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EFFECT OF FIVE ESSENTIAL OILS AS GREEN DISINFECTANTS ON SELECTED PHOTOGRAPHIC PRINTS: EXPERIMENTAL STUDY

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1. Introduction

Old photographs found in private collections, archives, fine art collections, or museums are rich and valuable resources that visually document information on individuals, social groups, places and events that have shaped our history [1]. Photographic heritage is now recognized as having a key role in the documentation and conservation of cultural heritage [2]. Preservation of these precious records significantly contributes to giving us a sense of identity, responsibility and continuity [3]. Nevertheless, photographic materials do present special challenges to conservators due to their complex nature which varies from one photographic process to another [4, 5].

Photographic images exist in many forms around the world, ranging from rare prints and glass negatives to photo albums, 35mm slides and color prints [6]. Albumen, silver gelatin and chromogenic prints are by far the most common positive printing photographic processes existent among photographic collections in Egypt. The albumen process invented by French photographer Louis-Désiré Blanquart-Evrard in 1850 was the dominant positive monochromatic printing photographic process of the 19th century [7]. Blanquart-Evrard published a total of 24 albums which were thoroughly investigated by Isabelle Jammes in Blanquart-Evrard et Les Origines de L'édition Photographique Française: Catalogue Raisonné des Albums Photographiques Edités [8]. Albumen prints were commonly used as book illustrations from 1855 to 1858, resulting in numerous albums providing biographical, historical, scientific and topographical images that featured sharp definition, a glossy surface and strong contrast as mentioned by Naomi Rosenblum in A World History of Photography [9]. Albumen prints are composed of two layers: the primary support (i.e. a thin smooth sheet of rag paper) and the albumen binder layer (i.e. egg white) carrying the final image material (i.e. toned photolytic silver particles) [10]. In the 20th century, the silver gelatin process was the main positive monochromatic printing photographic process. Basically, a silver gelatin print is composed of three layers: the primary support (i.e. paper), the baryta layer (i.e. fine particles of barium sulfate in a gelatin layer) and the gelatin binder layer, which carries the final image material (i.e. filamentary silver particles) [11-13]. As for chromogenic prints, they were the classic form of color photography in the latter half of the 20th century. Chromogenic

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prints are composed of yellow, magenta and cyan organic dyes distributed in three superimposed layers of gelatin (i.e. the binder). These three binder layers are supported on a paper support coated with baryta [14, 15]. Silver gelatin prints and chromogenic prints were also supported on resin-coated paper supports. The paper base of this type of support is coated on both sides with a thin layer of polyethylene. A white pigment, usually titanium dioxide, is added to the polyethylene layer on the binder side of the print [16]. In general, all three types of photographs are considered composite objects; however, chromogenic prints are much more complex in structure than monochromatic prints [17]. With regard to historical and technical background on the previous photographic processes, detailed studies are provided by Robert Hirsch in Seizing the Light: A Social & Aesthetic History of Photography [18].

Photographs preserved in libraries, archives and museums are subject to deterioration caused by physical, chemical and biological agents [19, 20]. For photographic collections, fungal development is a recurring problem and is therefore considered a major cause of deterioration [21]. Depending on their geographical location and weather conditions, archives and libraries contain more fungi compared to other enclosed spaces [22]. These microorganisms play a substantial role in the deterioration of most photographs due to their enormous enzymatic activity and their ability to grow at low values of water activity [23]. Photographic binders with their high protein content, and paper supports with their high cellulose content, provide the culture medium required for fungal growth [24]. The high water content and hygroscopic nature of photograph components make them more susceptible to damage by fungi [14, 25, 26]. For many types of fungal growth, the optimum environment is over 22°C and over 70% relative humidity with poor air circulation [27]. When an appropriate combination of nutrients and environmental conditions are present, spores absorb water and grow rapidly, branching out repeatedly to form a colony [14]. The most representative fungal species found in photographic collections belong to the Aspergillus, Penicilluim, Mucor, Cladosporium, Trichoderma, and Phoma Species [28]. A. ustus, A. nidulans, A. versicolor, seven Penicillium chrysogenum strains, A. alternata, C. cladosporioides, Mucor racemosus, Phoma glomerata, and Trichoderma longibrachiatum were isolated from selected samples of cinematographic films collected from archives around Spain [29]. Fusarium, Humicola, Paecilomyces, Trichoderma and Ulocladium species were isolated from art photographs that were temporarily stored at the Cultural Center of Belgrade [30]. Microbiological studies conducted in two repositories of the National Archive of the Republic of Cuba on silver gelatin prints, albumen prints, collodion prints and dry glass plates, identified Aspergillus and Penicillium as the predominant genera. Other genera, including Emiricella, Eurotium, Cladosporium, Talaromyces, Candida and Rhodotorula were also detected [22].

