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IDENTIFICATION OF FIBRES FROM BYZANTINE AND POST-BYZANTINE ICONS OF THE MUSEUM OF BYZANTINE CULTURE IN THESSALONIKI: USE OF OM, SEM AND SPSS ANALYSIS

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ABSTRACT

Fibre samples from the fabric support of 33 Eastern Orthodox icons dating from the 14th to the 18th centuries A.D, owned by the Museum of Byzantine Culture in Thessaloniki, Greece, were studied in order to identify the construction material of their fabric substrate. The methods employed included sampling, preparation on glass slides, Optical Microscopy (OM), Scanning Electron Microscopy (ΣEM), and use of Microsoft Excel and IBM SPSS for the categorisation, visualisation and statistical analysis of the results. OM and SEM observations led to the recording of morphological features of the fibre types, allowing their identification as linen, cotton and hemp. SEM was proven valuable in the identification of features not otherwise visible, which helped distinguish between fibres of a similar appearance. OM and SEM observations combined, also led to notes on the preservation state of the fabric substrate, and the presence of foreign matter trapped within the fibres. Initial graphs prepared in an Excel environment suggest that linen is the predominant material for most centuries and most sizes of icons. Yet statistical analysis with SPSS through one way ANOVA, cross tabulation and chi-square tests contradict the initial conclusions. It is stressed out the importance and need of statistical analysis for the drawing of safe conclusions regarding the interpretation of results.

KEYWORDS: orthodox icons, fabric support, cotton identification, hemp, linen, SEM-EDS

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1. INTRODUCTION

The Eastern Orthodox Church has always treated icons in high regard and respect, due to their spiritual value and importance as a means of sanctification and communion of the believers with the depicted holy figures. Orthodox iconography is regarded as -and indeed is- a significant visual means of teaching a conjectural language of the main theology of the Church. Icons have been presented as works of art, as historic objects reflecting societies, and as a source of spiritual awakening, divine energy and miraculous events.

Iconography was given special attention and was favoured by the early Byzantine Empire. The first Byzantine emperor Constantine the Great relieved the artists who created the mosaics for the churches, free of all taxation. Iconography flourished through and throughout the Empire in the form of mosaics, wall paintings and portable icons, and became most fully developed and widely spread in the 6th century. However, during the iconoclastic period (7th-8th c) many icons were destroyed and therefore artefacts contemporary to and preceding that period are rare (Glykatzi-Arveler, 2012; Gregory, 2010; Runciman, 1990). Nevertheless, since then, monasteries and workshops have been producing large amounts of icons, thus maintaining the spirit of Christianity. In the coming centuries, and even after the decline and fall of the Byzantine Empire in the 15th c, and up until the 18th c., several schools blossomed, including the Palaeologan renaissance, the Macedonian and the Cretan school and others (Talbot, 1972). Throughout the centuries, hagiographers developed artistically, and the pictorial changes and the development of the icons, allows for the attribution of such artefacts to a specific school and era, even though the majority of artists did not sign their works.

Researchers, scientists, conservators and scholars agree that despite iconographical differences, most of the icon painters mainly used the same traditional 'recipes' for centuries (Haack Christensen and Jager, 2019). However, from the 18th century onwards, some workshops started changing their paint medium using oil and other mixtures replacing the traditional egg tempera, producing more naturalistic figures of a western influence (Gettens and Stout, 1942). Nowadays, some workshops use unorthodox materials, not in line to the tradition of the religious painting of the Eastern Church, such as synthetic gesso ground, plastic or acrylic paint mediums or synthetic fabrics to produce an easy and quick result.

An Orthodox icon traditionally consists of several layers:

1. A thick wooden panel used as a base.

2. A fabric support adhered on the wood. This is present on most icons, yet not all, while others bear a paper support.

3. The gesso layer, often sandwiched between layers of usually animal glue.

4a. (for non-gilt icons) The paint layer, comprising of pigments mixed with egg tempera, yet icons in oil are also found.

4b. (for gilt icons) Bole (usually red), gold leaf and paint layer. The images represented may be painted onto the gold leaf, or onto the gesso. In the second case, gilding is partial. Silver leaf is also found, mostly on Slavic and Russian icons.

5. The top varnish layer.

Fabric supports on icons were most commonly made of linen, cotton and jute. Dionysius of Fourna (c. 1670-1774 AD) the famous hagiographer monk from Athos, and Cennino Cennini (c. 1390 AD) describe the different techniques, application and materials of the fabrics on the wooden panels (Dionysius of Fourna, 1909; Cennini, 1991). Vegetable fibres such as cotton, and bast fibres such as linen, jute and hemp can be found on Byzantine and post byzantine icons, yet the identification and study of the fibres from the fabric substrate of Orthodox icons have not been thoroughly investigated by researchers. It has however been suggested that most of the times hagiographers prefer using stronger, close-weaved fabrics for large icons, and more openly weaved ones for smaller ones (Karydis, 2006).

