alum	65.32	4.69	21.78	676	22.93

archeological textile without deterioration. SEM showed damage to surface appearance of linen fibers such as shrinking, breaking .There was a significant decrease in the strength and elongation of aged linen samples. The results show change in color shade degree of aged dyed linen. IR analysis showed significant absorbance change in the spectra of aged dyed linen fabric at the carbonyl group, which may be due to the dehydration hypothesis and oxidation.

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تأثير الظروف المتحفية غير المتحكم بها على خصائص منسوجات الكتان التاريخية المصبوغة بالصبغات الطبيعية

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تتعرض المنسوجات المصرية التاريخية القديمة في المتاحف غير المتحكم في ظروفها البيئية الى العديد من التحديات وعوامل التلف مثل التذبذب في الرطوبة النسبية وأيضا درجات الحرارة. ويهدف هذا البحث الى دراسة تأثير التأثير الحراري الناتج عن التذبذب في درجات الحرارة في المتاحف على خصائص المنسوجات الكتانية القديمة المصبوغة بالصبغات الطبيعية مثل صبغه الفوه، الكركم والمرسخة باستخدام مرسخ الشبه، الحديد، النحاس. والهدف الأساسي من التقادم الحراري المعجل في المعمل زيادة معدل التلف والتدهور للمنسوجات بزيادة شدة التأثير الحراري. وتم فحص واختبار الخصائص الميكانيكية مثل قوه الشد والاستطالة، الخصائص الكيمائية، المظهر السطحي للألياف، وأيضا التغير اللوني للمنسوجات الكتانية المصبوغة معمليا قبل وبعد عمليات التقادم الحراري. تم الحصول على نتائج غاية في الأهمية سوف تساعد في تشييد نظم عرض متحفي مناسبة وتعديل الظروف المتحفيه الحالية الى ظروف قياسية مثل الحرارة والضوء وذلك لعرض المنسوجات التاريخية دون حدوث تلف لها.