Damage caused by fungi can be extremely devastating since they are capable of mechanically, chemically and aesthetically damaging photographs [31]. Fungal hyphae can burrow extensively, forming a network of tunnels below the binder surface [32]. Fungi can also produce chromatic alterations such as stains of various colors due to mycelium growth and the release of colored metabolites [33]. They feed on the organic components of photographs by extracting carbon and nitrogen through an enzyme hydrolysis reaction that weakens and lowers their mechanical strength [20]. They can produce hydrolytic enzymes such as cellulase, xylanase, pectinase, etc. [34, 35]. The photographic binder is more hygroscopic than paper and its proteinous nature makes it highly receptive to fungi [36]. Binder degradation by fungal growth is a serious problem since it causes the loss of the image [37].

Different disinfection methods can be used to prevent and/or stop the biodeterioration caused by fungi in paper-based objects. These methods include controlling the surrounding environmental conditions, using biocides, application of heat or radiation, and plasma [38, 39]. Installing an efficient climate control system can either be too costly or too complicated [40, 41]. Fungicides have been widely used to disinfect contaminated paper such as thymol [42], ethyl alcohol [24, 43, 44], ethylene oxides [45-47], formaldehyde [48] and many others. However, the use of chemical disinfection methods is becoming increasingly restricted mainly due to their damaging effect on the environment and human health [49, 50]. Moreover, they are known to cause damage to paper collections; for example, thymol causes changes in the physical-chemical characteristics of paper, as well as the yellowing of prints sealed in frames [38]; radiation causes the deterioration of paper [39]. These factors have forced researchers to search for other safe and natural alternatives.

The use of essential oils in the conservation field has received great attention in recent years due to their antibacterial and antifungal properties [51]. Essential oils are a mixture of volatile aromatic concentrated hydrophobic oily liquids which are extracted from various plant parts [52, 53]. Many publications have discussed the successful use of essential oils (i.e. Artemisia, boldo, eucalyptus, Ravensara aromatica, lavender, tea tree, Thuja, clove, wormseed, anise, cumin, garlic, laurel, sweet orange, oregano, thyme, cinnamon, and others) in controlling the biodeterioration of documentary heritage, focusing mainly on paper [39, 40, 51, 54, 55]. One study evaluated the effect of linalool, a compound found in essential oils, on silver gelatin prints and it was found to be damaging [41]. On this basis, the aim of this research was to assess the effect of five selected essential oils in vapor phase on the optical and chemical properties of common photographic materials found in Egypt in search of a disinfection method that is user-friendly, environment-friendly and safe to use with the selected photographic materials.

2. Materials and methods

2.1. Test materials

For this experiment, 10 naturally aged silver gelatin (DOP) and chromogenic prints, five of each type, were selected as samples in order to give a more practical, rather than theoretical focus to this study. Five albumen prints were also used as test samples; however due to lack of antique prints, the sample set used in this study was prepared in the Photography Laboratory at the Faculty of Archaeology, Cairo University following the steps of the original process [56, 57]. The albumen prints were artificially aged at 80°C and 65% RH for 5 days, which is equivalent to the aging of paper under natural conditions for 25 years. The aging procedure was in accordance with ISO 5630-3:1996 standard [58, 59]. This process was performed in a BINDER drying oven with digital indicator, model no. 92403000002000 at the National Institute of Standards (NIS) in Cairo, Egypt (Figure 1).

Mylar templates were made to mark the precise area on each photographic print to investigate and measure, using a digital microscope, spectrophotometer and FTIR spectrometer, before exposure to essential oil vapors and after exposure and artificial aging (i.e. accelerated aging). Investigations and measurements were done on two areas of each sample; one Dmin which was given the number 1 and another Dmax which was given the number 2 (Figure 2).

Figure 1. Test samples. (A) Artificially aged albumen prints; (B) naturally aged developed-out silver gelatin prints; and (C) naturally aged chromogenic prints.

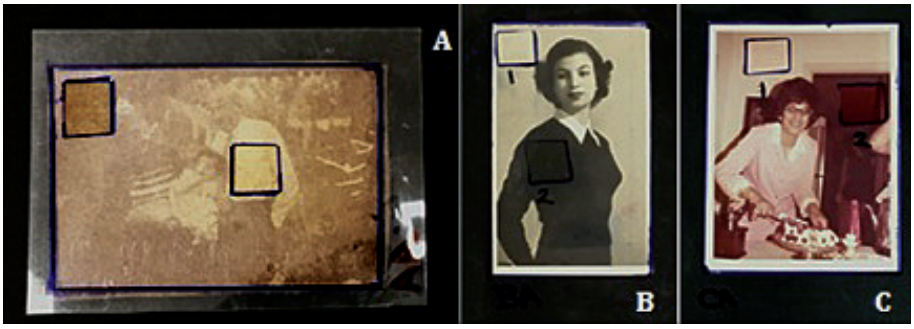

Figure 2. Mylar templates for anise oil sample set. (A) Artificially aged albumen print; (B) naturally aged developed-out silver gelatin print; and (C) naturally aged chromogenic print.