Icon conservators often neglect to document the fabric support or its weaving pattern, as they are mostly interested in the painted surface, rather than its substrate. However, fibre identification is one of the skills of both textile as well as icon conservators and has been taught for years in conservation schools. The methods employed by conservators in the past for the study and identification of fibres were mostly *in situ* visual observation and destructive techniques such as burning tests or chemical tests (Kousouni and Panagopoulou, 2018; Khan *et al*, 2017; Farnfield, 1975). Optical microscopy, embedding in resin and microscopic observation of cross sections are often employed (Janaway and Wyeth, 2005; Rogerson and Eastop, 1999; Goodway, 1987), providing more reliable results. Information about fibre structure, texture, colour, and preservation state can be revealed under specific magnifications of the surface or sample under examination. Morphological features help in distinguishing among different plant fibres. Cotton appears as a twisted ribbon (Catling and Grayson

2004; Galanopoulou-Sendouka, 2002; Timan-Balazsy and Eastop, 1999; Cook, 1984; Farnfield, 1975), linen fibres are cylindrical with lines perpendicular and parallel to their axis, present irregular width, lack of windings, and often split ends (Lewin, 2007), and hemp fibres are cylindrical with thick walls, longitudinal crossed lines and blunt endings (Baldinger, 1994; Goodway, 1987; Schaffer, 1981). Scanning Electron Microscope coupled to Energy Dispersive X-ray Spectrometer (SEM-EDS), a microstructural invasive and partially destructive technique, can be even more reliable for the observation of the morphological and structural features, due to the ability to obtain images of a better resolution. More information is retrieved on the fibre surface, preservation state, nature of deterioration, presence of salts, dust, dirt and other deposits (Garside and Wyeth, 2003). SEM has been used for fibre identification especially on archaeological and historical fibres, and SEM-EDS has been extensively used on historical textiles for the identification of the metal compounds of metal threads (Karatzani, 2010; Protopapas *et al,* 2002; Jaro *et al,* 2000). Transmission Electron Microscopy (TEM) has also been used to determine the composition of metal threads from Byzantine and post-Byzantine textiles (Photos-Jones *et al*., 1996; Greaves and Saville, 1995).

This paper presents the first study on fibre identification ever attempted on the fabric supports of icons of the Museum of Byzantine Culture in Thessaloniki, Greece. The Museum was inaugurated in 1994 (Museum of Byzantine Culture, 2019 a) and houses approximately 1000 icons dating between the 12th – early 20th c, coming from a wide geographic area, including mainland Greece, the Greek islands and Asia Minor (Museum of Byzantine Culture, 2019 b). 33 items dating from the 14th to the 19th c, comprising of portable icons, iconostasis icons, *lypera* and iconostasis doors, covering a great chronological extent and coming from all aspects of icon-on-wood artefacts exhibited in the Museum, were selected (Table 1). All of the objects had already undergone conservation treatment in the past. The sampling process and study of the obtained samples was conducted after the necessary permission granted by the Ministry of Culture. The fibre samples were studied through OM and SEM observations and morphological comparison, aiming to identify textile fibres from the fabric support of byzantine and post-byzantine icons. The icons are exhibited in three different sections of the Museum's permanent collection (exhibition rooms 7, 9 and 10), with many of them coming from the multi-thematic collection of Demetrios Economopoulos, a significant private collector who donated 400 icons to the Museum (Museum of Byzantine Culture, 2019 b).

2. RESEARCH AIMS

The aims of the research were to:

1. Identify the construction material of the fabric of icons of the Museum of Byzantine Culture.
2. Investigate whether the fibre material of the fabric was the same across the centuries.
3. Investigate whether the choice of fabric was related to the size of the icon.
4. Investigate whether fibre identification is feasible on small samples, due to strict sampling restrictions.
5. Investigate whether fibre identification is feasible when the samples come from already damaged and exposed surfaces that had undergone conservation treatment.

3. MATERIALS AND METHODS

Methodology included record photography, sampling, optical microscopy, scanning electron microscopy and use of computer software for the statistical analysis of results.

3.1. Object selection, initial recording and coding

Thirty-three (33) exhibits of the Museum of Byzantine Culture of Thessaloniki were selected, dating from the Palaiologan to the post-Byzantine period (14th-18th c). Belonging to different eras and created by various anonymous hagiographers, they were chosen as representative examples of the eras they represent. The number of the icons selected, accounts for approximately 0.3% of the total icon collection of the Museum. Given the analogy of the Economopoulos collection (400 out of a total of approx. 1000 icons), great care was taken so that many of the icons to be studied came from that collection, which finally accounted for 21 of the samples. It was the desire of the museum that research be performed only on artefacts that are permanently exhibited. The icons chosen were the only ones presenting visible losses of the gesso and paint layers, a damage that revealed the underlying fabric. Most of the items had been conserved in the past. The items include portable icons, iconostasis icons, iconostasis doors and one *lypero*. The objects were mostly painted on one of their surfaces, yet occasions of double-sided icons were also noticed. For the purposes of this study, the studied items were given the code numbers 1-33, numbered in chronological order, as presented in Table

1. Apart from the record photography of the items, information recorded during this stage, included the depicted theme, the age of each item based on the iconographical study of the Museum researchers, the dimensions, the Accession Number given by the Museum, and the location of each object within the museum collection (Table 1).

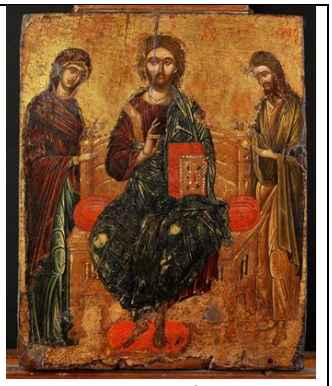
Table 1. List of the examined portable icons from the Museum of Byzantine Culture, Thessaloniki

