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Analysis of Morphological Degradation Examined in Bast Fibers of Archaeological Textiles

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미국 Seip토루의 직물유물 중 인피섬유에서 관찰되는 형태학적 손상에 관한 연구

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Abstract

미국 오하이오주 남서쪽에 위치한 Seip 토루군(100 B.C.~A.D. 500경)의 출토유물들에 대하여 현미경으로 관찰되는 인피섬유의 형태학적 손상을 분석하였다. 형태학적 손상이란 외부로부터의 물리적 혹은 화학적 요인에 의해 섬유의 표면과 내면에 발생하는 형태변형을 말한다. Seip직물에 포함된 인피섬유의 형태학적 손상 정도는 본 연구를 위해 제작된 인피섬유손상지표(IBFM)의 점수의 합으로 나타내었다.

Seip 직물들은 육안으로 보았을 때 우선 숯과 같이 검은 색을 띄고 있는 직물들과 그렇지 않은 직물군으로 분류되었는데 발굴보고서에 설명된 시신과 관련 부장품들의 수습상황으로 미루어 볼 때 검게 된 직물군은 부분적으로 화장된 시신의 부장품이었으며 검게 되지 않은 직물군은 일반매장된 시신의 부장품으로 보였다. Seip직물들은 다시 서로 다른 조직에 따라 분류되는 직물군으로 나뉘어 질 수 있었는데 본 연구에서는 이들 중 가장 빈번히 보이는 교차쌍 위사 트와인조직(Spaced alternate-pair weft-twining)으로 만들어진 직물군과 그 밖의 조직으로 되어 있는 직물군으로 나누고 이들을 각각 얼터네이트(Alternate)와 기타조직(Pooled)으로 명명하였다. 본 연구에서는 Seip직물들 간에 매장방법에 의해 손상정도의 차이가 발생했으며 특히 부분적으로 화장된 직물과 그대로 묻혀진 직물들 간에 섬유손상 정도의 차이가 있었을 것으로 보고 이를 확인하기 위해 검게된 직물군과 검게 되지 않은 직물군 간에, 그리고 얼터네이트와 기타조직으로된 직물군들 간에 IBFM 점수의 차이가 있는지 조사하였다. 섬유의 형태학적 손상은 광학현미경과 주사전자현미경을 사용하여 분석하였으며 분석에 이용된 총 샘플수는 총 132개였다. 수집된 데이터는 t-test를 이용하여 분석하였다.

T-test의 분석결과 Seip 직물들은 검게된 직물군과 검게되지 않은 직물군 사이에서 유의한 손상정도의 차이를 볼 수 있었으며 반면에 조직에 따른 분류에서는 유의한 차이를 볼 수 없었다. IBFM의 평균점수를 비교하면 검게된 직물군보다 검게되지 않은 직물군이 더 높은 점수를 나타내어 후자가 더 많이 손상된 것으로 보여졌다. 7개의 손상형태를 독립적으로 보았을 때 섬유속의 분리정도(degree of bundle separation), 횡금(transverse crack), 그리고 횡선(transverse striations)이 검게된 직물군과 검게 되지 않은 직물군 사이에서, 섬유속의 분리정도, 종금(lengthwise striations)과 횡금이 얼터네이트와 기타조직 사이에서 각각 유의한 차이를 보였다.

Key words: Seip textiles, bast Fibers, morphological degradation, Blackend, cremation; 인피섬유, 형태학적 손상, 부분화장

Ⅰ. Introduction

This research deals with the analysis of the textiles excavated from one of the prehistoric Indian mounds of North America. The prehistoric textiles of North America are in most cases made up of bast fibers of different types. Unlike the identification of animal fibers, the identification of plant fibers into specis level is difficult even when sophisticated analytical techniques are used (King, 1978; Catling and Grayson, 1982; Goodway, 1987). Due to such difficulty, fiber analyses of archaeological textiles made of plant materials need to be directed to the examination of other physical and elemental characteristics than the typical fiber identification. In this study, the prehistoric textiles from the Seip Group of Mounds (ca. 100 B.C. to A. D. 500) of southwest Ohio were examined in regard to their degree of fiber degradation which is represented in the microscopic morphology of bast fibers.