Photographic samples were numbered on the reverse using a graphite pencil according to the photographic process used (i.e. A for albumen prints, B for silver gelatin prints and C for chromogenic prints) and the type of essential oil to be tested (i.e. A for anise, CL for clove, L for lavender, C for cinnamon and T for thyme) as shown in Table 1.

Table 1. Labelling of print samples according to the tested essential oil

	Albumen prints	Silver gelatin prints	Chromogenic prints
Anise oil sample set	AA	BA	CA
Cinnamon oil sample set	AC	BC	CC
Clove oil sample set	ACL	BCL	CCL
Lavender oil sample set	AL	BL	CL
Thyme oil sample set	AT	BT	CT

2.2. Essential oils

The following five essential oils were selected owing to their antibacterial and antifungal properties as mentioned earlier: lavender, clove, anise, cinnamon and thyme, all

of which were extracted using the cold press method. The essential oils were provided by the National Research Center (NRC) in Cairo, Egypt.

2.3. Application method

Samples were exposed to selected essential oils in vapor phase to avoid direct contact of the oils with the photographic surfaces which would undoubtedly lead to severe staining. Five glass test-chambers (i.e. desiccators) were used, one for each selected essential oil. 25 ml of each oil was poured into a glass beaker and placed in a desiccator. A petri dish with saturated magnesium sulfate solution was placed in each desiccator to maintain humidity at 80%. Each desiccator contained an albumen print, a silver gelatin print and a chromogenic print. Samples were exposed to the vapors of the oils for a period of 5 days (Figure 3).

2.4. Artificial aging

The samples went through accelerated aging post exposure to evaluate the long-term effects of tested oils on the optical and chemical properties of photographic samples and determine if the tested treatments could cause damage in the future. The treated samples were artificially aged at a temperature of 80°C and 65% RH for 5 days at the National Institute of Standards (NIS) in Cairo, Egypt. Artificial aging was performed three days after samples were removed from the desiccators.

Figure 3. Exposure of the samples to the essential oil vapors using a desiccator.

2.5. Assessment methods

Examination and measurements were made before oil exposure and after exposure and artificial aging. Surface, optical (i.e. CIELAB color coordinates) and chemical properties of the tested samples (i.e. changes in chemical structure) were determined as follows.

2.5.1. Digital microscope

A SUPEREYES PZ01 500X USB Digital Microscope was used to document the resultant forms of damage caused by exposure of the photographic samples to each of the five selected essential oils and artificial aging.

2.5.2. Colorimetric measurements

The change in color was measured using a MiniScan Model No. EZ MSEZ0693. All samples were measured in a visible region, with an interval of 10 nm using a D65 light source and a viewing angle of 10 degrees. The CIELAB color parameters (L*, a*, b*) were used, where L* defines lightness and varies from 0 (black) to 100 (white); a* represents the red/green axis, where +a means red and – a means green; b* represents the yellow/blue axis, where +b means yellow and – a means blue. All values of L*, a*, and b* were obtained before exposure to oil vapors, and after exposure and artificial aging. Each reading was the average of three measurements. The total color difference ΔE* was also calculated from the following formula: $\Delta E^* = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{½}$ [60-62]. The analysis was carried out at the Faculty of Archaeology, Cairo University.

2.5.3. Attenuated total reflectance Fourier transform infrared (ATR-FTIR)

Spectra were obtained using a Nicolet 380 Ft-IR Spectrometer, in the frequency range of 4000 – 400 cm-1. The ATR accessory was a Thermo Scientific ™ Performer Plate ZnSe Crystal with an angle of incidence of 45°. The diamond has an active area of 1 mm in diameter and the depth of each scan was approximately 2 microns below the surface. No sample preparation was necessary before scanning. The analysis was carried out at the National Institute of Standards (NIS) in Cairo, Egypt.

3. Results and discussion

3.1. Digital microscopy

Visually speaking, in terms of surface characteristics (i.e. image color and sheen), from no change to a very slight change was observed in all tested samples post exposure and artificial aging (Figure 4). However, after exposure to clove oil, sample BCL1 showed drops of oil on the surface. Albumen prints showed the most change in color, which is logically due to the artificial aging and not the oil vapor exposure, since albumen prints are known to be very sensitive to the surrounding environmental conditions and over time tend to fade and yellow [10]. Sample CL2 showed dust particles on the surface after exposure to lavender oil vapors and artificial aging.