 **1. Panagia Eleousa (Virgin Mary the Merciful) & St Anna (Double – sided)** 2nd decade of the 14th c. Dim. * 85 x 105 cm Acc.No. * BEI 780, Ex.R.* 7	 **2. Panagia (Virgin Mary) Hodegetria** Late 14th c. – Early 15th c. Dim. 82 x 113 cm Acc.No. BEI 505, Ex.R. 7	 **3. Madre della Consolazione** 2nd half of the 15th c. Dim. 39 x 51 cm Acc.No. BEI 82, Ex.R. 9, Ec.Col. *	 **4. (Jesus) Christ Pantocrator** 2nd half of the 15th c. Dim. 50 x 60cm Acc.No. BEI 5, Ex.R. 9, Ec.Col.
 **5. (Jesus) Christ Pantocrator** 15th c. Dim. 11 x 26.2 cm Acc.No. BEI 95, Ex.R. 9, Ec.Col.	 **6. Two-zoned Sanctuary (Royal) door: The Annunciation (top) and Apostles Peter & Paul (bottom)** 15th c. Dim. 69.5 x 120 cm Acc.No. BEI 97, Ex.R 9, Ec.Col.	 **7. Panagia (Virgin Mary) Vrephokratousa** 15th c. Dim. 108 x 160 cm Acc.No. BEI 504, Ex.R. 10	 **8. Panagia (Virgin Mary) Pantanassa (the Queen of All)** 15th – 16th c. Dim. 78.5 x 101 cm Acc.No. BEI 464, Ex.R. 10
 **9. St. George** Late 15th c. – Early 16th c. Dim. 43.5 x 55 cm Acc.No. BEI 77, Ex.R. 9, Ec.Col	 **10. Panagia (Virgin Mary) Glykophilousa** Early 16th c. Dim. 41 x 53.5 cm Acc.No. BEI 98, Ex.R. 9, Ec.Col.	 **11. "Lypero" (mourning figure) of the Virgin Mary** Mid. 16th c. Dim. 44 x 57 cm Acc.No. BEI 53 (d,e), Ex.R. 10	 **12. Resurrection** Mid. 16th c. Dim. 44 x 57 m Acc.No. BEI 462, Ex.R. 10

13. Archangels Gabriel & Michael
16th c.
Dim. 23.8 x 30 cm
Acc.No. BEI 137, Ex.R. 9, Ec.Col.

14. St Constantine & St Helen
16th c.
Dim. 36 x 47. 5 cm
Acc.No. BEI 481, Ex.R. 10

15. Archangel; Part of a Royal door.
16th c.
Dim. 33.3 x 90 cm
Acc.No. BEI 471, Ex.R. 10

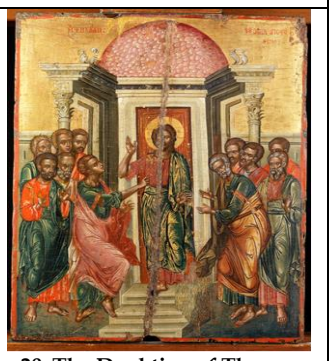


16. Deesis
Late 16th c.
Dim. 24.2 x 30.2 cm
Acc.No. BEI 81, Ex.R.9, Ec.Col.

17. St Demetrios
First half of the 17th c.
Dim. 54 x 101 cm
Acc.No. BEI 184, Ex.R. 9, Ec.Col.

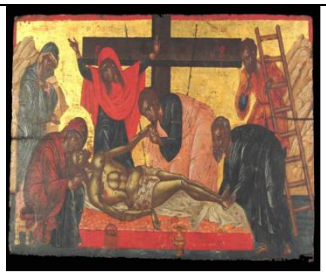
18. St. George
17th c.
Dim. 22.3 x 29 cm
Acc.No. BEI 419, Ex.R. 9 Ec.Col.*

19. St John the Baptist
17th c.
Dim. 39 x 76 cm
Acc.No. BEI 59, Ex.R. 9, Ec.Col.



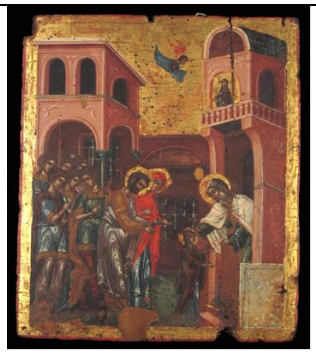
20. The Doubting of Thomas
17th c.
Dim. 36 x 45.5 cm
Acc.No. BEI 169, Ex.R. 9, Ec.Col.

21. St Savvas
17th c.
Dim. 62 x 107 cm
Acc.No. BEI 124, Ex.R. 9, Ec.Col



22. Epitaphios Threnos (Lamentation upon the Grave)
17th c.
Dim. 64 x 33 cm
Acc.No. BEI 499, Ex.R. 10

23. The Raising of Lazarus
Late 17th c.
Dim. 33 x 46 cm
Acc.No. BEI 182, Ex.R.9, Ec.Col.



24. The Entry of the Most Holy Theotokos into the Temple (The Presentation of the Blessed Virgin Mary)
Late 17th c.
Dim. 33.3 x 39 cm
Acc.No. BEI 570, Ex.R. 10

25. The hospitality of Abraham
Early 18th c.
Dim. 78 x 118 cm
Acc.No. BEI 496, Ex.R. 10, Ec.Col.

26. Madre della Consolazione
18th c.
Dim. 17.5 x 22.6 cm
Acc.No. BEI 145, Ex.R. 9, Ec.Col.

27. Deesis
18th c.
Dim. 11 x 26.2 cm
Acc.No. BEI 286, Ex.R. 9, Ec.Col.

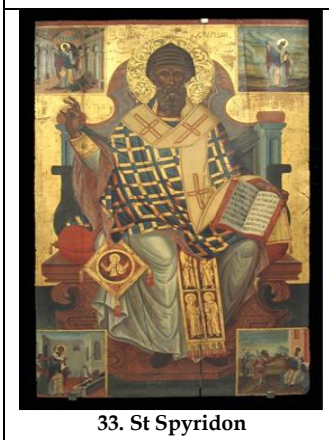
28. The Baptism
18th c.
Dim. 40 x 65 cm
Acc.No. BEI 200, Ex.R. 9, Ec.Col.