A textile artifact under investigation exhibits the cumulative sum of physical and chemical changes which have occurred after the site excavation as well as during its phases of production, usage, and deposition after discard. Physical and chemical changes in fibers cause fiber degradation which gradually modifies the surface and inner shapes of individual fibers. Fiber degradation in a textile may be investigated through microscopic observations of the fiber's surface and inner morphologies and the technique has been found to be effective by different researchers (Zeronian, Alger, Ellison, and Al-Khayatt, 1986; Bresee and Goodyear, 1986; Cooke and Lomas, 1987). The present research was based upon such microscopic analysis of the Seip textiles in which the microscopic fiber morphologies were considered to represent the cumulative fiber damage due to production, utilization, burial, and post-excavation treatments imposed on the Seip textiles.

Prior research on the Seip textiles revealed that the Seip textiles could be grouped according to several distinct visual traits (Song, Jakes, and Yerkes, 1996), and three different fiber compositions were identified among them. A certain number of Seip textiles are composed only of bast fibers or of rabbit hair fibers, while others contain both rabbit hair and bast fibers. It was also found that the three different fiber compositions each belong to the separate visual groups. Based upon these results, the purpose of this research reported herein was to examine whether there is a difference between the different groups of the Seip textiles and the cumulative degradation of bast fibers observed in each. The research concentrated on the bast fibers of the Seip textiles, either found alone or in conjunction with rabbit hair fibers.

In order to measure the cumulative fiber degradation, a survey tool labelled, the "Index of Bast Fiber Morphology" was developed based on the following review of literature on the degradation of bast fibers.

The survey tool has its theoretical basis on Ahn (1993) who introduced a theoretical model which illustrated that the ultimate fiber morphology (Δ) is the sum of all the degraded morphologies ($\Delta_1 \sim \Delta_4$) which have occurred during the four life stages of an archaeological textile; the biologic as the growth stage, systemic as the manufacture, use, and discard stage, archaeologic as the long-term burial stage, and the post-excavation stage.

Literature Review on Bast Fiber Degradation

According to Hearle, Lomas, Cooke, and Duerden (1989) and Cooke and Lomas(1987), different forms of damages occur in the fibers of archaeological textiles during growth, manufacture, use, burial, and post-excavation stages. These damages produce changes in fiber's morphology whether they

are due to biological degradation, burning (or carbonization), or chemical attack (Hearle et al., 1989). Even among the textiles made of the same fiber types, each textile would exhibit its unique variation in fiber morphologies as a result of differential degrees of degradation during its life.

Ray, Sengupta and Das (1986) report that the scanning electron microscopy of jute fibers at different stages of fiber processing showed the increasing amount of longitudinal and transverse cracks on the surface of the fiber as a result of progressive delignification. This is similar to what Appleyard (1972) examined as the effect of mechanical processing which caused fibrillation and transverse cracking on wool and some synthetic fibers.

The initial difference in fiber morphologies are due to the different species or genera of fibers. Among the four types of vegetable fibers- woody fibers, bast fibers, leaf fibers, or seed fibers- Schaffer (1981) explained that the seed fibers were not introduced to the native Americans until the European contact began. A textile which may be an example of the possible usage of the woody fibers was reported by Shetrone and Greenman (1931) in the Seip excavation report. Among the four types of vegetable fibers, the bast fibers which are obtained from the stalks of dicotylodonous plants were predominantly used for the fabrication of finer fabrics by the prehistoric people of North America. Table 1 shows the types of bast fibers known to have been used for textiles and related materials of the ethnological and archaeological collection of the Indians of eastern North America. Among those in the figure, Whitford (1941) suggests that Indian hemp, swamp milkweed, basswood, yucca, and slender nettle were found in the fabrics of the Ohio Hopewell.