3.2. Colorimetric measurements

The total color difference (ΔE*) is a value that is useful as an indicator of the difference between the sample and the reference. In literature, a chromatic variation of 2-3 can be considered noticeable by the human eye; however, it is clearly lower than the threshold limit required (ΔE* = 5) for the maintenance and restoration of historical surfaces [63].

The obtained results show from an insignificant to minimal change for all three color coordinates (i.e. L*, a* and b*) in the silver gelatin and chromogenic print sample sets. On the other hand, measured L*, a*, and b* values for albumen prints showed extreme changes for both Dmin and Dmax areas due to the artificial aging of the samples rather than oil exposure. Results are presented in Table 2. All samples showed total color change below 5 (ΔE*≤ 5) excluding BA2, BC1 and CC2, which showed ΔE* values of 5.97, 5.90 and 6.36, respectively (Figure 5).

Figure 4. Microscopic inspection of photographic samples before exposure to vapors of: A) anise, B) cinnamon, C) clove, D) lavender and E) thyme oils and after exposure and artificial aging.

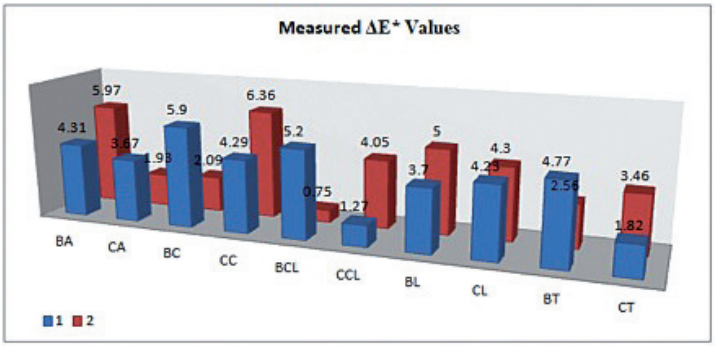

Figure 5. Measured ΔE values for photographic samples after exposure to vapors of oils and artificial aging.*

*Table 2. Measured L*a*b* values for photographic samples before and after exposure to vapors of oils and artificial aging*

Samples		L*	a*	b*
Anise-treated samples				
AA1	Before anise oil exposure	64.21	4.89	22.22
	After anise oil exposure and artificial aging	57.42	4.20	16.28
AA2	Before anise oil exposure	51.46	6.46	14.97
	After anise oil exposure and artificial aging	45.70	4.49	11.20
BA1	Before anise oil exposure	74.63	1.39	14.31
	After anise oil exposure and artificial aging	71.26	1.25	11.57
BA2	Before anise oil exposure	34.83	0.51	5.25
	After anise oil exposure and artificial aging	29.19	0.27	3.29
CA1	Before anise oil exposure	75.17	13.51	14.43
	After anise oil exposure and artificial aging	73.38	13.64	11.22
CA2	Before anise oil exposure	30.43	33.19	6.93
	After anise oil exposure and artificial aging	31.67	33.28	5.45
Cinnamon-treated samples				
AC1	Before cinnamon oil exposure	58.73	4.85	20.84
	After cinnamon oil exposure and artificial aging	43.95	3.25	12.02
AC2	Before cinnamon oil exposure	51.57	5.02	16.57
	After cinnamon oil exposure and artificial aging	35.30	3.20	9.20
BC1	Before cinnamon oil exposure	97.99	0.96	6.44
	After cinnamon oil exposure and artificial aging	92.30	2.08	5.37
BC2	Before cinnamon oil exposure	31.91	0.47	2.14
	After cinnamon oil exposure and artificial aging	29.92	0.49	1.48
CC1	Before cinnamon oil exposure	81.30	4.08	13.37
	After cinnamon oil exposure and artificial aging	84.98	5.58	11.76
CC2	Before cinnamon oil exposure	40.30	29.66	17.53
	After cinnamon oil exposure and artificial aging	38.98	29.72	11.30
Clove-treated samples				
ACL1	Before clove oil exposure	60.46	5.53	23.33
	After clove oil exposure and artificial aging	49.88	4.60	14.87
ACL2	Before clove oil exposure	46.70	6.46	16.87
	After clove oil exposure and artificial aging	38.36	4.61	11.25