29. The Myrrhbearers in the tomb (Touch me not)
18th c.
Dim. 29 x 39cm
Acc.No. BEI 455, Ex.R. 9, Ec.Col.

30. Three – zoned Icon of Panagia (Virgin Mary) in the type of Vlachernitsa and Saints
18th c.
Dim. 33.5 x 41 cm
Acc.No. BEI 398, Ex.R. 9, Ec.Col.

31. Panagia (Virgin Mary) Hodegetria
18th c.
Dim. 32.3 x 41 cm
Acc.No. BEI 108, Ex.R.9, Ec.Col.

32. Two zoned icon of Panagia (Virgin Mary) Enthroned Vrephokratousa with Archangels & Saints
18th c.
Dim. 43 x 64.5 cm
Acc.No. BEI 615, Ex.R. 10



33. St Spyridon
18th c.
Dim. 68.5 x 109 cm
Acc.No. BEI 712, Ex.R. 10

***Abbreviations and Notes:**

Dim. = Dimensions; All dimensions are given in width x height

Acc.No. = Accession Number

Ex.R. = Exhibition Room

Ec.Col. = Economopoulos Collection

3.2. Sampling

All items were digitally photographed with a Nikon® D 3100 at magnification x5, x10, x20 in order to record the sampling spots. One sample was retrieved per studied object. All samples were taken with the aid of tweezers and a scalpel, from already damaged areas, mostly from the edges of the icons, cracks and areas where the textile was revealed and the gesso and painting surface were lost. Following the instructions set within the official sampling permission by the Greek Ministry of Culture, the size of the samples was the smallest possible, not exceeding 1 cm^2.

3.3. Optical Microscopy (OM)

The extracted fibres were placed on microscope slides for OM observation, carried out with a Leica® DM2500M microscope under transmitted light. Leica® DM2500M Optical Microscope provides accurate results due to its top quality optics with two incident light axis and multiple light sources that can be adapted (transmitted light 12V 100W halogen). It can process samples with a size up to 100 x 100 mm and thickness of up to 80 mm with an optional magnification changer (1x, 1.5x, 2x) and a built–in focus stop. The samples were observed under magnification x5, x10, x20.

3.4. Scanning Electron Microscopy (SEM)

For observation under higher magnifications, a Scanning Electron Microscope - Energy Dispersive X-ray Spectroscopy (SEM-EDX) Jeol & Oxford was used at SEM resolution 4.0 nm at 30 kV, EDX resolution 137 eV at 5.9 keV, acceleration voltage 0.5 - 30 kV and stage movements 10 mm × 20 mm. The samples observed were processed through a carbon evaporator in order to create a thin conducting surface layer as protection to reduce heating caused by the electron beam. The SEM observations took place upon completion of the OM observations. A total of six (6) samples, two of each of the fibre categories identified during OM were observed at magnifications x200, x400, x800, x1000, x1400, x2000, x3000.

3.5. Commercial spreadsheet application for result interpretation

All data collected were inserted into a Microsoft Excel spreadsheet, in order to organize the information, classify it into categories and produce graphs to assist the visual understanding of the results obtained. The initial information that was inserted as data in the spreadsheet included sample no, BEI code, width (cm), height (cm), the fibre type as resulting from the OM and SEM observation, and the iconographical theme.

Using the appropriate Excel functions, the surface of the fabric of each icon was calculated by multiplying the measured width and height. At this point, it was possible to further classify the studied icons into 5 size categories, according to their surface: A: less than 500 cm^2, B: 501-1000 cm^2, C: 1001-2000 cm^2, D: 2001-3000 cm^2, and E: over 5000 cm^2, as no items were found to measure 30001-5000 cm^2. Regarding information of the age of the objects, this was generalized into the century when each icon was constructed, omitting any additional information such as early, mid, late, first and second half that was initially provided by the archaeologists. For classification purposes, object No 2, originally identified as 14^{th}-15^{th} c was classified as 15^{th} c. Similarly, objects No 8 and 9, originally identified as 16^{th}-17^{th} c, were classified as 17^{th} c.

The next step was to use the above data to produce two pie charts to present the number of samples according to the era they belonged to (Graph 1) and according to the type of fibre identified (Graph 2). Two multiple bar graphs were also created, presenting the number of samples per type of fibre according to era (Graph 3) and according to the size of the icon (Graph 4).

3.6. Statistical package software for result interpretation

The columns of the initial excel table were inserted into an IBM SPSS (Statistical Package for the Social Sciences) free download trial environment, in order to analyse the data and run statistical tests.

The most important of the initial stages was to define which variables were quantitative, to allow mathematical calculations, and which ones were qualitative variables, allowing to answer questions. Therefore, the variables needed to be defined in order to allow statistical analysis. Non-numerical categorical values (i.e. "fibre type") were turned into numerical, and so in example "cotton" was named "1", "hemp" was named "2" etc, and were stated as nominal measures. String variables, such as "surface", were defined as numerical type with a scale measure, etc.

The first question was whether the choice of fabric differentiates according to the surface that it needed to cover. The statistical test run was one-way ANOVA (ANalysis Of VAriance). Variable "surface" being quantitative was stated as dependent variable, and "fibre type" being a qualitative variable was stated as factor. One-way ANOVA would therefore compare the categorical groups of icons with cotton, hemp, linen, linen or hemp, and unidentified fabric substrate. In this case, two hypotheses are made. In the null hypothesis (H_0), there are no differences between the groups, meaning that all icons may have the same surface regardless of the type of fabric used in their substrate. In the alternative hypothesis (H_1), there is a difference between the means of groups, meaning that icons have different sizes for different types of fabric.