Within a fiber type, the growth conditions (environmental) and the activities related to the cultivating and the collecting of the fibrous materials affect the variations in fiber morphology. Different dislocation structures can occur due to the differential rate of the compression of cell walls during growth, The degree of maturity can affect fiber width, lumen size, and other morphological factors.

The spinning and fabrication processes employed by the prehistoric people of North America may be similar to that employed by the historic Indian tribes (DuPratz, 1972[1774]; Smith, 1970[1624]). Hearle et al. (1989) suggest that in most cases the preparation of textiles using hand manipulation yields little to no damages on the fibers. Cooke and

Table 1. Types of Bast Fibers Found among the Prehistoric Textile Related Artifacts of the Eastern North America

Botanical name	Common name	Artifact type
Asimina triloba	paw paw	cords, mats, rope
Apocynum androsaemifolium	dog-bane	fish net
Apocynum cannabinum	Indian hemp	fabric, fish net
Asclepias tuberosa	highland milkweed	fabric
Asclepias pulchra	swamp milkweed	rope, fabric
Asclepias incarnata	milkweed	rope, fabric
Asclepias syriaca	milkweed	fish net, cord, burden strap
pirca palustris	moose or leather wood	rope, fabric
Tilia americana	basswood	finer cord fabric
Eryngium yuccaefolium	yucca	cord, cloth
Boehmeria cylindrica	stingless nettle	soft material
Urtica gracilis	slender nettle	cloth, cord
Laportea canadensis	woods nettle	cord

Lomas (1987) discuss the effect of wear and long-term burial on the degradation of the fibers of archaeological textiles. They suggest that different types of wear damage produce recognizably different fracture morphologies in fibers; fiber failure due to normal wear results in fibrillation, whereas ageing due to oxidation, light degradation, chemical, fungal orbacterial attack results in transverse cracks or embrittlement of fibers. Bresee and Goodyear (1986) also found distinct fracture morphologies of naturally aged historic silk fibers compared to modern, artificially damaged silk fibers where the historic silk fibers showed more diverse and complex damaged morphologies than the modern ones.

After being discarded and buried, the textile in the archaeological environment gradually becomes decayed over time due to microbiological attack. Transverse cracks or embrittlement of fibers may be presented in fibers after a prolonged stay in the burial environment (Goodway, 1987). Hearle et al. (1989) noted, however, that if the textile had been burned in a controlled manner (i.e. without destruction of fiber structure), the charring of cellulose could eliminate most of the risk of biodegradation which might naturally occur in a buried textile. The charred textile may be obtained through a slow combustion with a low supply of oxygen (Hearle et al., 1989). The buried textile will adapt to its new environment through modification until it builds a stable relation between it self and the soil (Dowman,1970).

Index of Bast Fiber Morphology

Based on the above literature review, the Index of Bast Fiber Morphology (denoted as IBFM hereafter) was developed. Although it is possible that fiber types other than bast fiber (such as animal hair, feathersor seed hair fiber) are present among the Seip textiles, the IBFM was designed for bast fibers alone because chemically different fiber types undergo different degradative mechanisms and because bast fibers constitute a large part of the composition of fibers in the textiles of eastern North America.

Through the review of related literature, the researcher was able to select and limit the expected morphological features on the bast fibers of a degraded textile artifact. They are the 'degree of bundle separation,' 'lengthwise striations,' 'transverse striations,' 'surface folds,' 'fibrillation' and 'transverse cracks.' The index was constructed in the form of a checklist with 6 items, each of which represent the morphological features discussed above. The definition set forth in this study for each morphological feature is displayed in Table 2.