BCL1	Before clove oil exposure	78.69	2.62	18.46
	After clove oil exposure and artificial aging	78.12	1.45	13.42
BCL2	Before clove oil exposure	27.25	1.00	5.41
	After clove oil exposure and artificial aging	26.80	0.68	4.90
CCL1	Before clove oil exposure	78.34	6.08	9.71
	After clove oil exposure and artificial aging	78.90	6.41	8.62
CCL2	Before clove oil exposure	26.64	32.75	5.02
	After clove oil exposure and artificial aging	26.12	29.11	3.33
Lavender-treated samples				
AL1	Before lavender oil exposure	62.64	6.94	27.34
	After lavender oil exposure and artificial aging	47.50	3.96	13.96
AL2	Before lavender oil exposure	51.53	6.53	19.59
	After lavender oil exposure and artificial aging	44.51	4.14	11.54
BL1	Before lavender oil exposure	97.10	- 0.46	7.92
	After lavender oil exposure and artificial aging	93.68	- 0.37	6.52
BL2	Before lavender oil exposure	58.37	0.66	8.98
	After lavender oil exposure and artificial aging	54.53	0.17	5.81
CL1	Before lavender oil exposure	79.01	11.42	21.42
	After lavender oil exposure and artificial aging	78.58	11.14	17.22
CL2	Before lavender oil exposure	38.14	26.82	24.96
	After lavender oil exposure and artificial aging	36.14	28.74	21.67
Thyme-treated samples				
AT1	Before thyme oil exposure	54.68	5.92	21.44
	After thyme oil exposure and artificial aging	49.42	5.70	17.01
AT2	Before thyme oil exposure	51.77	7.32	19.35
	After thyme oil exposure and artificial aging	41.89	5.07	12.78
BT1	Before thyme oil exposure	89.84	0.85	11.39
	After thyme oil exposure and artificial aging	85.41	0.76	9.60
BT2	Before thyme oil exposure	30.99	0.66	6.78
	After thyme oil exposure and artificial aging	31.20	0.56	4.23
CT1	Before thyme oil exposure	94.87	1.31	13.26
	After thyme oil exposure and artificial aging	94.29	1.93	11.65
CT2	Before thyme oil exposure	32.64	31.79	7.04
	After thyme oil exposure and artificial aging	31.47	29.63	4.60

3.3. Attenuated total reflectance Fourier transform infrared (ATR-FTIR)

FT-IR spectra for the tested samples show the absorption bands characteristic of protein. Amide I and amide II are the most prominent vibrational bands of protein [64]. The amide I band within the 1600-1700 cm-1 region primarily originates from the C=O stretching vibrations of the peptide linkage (70 – 85%) [65, 66]. The amide II band within the 1500 – 1600 cm-1 region corresponds to a combination of several types of vibrations, in-plane N-H bending (40 – 60 %), C-N stretching vibrations (18 – 40%) and C-C stretching vibrations (about 10%) [66, 67]. The absorption band at around 3600 – 3100 cm-1 corresponds to OH stretching vibrations and the 1160 – 898 cm-1 region corresponds to C-O stretching of COH/C-O-C [68] (Figure 6).