The second question was whether the century in which an icon was created affected the choice of material for the fabric substrate. In this case, both of the variables "century" and "fibre type" are qualitative. Therefore the cross tabulation and Chi-Square analysis was performed.

Table 2. Indicative sampling points and results of OM and SEM visual observation

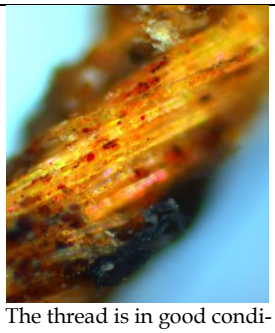
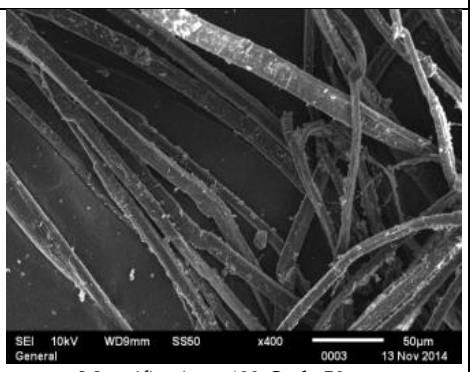
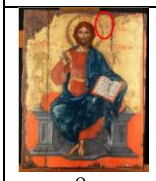
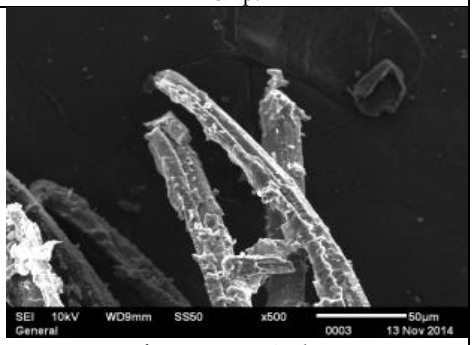
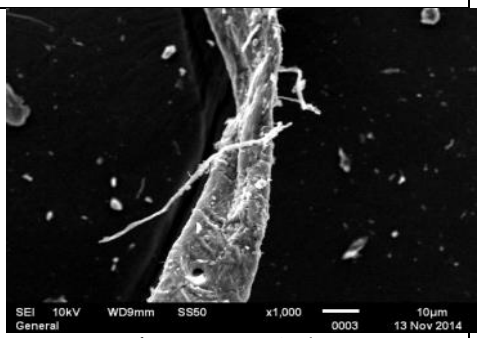
Object, Code No. (Acc.No.)	Sampling area	OM image	SEM image
 2 (BEI 505)	 Fibre sample retrieved from crack below Virgin Mary's elbow.	 The thread is in good condition, covered by a hard, yellowish varnish, darkened due to ageing, yet the fibres retain a level of transparency. The fibres are well attached to one another.	 Magnification x400. Scale 50 µm Although similar to linen, the transparency observed in OM and the distinct lines observed in SEM led to the identification of the fibre as hemp.
 9 (BEI 5)	 Fibre sample retrieved from crack over Christ's shoulder.	 Very worn thread with a dull yellowish appearance. The fibre edges appear smooth. Linear features are observed across the body of the fibre.	 Magnification x500. Scale 50 µm A large line along the centre of the fibre and lines crossing its body allowed its identification as linen
 19 (BEI 124)	 Fibre sample retrieved from crack below the scroll.	 Very dense thread with an orangey appearance. The fibres are extremely thin, flat, ribbon-like and twisted.	 Magnification x1000. Scale 10 µm The intense twisting of the fibre allowed its identification as cotton.

Table 3. Main results on the observation of the 33 icons

no	BEI	width (cm)	height (cm)	surface (cm^2)	size class	century	fibre	iconography
1	780	85	105	8925	E	14	hemp	Panagia Eleousa & St. Anna
2	505	82	113	9266	E	15 *	hemp	Panagia Hodegetria
3	82	39	51	1989	C	15	linen	Madre della Consolazione
4	5	50	60	3000	D	15	linen	Christ Pantocrator
5	95	11	26.2	288.2	A	15	linen	Christ Pantocrator
6	97	69.5	120	8340	E	15	cotton	Annunciation & Peter & Paul; Sanct. Door
7	504	108	160	17280	E	15	cotton	Panagia Vrephokratousa
8	464	78.5	101	7928.5	E	16**	cotton	Panagia Pantanassa
9	77	43.5	55	2392.5	D	16**	cotton	St. George
10	98	41	53.5	2193.5	D	16	linen	Panagia Glykophilousa
11	53	44	57	2508	D	16	cotton	Lypero Virgin Mary
12	462	44	57	2508	D	16	cotton	Resurrection of Christ
13	137	23.8	30	714	B	16	linen	Archangels Gabriel & Michael
14	481	36	47.5	1710	C	16	linen	St. Constantine & St .Helen
15	471	33.3	90	2997	D	16	hemp	Archangel; Part of a Royal door.
16	81	24.2	30.2	730.84	B	16	linen	Deesis
17	184	54	101	5454	E	17	cotton	St. Demetrios
18	419	22.5	29	652.5	B	17	cotton	St. George
19	59	39	76	2964	D	17	linen	St. John the Baptist
20	169	36	45.5	1638	C	17	linen	The Doubting of Thomas
21	124	62	107	6634	E	17	cotton	St. Savvas
22	499	64	33	2112	D	17	linen	Epitaphios Threnos
23	182	33	46	1518	C	17	linen or hemp	The Raising of Lazarus
24	570	33.3	39	1298.7	C	17	linen	The Entry of the Theotokos into the Temple
25	496	78	118	9204	E	18	linen	The hospitality of Abraham
26	145	17.5	22.6	395.5	A	18	cotton	Madre della Consolazione
27	286	11	26.2	288.2	A	18	undefined	Deesis
28	200	40	65	2600	D	18	cotton	The Baptism
29	455	29	39	1131	C	18	linen	The Myrrh bearers in the tomb
30	398	22.5	41	922.5	B	18	linen	Panagia Vlachernitsa and Saints
31	108	32.3	41	1324.3	C	18	linen	Panagia Hodegetria
32	615	43	64.5	2773.5	D	18	linen	Panagia Enthroned with Archangels & Saints
33	712	68.5	109	7466.5	E	18	linen	St. Spyridon

* The object was presented as 14th-15th c, yet for classification and statistical analysis purposes, it is here stated as 15th c.
** The object was presented as 16th-17th c, yet for classification and statistical analysis purposes, it is here stated as 17th c.

*Table 4. Chi-Square Tests based on Fibre type * Century Cross tabulation*

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	18.899	16	0.274
Likelihood Ratio	14.723	16	0.545
Linear-by-Linear Association	1.940	1	0.164
N of valid cases	33		

4. RESULTS

Optical Microscopy combined with Scanning Electron Microscopy, revealed information on the morphological structure of the fibres, allowing for their identification. In general, three types of fibres were identified, namely hemp, linen and cotton (Tables 2, 3). The observed samples presented various differences in terms of regularity and irregularity of fibril shape. Additionally, microscopic observations provided information on the preservation state of the surface of the samples. Dust, dirt and small dark particles into the internal of the fibre structure were also observed. Scanning Electron Microscopy provided further information on the morphological structure of the fibres especially on the heavily damaged samples. Abrasions, damages and losses were visible under SEM.

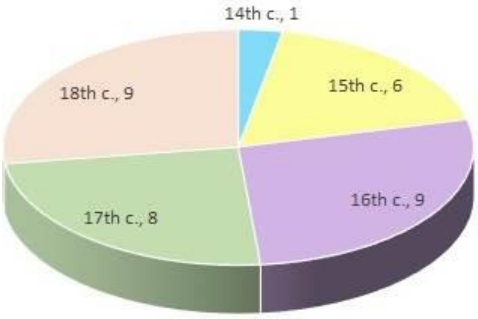
Most of the samples were identified as linen (17), followed by cotton (11), and hemp (3) (Table 3, Graph 2). One sample was not identified, due to its small size, and one could be either linen or hemp. Linen is the type of fabric most represented in the samples and is particularly predominant in the 18th century samples group (Graph 3). In general, linen appears to be the material employed in half of the icons studied (Graph 2), and appears to

be predominant in nearly all size categories (Graph 4).

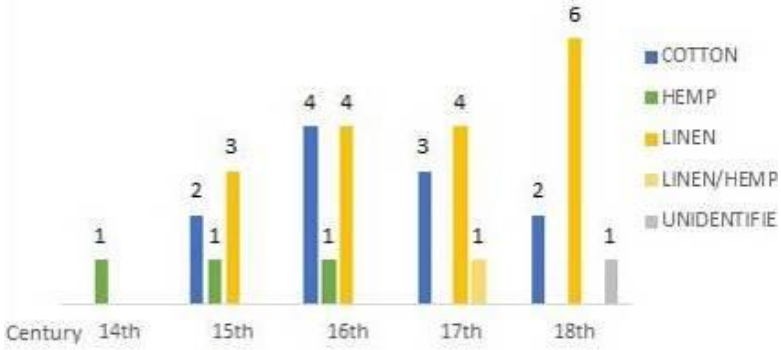
However, the one-way ANOVA statistical test on the variables of surface and fibre type, resulted in sig=0.123. Since 0.123 is greater than significance level α=0.01, the test reveals that the two variables are independent, meaning that for the set of data analysed, the extent of the surface and the choice of fabric are not related to each another.

The results of the century*fibre type cross tabulation and Chi-Square analysis are presented in Table 4. As it can be clearly seen, in all tests run, sig>0.01, meaning that these variables are also independent according to the statistical analysis.

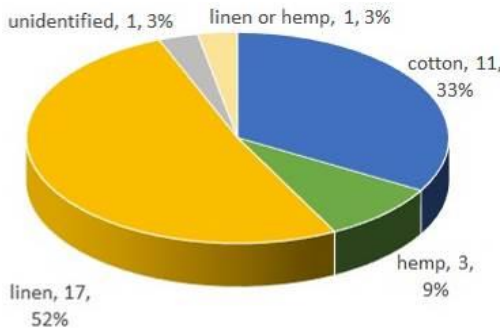
Graph 1. Number of samples according to era



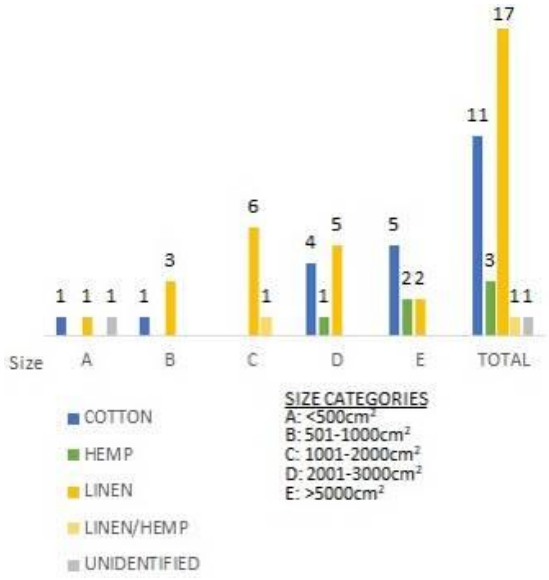
Graph 3. Number of samples per type of fibre according to era