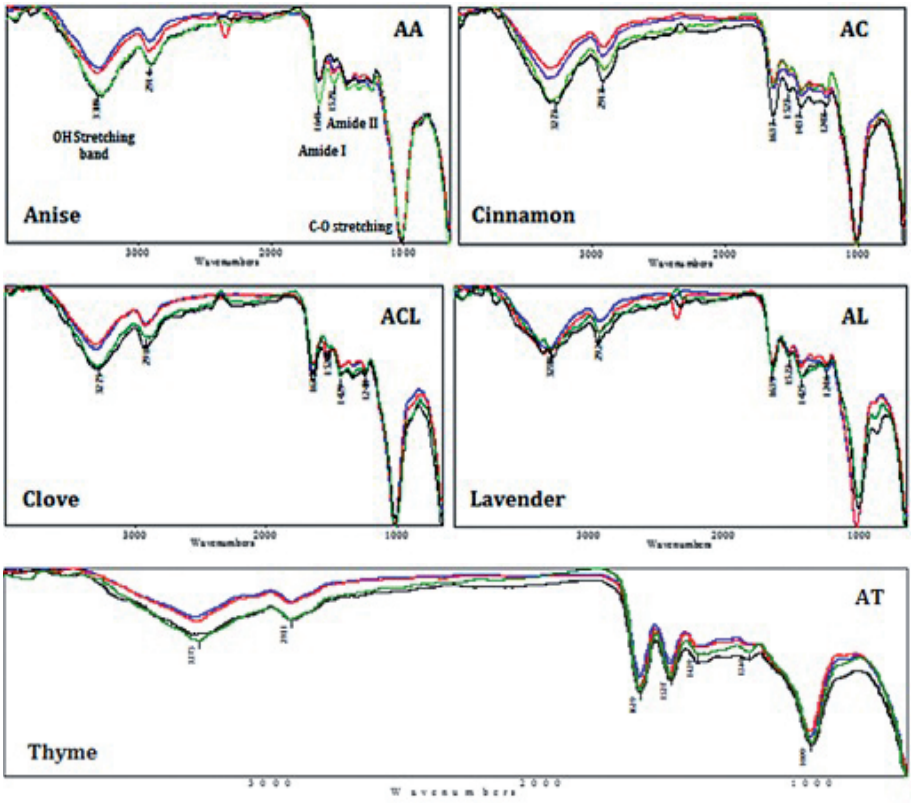

Figure 6. FT-IR spectra representing the Dmin area in blue and the Dmax area in red for the albumen print sample set compared to the equivalent areas, in green and black, respectively, post exposure to vapors of the selected essential oils and post artificial aging.

Based on the obtained ATR-FTIR spectra, samples treated with lavender oil vapors showed no change, as in the case of the albumen print sample (AL) (Figure 6) and the silver gelatin print sample (BL) (Figure 7), and a very minor change in the OH stretching vibration in the case of the chromogenic print sample (CL) (Figure 8). For the albumen

sample set, the resultant spectra showed an increase in the OH stretching band indicating more hydrogen bonding, which may be due to the hydrolysis of the albumen. Sample AA treated with anise oil and sample AC treated with cinnamon oil exhibited an increase in the intensity of the amide I band which is also associated with albumen hydrolysis. The increase in the width of the amide I band in sample AC is an indication of the oxidation of the protein [69]. The sample treated with clove and thyme showed insignificant changes (Figure 6). The cinnamon and thyme treated silver gelatin prints showed a very slight change in the OH stretching and amide I and amide II bands. Changes in the amide I band were observed in the case of sample BA treated with anise and BCL treated with clove (Figure 7).

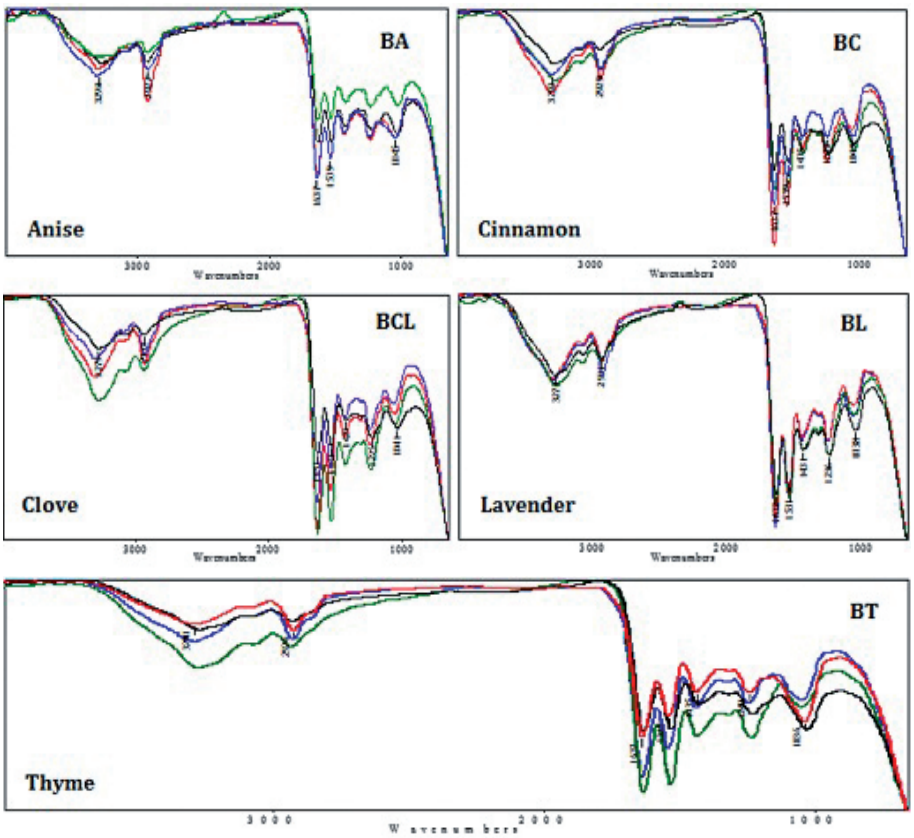

Figure 7. FT-IR spectra representing the Dmin area in blue and the Dmax area in red for the silver gelatin print sample set compared to the equivalent areas, in green and black, respectively, post exposure to vapors of the selected essential oils and post artificial aging.

For the chromogenic print sample set, all treated samples showed minor changes in the OH stretching band when compared to standard samples, with the sample treated with lavender showing the least change (Figure 8).

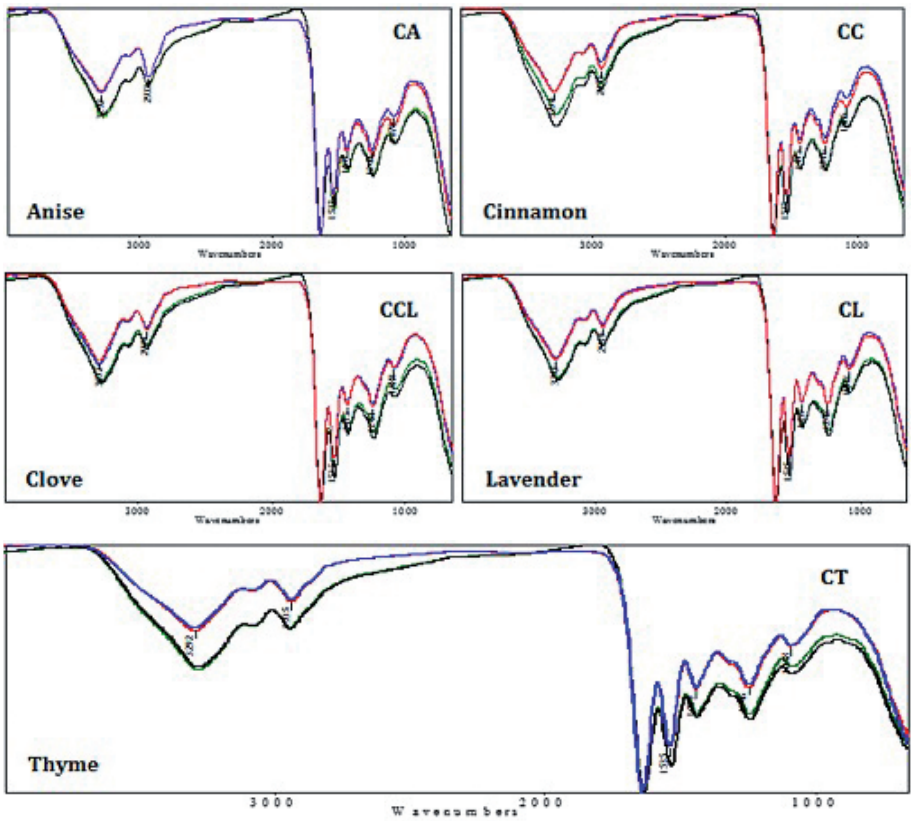

Figure 8. FT-IR spectra representing the Dmin area in blue and the Dmax area in red for the chromogenic print sample set compared to the equivalent areas, in green and black, respectively, post exposure to vapors of the selected essential oils and post artificial aging.

4. Conclusion

Based on available literature, the antimicrobial activities of the five essential oils (i.e. lavender, clove, anise, cinnamon and thyme) selected for this study are well established. It has been proven that the tested oils are capable of inhibiting or slowing the growth of bacteria and molds. Results also showed that the antimicrobial activities of essential oils are different, depending on the type of microorganisms and the type and concentration of each oil. Essential oils with a high concentration of phenolic compounds such as clove and thyme are the most effective, even at low concentrations. On the other hand, scientific publications provide extremely limited data about the effect of essential oils in vapor phase on the properties of photographs and thus, their potential use in the preservation of valuable photograph collections. Based on the obtained data from visual inspection, microscopic examination, colorimetric measurements and ATR-FTIR spectroscopy, this research has shown that all tested essential oils in vapor phase have little or no effect on the selected photographic materials (i.e. albumen, silver

gelatin and chromogenic prints). Visually speaking, all tested samples showed either no change to only a slight change in image surface characteristics (i.e. color and sheen). Obtained ΔE^* values were ≤ 5 in most tested samples, which is within the accepted limit for the maintenance and restoration of historical surfaces. In terms of chemical changes, all oil vapors showed insignificant changes in positions and intensities of the OH stretching, amide I and amide II characteristic IR bands of proteins (i.e. albumen and gelatin) after treatment and artificial aging. However, lavender oil gave the best results with all types of tested photographic prints in terms of preserving the optical and chemical properties of the photographs. This research does not include the effect of the oil on the image silver, chemically speaking. Moreover, the prepared albumen prints showed a major change in color post oil vapor exposure and artificial aging, which is more likely due to the aging conditions rather than the oil treatment. Naturally aged albumen prints were not an option since they were not available for experimental use.