Graph 2. Number of samples according to type of fibre



Graph 4. Number of samples per type of fibre according size of icon



5. DISCUSSION

This is the first time that OM and SEM observations are made on the fabric substrate of any of the icons of the Museum of Byzantine Culture in Thessaloniki, Greece, and the first time that computer software on spreadsheets and statistical analysis are used to interpret the outcomes of such research in its collections. Thorough examination of the type of fabric, including identification of the fibre types and weaving is a generally neglected area among icon conservators.

In brief, three types of fibres were identified as construction materials of the fabric substrate of the studied artefacts: linen, cotton and hemp. The combined use of OM and SEM allowed for further observation of microscopic features that would otherwise not have been noticed, and therefore allowed reaching safer conclusions regarding fibre identification, especially in the case of fibres of a poor preservation state.

The identified materials are in accordance to the known bibliography, as in the practice of hagiographers, these three types are the ones that have been vastly used over the centuries. All of the samples were proven to be of plant origin, while animal fibres, i.e. wool or silk were not found in any of the icons studied. This may be explained by

the fact that silk and wool are considered to be fragile and unstable materials, and therefore their use as fabric substrate for icons would not have been recommended by hagiography masters who had for centuries kept the tradition and passed their knowledge to their apprentices.

The findings of OM and SEM examination, were indicative of the preservation state of the fabric substrate of the icons studied. The observation of various deposits (including dust, dirt, varnish, glue remains etc) on the surfaces of artefacts that had already been treated in the past, stresses the importance of the use of optical and scanning electron microscopy, which can emerge as valuable tools for the icon conservator. Conservators will therefore be enabled not only to identify of the materials present, but will be also provided with indications on the preservation state and deterioration factors of artefacts prior to their conservation treatment.

The presence of dust, dirt and other foreign matter on the internal of the fibre structure is typical of fibres of plant origin, such as cotton, possibly due to the irregularity of their external surfaces, which is worsened due to improper environmental conditions during storage and exhibition, or wear-and-tear during handling or even during conservation treatments.

It should be stressed that the research presented in this paper confronted certain limitations. Although the amount of the icons studied can be considered as a representative percentage of the total icon collection of the museum, the authors were directed to retrieve samples from objects already exhibited, and already treated by conservators in the past. Permission for sample retrieval was granted only for artefacts whose fabric fibres were already exposed, therefore, the majority of the objects of the museum, which had already undergone conservation treatment, was inaccessible to the research team. The length of samples to be taken was limited to a minimum size, and thereafter, one of the samples was not large enough to allow for its identification.

The poor preservation state of the long-exposed fabric surfaces, the presence of deposits, and conservation materials, mainly consolidants, rendered the identification procedure even more difficult. This further strengthens the argument that samples be analysed and materials be identified and recorded prior to conservation treatment.

Another limitation regarding the identification of the collected samples lies in the nature of plant fibres themselves. It should be noted that, in general, linen fibres share similar features as hemp fibres, which often leads to difficulties in distinguishing and identifying between the two types. In the examination of the samples and after a review in relevant bibliography, the separation of hemp and linen was based on the different formations of the vertical and parallel lines, as well as the observation of the ends of the fibres (Lewin, 2007; Wiener *et al*, 2003).

Easily accessible software such as Microsoft Excel and IBM SPSS were proven relatively simple to use, and could prove useful tools for the future, enabling researchers to categorise, classify, visualize, and statistically analyse both quantitative as well as qualitative data retrieved after the identification of the materials of icons. The ability to correlate between selected variables opens new horizons for the researchers. However, in the statistical tests attempted within this research, a correlation between the size of the icons or the century in which they were created, to the type of fabric used as a substrate, was not rendered possible. This can be explained by the small number of samples, and the limitations set during sampling. This however could set the basis for the planning of a more carefully designed research in the future, that could include a greater number of samples that could allow a better classification of larger groups of data, such as icon size, era of construction, geographical origin etc. A greater number of samples would limit the statistical error factors and enable the drawing of more accurate conclusions in terms of statistical analysis.

Nevertheless, the outcomes of the present research could set the basis for the creation and development of a database, with the input from icon conservators, who would upload the data from their own research and studies. In this way, a valuable, hopefully online tool could be created, aiming to shed some light into the materials choice of the past hagiographers over the course of time, allowing future correlations of both quantitative as well as qualitative data.

6. CONCLUSIONS

Three types of fabric were identified as the material icon substrates at the Museum of Byzantine Culture in Thessaloniki: cotton, hemp and linen. Cotton and hemp seem to have been used throughout the centuries studied, especially 15th-18th, whereas hemp was identified on earlier icons of the 14th-16th c. Statistical analysis does not seem to indicate a correlation between the choice of fabric and century of the construction of the icons, nor between the type of fabric and size of the icon. Yet, this may be explained by the limited number of samples used in this study. In most cases, fibre identification through OM and SEM was possible,

even for small-sized samples, however the poor preservation state and the presence of deposits and conservation materials on the surface of samples may render identification difficult, unless higher magnifications, i.e. through SEM, are achieved. To safely reach conclusions on fibres of a similar appearance, SEM proved to be a valuable tool, allowing the identification of microscopic fibril features. A carefully planned research, with a representative number of samples, and particularly prior conservation treatment, and the use of statistical analysis of both quantitative and qualitative data can provide valuable information for the icon conservator and researcher.