In brief, essential oils in vapor phase can be safely used as natural biocides on albumen, silver gelatin and chromogenic prints for the control of biodegradation as alternatives to the currently available synthetic chemicals which are either hazardous or have detrimental effects on photographic collections. Exposure of photographs to the volatile compounds of essential oils can be performed in a desiccator cabinet or a clean chamber, in the case of over-sized objects. The duration of exposure is 15-20 days.

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Biographical notes

Maha Ali is currently a lecturer of photograph conservation at the Faculty of Archaeology, Cairo University. She received her doctorate degree in Conservation from Cairo University in 2016. She has also taught several photograph conservation classes at post graduate level in a joint International Master's Program in Conservation of Antique Photographs and Paper Heritage between Helwan University, Egypt and the University of Catania, Italy. She has held a number of workshops in Egypt, Lebanon, and Morocco with the aim of raising awareness on the significance of photograph heritage in Egypt and the Middle East and their preservation needs. She has also delivered a lecture on "Solvent Cleaning of Silver Gelatin prints: Is It Safe?" for staff members, and students at undergraduate and postgraduate level at the Ca' Foscari Univer-

sity of Venice, Department of Philosophy and Cultural Heritage, School of Cultural Production and Conservation of the Cultural Heritage in January 2017. Maha has published several papers discussing different issues related to photograph and paper conservation.

Summary

Albumen, silver gelatin and chromogenic prints are found abundantly among photographic collections in Egypt. Due to the uncontrolled environment in archives and libraries, this precious visual heritage with its high protein and cellulose content provides the right culture medium required for fungal growth. Many essential oils have been proven to have antibacterial and antifungal properties. Essential oils offer a safe alternative to other common disinfection methods; however, their effect on the properties of photographs have not received much study. This paper studies the effect of vapors of anise, cinnamon, clove, lavender and thyme oils on albumen, silver gelatin and chromogenic prints, to find a proper disinfection method that is user-friendly and environmentally safe and respects the nature of photographic materials. Essential oils were provided by the National Research Center (NRC) in Cairo, Egypt. Artificially aged albumen prints, and naturally aged silver gelatin and chromogenic prints were exposed in desiccators to the selected essential oils in the vapor phase for a period of 5 days. All samples were artificially aged at a temperature of 80°C and 65% RH for a period of 5 days to study the long-term effects of the tested treatments. Treatments were evaluated using several techniques including visual inspection, microscopic inspection, colorimetric measurements, and attenuated total reflectance Fourier transform infrared spectroscopy. Results showed that all tested essential oils had a very slight effect on the tested photographic samples; however lavender oil was found to be the best option, specifically in terms of preserving the chemical properties of the photographic surfaces.

Riassunto

Albumine, gelatine d'argento e stampe cromogeniche si trovano in abbondanza nelle collezioni fotografiche in Egitto. A causa dell'ambiente non controllato negli archivi e nelle biblioteche, questo prezioso patrimonio visivo con il suo alto contenuto di proteine e cellulosa fornisce il terreno di coltura per la crescita dei funghi. Molti oli essenziali hanno dimostrato di avere proprietà antibatteriche e antimicotiche. Gli oli essenziali offrono un'alternativa sicura ad altri metodi di disinfezione comuni; tuttavia, non ci sono molti studi sul loro effetto sulle proprietà delle fotografie. Questo articolo descrive l'effetto dei vapori di oli di anice, cannella, chiodi di garofano, lavanda e timo su albumine, gelatina d'argento e stampe cromogeniche, per trovare un metodo di disinfezione adeguato che sia facile da usare e sicuro per l'ambiente nel rispetto dei materiali fotografici. Gli oli essenziali sono stati forniti dal National Research Center (NRC) del Cairo, in Egitto. Stampe all'albume invecchiate artificialmente, gelatine d'argento invecchiate naturalmente e stampe cromogeniche sono state esposte in essiccatori agli oli essenziali selezionati in fase vapore per un periodo di 5 giorni. Tutti i campioni sono stati invecchiati artificialmente a una temperatura di 80 °C e 65% di umidità relativa per un periodo di 5 giorni per studiare gli effetti a lungo termine dei trattamenti testati. I trattamenti sono stati valutati utilizzando diverse tecniche tra le quali ispezione visiva, ispe-

zione microscopica, misurazioni colorimetriche e spettroscopia a infrarossi in trasformata di Fourier a riflettanza totale attenuata. I risultati hanno mostrato che tutti gli oli essenziali testati hanno avuto un lieve effetto sui campioni fotografici testati; l'olio di lavanda è risultato essere l'opzione migliore, in particolare, in termini di salvaguardia delle proprietà chimiche delle superfici fotografiche.