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REFERENCES

Baldinger, S. (1994) *Textiles a Classification of Techniques*. Washington, Smithsonian Institution Press.

Catling, D. and Grayson, J. (2004) *Identification of Vegetable Fibres*. London, Archetype.

Cennini, C. (1859), *Il libro dell' arte o trattato della* pittura. Pub. F. Le Monnier. Original publication available online at https://archive.org/details/illibrodellarte00cenngoog (accessed 10/06/2019).

Cook, J., G. (1984) *Handbook of Textile Fibres. Volume I. Natural Fibres*, Woodhead Publishing.

Dionysius of Fourna (1909), Interpretation of the painting art. Original publication available online at https://archive.org/details/hermeneiateszogr00dion (accessed 10/06/2019)(in Greek)

Easmond, A and Liz, J. (2000) *Icon word - The power of image in Byzantium*. New York, Metropolitan Museum of Art.

Farnfeld, C. A. (1975) *Identification of Textile Materials*. Manchester, The Textile Institute.

Galanopoulou-Sendouka, S. (2002) Industrial plants. *Cotton and others. Textile, Olive oil, Sugar Beet, Tobacco*, Thessaloniki, Stamoulis (in Greek).

Garside, P and Wyeth, P. (2003) Monitoring the Deterioration of Historic Textiles -Developing Appropriate Micromethodology. In: *Papers of the Conservation Science Conference*, Edinburgh, 22-24 May, 2000. London, Archetype.

Gettens, R. and Stout, G. (1942) *Painting materials - A short encyclopaedia*. New York, Dower publications.

Glykatzi-Arveler, E. (2012) Why the Byzantium?, Athens, Metaixmio (in Greek).

Goodway, M. (1987) Fiber identification in practice. *Journal of the American Institute of Conservation,* Vol 26, No1, pp. 27-44.

Greaves, P.H and Saville, B.P. (1995) *Microscopy of textile fibres*. Oxford, Bios Scientific Publishers.

Gregory, T.E. (2010) *A History of Byzantium*, Malden, Wiley-Blackwell.

Haack Christensen, A and Jager, A. (eds) (2019) *Trading Paintings and Painters' Materials 1550–1800*. London, Archetype.

Janaway, R and Wyeth, P. (2005) *Scientific Analysis of Ancient and Historic Textiles,* London, Archetype.

Jaro, M.; Gal, T. and Toth, A. (2000) The Characterisation and Deterioration of Modern Metallic Threads. *Studies in Conservation*, Vol. 45, pp. 95-105.Karatzani, A. (2010) Morphological Approach on the Analytical Investigation of metal threads. *Conservation Science Today*, Thessaloniki 26-28 November 2010.

Karydis, C. (2006) The Fabric Support in Portable Icons: Investigation, Documentation & Conservation. In: *ICOM-CC International Conference for Icons. Research, Conservation & Ethical Issues, Benaki Museum,* ICOM-Greek Group, 3-7 December, Athens, pp. 1-24.

Kousouni, CK and Panagopoulou, A. (2018) Non - destructive physicochemical analysis and conservation of metallic book covers of ecclesiastical books from saint Mavra and Timotheos church in Zakynthos (Greece). *Scientific Culture*, Vol. 4, No 2, pp. 85-95 (DOI: 10.5281/zenodo.1214571).

Lewin, M., (2007) *Handbook of fiber chemistry*. 3rd Edition, Taylor & Francis Group CRC Press.

Khan, A.N.; Abir, N.; Rakib, M.A.N.; Saberin Bhuiyan, E.M.; Howlader, M.R. (2017) A review paper on Textile Fiber Identification, *IOSR Journal of Polymer and Textile Engineering (IOSR-JPTE)*, Vol.4, Is. 2, pp. 14-20.

Museum of Byzantine Culture (2019 a) *Founding History* [online]. Available at https://www.mbp.gr/en/founding-history (accessed 06/06/2019).

Museum of Byzantine Culture (2019 b) *Wooden Icons* [online]. Available at https://www.mbp.gr/en/wooden-icons (accessed 06/06/2019).

Photo-Jones, E., Henry, A and Kavasila, P. (1996) SEM and TEM examination of byzantine & post-byzantine metal thread in Greek Orthodox Ecclesiastical Textiles. In: *Preptints of the 3rd Symposium of H.S.A*, Athens, 1996. Athens: Hellenic Society for Archaeometry.

Protopapas, S., Christophoridou, E and Karampotsos, A. (2002) Physicochemical Investigation of Metal Threads in Historic Textiles. *Archaeology & Arts*, Vol. 85A, pp. 61-65. (in Greek)

Rogerson, C. and Eastop, D. (1999) The Application of Cross- Sections in the Analysis of Historic Textiles. *The Conservator*, Vol. 23, pp. 49-56.

Runciman, S. (1990) *The Fall of Constantinople, 1453*, Cambridge, Cambridge University Press.

Schaffer, E. (1981), Identification in Ethnological Textile Artifacts. *Studies in Conservation*, Vol 26, pp. 119-129.

Talbot, R.D. (1972) *The appreciation of byzantine art - Christian art*. London, Oxford University Press.

Timar-Balazsy, A and Eastop, D. (1999) *Chemical Principles of Textile Conservation*, London, Butterworth-Heinemann.

Wiener, J., Kovacic, V., Dejlova, P. (2003) *Differences between flax and hemp*. Technical University of Liberec Hálkova, Liberec, Czech Republic.