Table 2. Definitions of Six Degradative Morphologies

Degradative Morphology	Definition (Reference Citation)
Separation of Bundle	Bundle of schlerenchyma cells which forms a single unit(Rahman and Sayed -Esfahani, 1979)
Lengthwise Striation	Striations which run longitudinally along the fiber length (Rahman and Sayed -Esfahani, 1979)
Transverse Striation	Striations which run crosswise along the fiber length (Rahman and Sayed -Esfahani, 1979)
Surface Fold	Folds which occur on ultimate fibers due to the loosening of the bonding, and thus the volume change, between thefibrils and the cementing materials (Rahman, 1979)
Fibrillation	Breakdown or separation offibrils from the fiber (Mukherjee, Mukhopadhysy, and Mukhopadhyay, 1986)
Transverse Crack	Breakage of fiber which occur on the crosswise direction of the fiber (Cooke and Lomas, 1987)

Each item in the IBFM contains its sub-items concerning the presence or absence, or the degree of presence of a specific morphological feature. The sub-items of each of the 7 items were given the score from 0 to 3, depending on the levels of sub-items. A score stands for the extent of fiber degradation, the highest number representing the most degraded level. A score of 0 of degree of bundle separation stands for the situation when the specific morphological feature is not identifiable, or it is difficult to define the level within the feature, whereas scores 1, 2, and 3 stands for the degree of separation as 'single ultimate fibers present,' 'bundle and single ultimate fibers co-exist,' and 'all fibers are of a bundle form,' consequetively. The rest of the morphological features have only two score levels in which a score of 1 representing 'absence' and a score of 2 representing 'presence' of a certain morphological feature.

The appropriate sub-items of each item were checked while conducting the microscopic analysis. Before carrying out the microscopic analysis, content validity of the instrument was tested by a panel comprised of three experts in the field of textiles and clothing. Reliability of the instrumentwas also checked by the members of the panel through a pretest on the Seip textiles.

Seip Fiber Analysis

The Seip textiles examined in this research are associated with the prehistoric Hopewell culture of southwest Ohio. Over two hundred fragments of textiles of varying sizes were recovered among numerous artifacts of different classes during the two series of excavations which took place from 1906 to 1926. The publications of the two different excavations of the Seip Mound Group provide ample evidence that the textiles were of ceremonial significance to the Seip population (Mills, 1909; Shetrone and Greenman, 1931). The Seip textiles are currently curated at the Ohio Historical Society of Columbus, Ohio.

After the excavation, the Seip textiles are said to have been carefully dusted with brush without any further washing, mending, or disinfecting (personal conversation, M. Otto). Except for 7 pieces which were in direct contact with copper artifacts, all the remaining textiles were mounted between two rectangular glass plates. As few as twenty different fragments of sizes less than $3\times3\ cm^2$ were mounted in each set of glass plates. In this manner, the textiles were stored in a temperature and humidity controlled storage room. The textiles received least handling with limited access of museum personnels or researchers over the years.

Early discussion on the Seip textiles appeared in Mills (1909) and Shetrone and Greenman (1931) in their report of excavations. Willoughby (1938) examined the fabrication structure, and Whitford (1941) reported the result of fiber identification using a simple microscopic technique. Church (1983, 1984) suggested the social implications which may be inferred from the different fabrication types. Song (1991) conducted an extensive survey of the microscopic characteristics of the Seip textiles. And Jakes, Chen, and Sibley (1993) attempted to identify the bast fiber species found in selected number of the Seip textiles using a comparative plant collection. Recently Song, Jakes, and Yerkes (1996) led to a cultural inference on the textile production, utilization, and discard behaviors of the Seip population based on the analysis of the Seip textile.

As noted earlier, the prior research on the Seip textiles indicated that some of the textiles were made only of bast fibers, and some were made of both animal hair and bast fibers (Whitford, 1941; Song, 1991; Song, etal., 1996). It was also found that the textiles could be grouped into two distinct visual categories. One group of textiles were totally soot black, whereas the other group of textiles were

of natural color of bast fiber. Such characteristic seems to be a good proof of the Seip burial treatments described in the excavation reports.

The excavation reports by Mills (1909) and Shetrone and Greenman (1931) suggest that the archaeological evidence of the Seip Mound Groups reflects extensive mortuary rituals practiced upon death of an individual. Two methods of treatment for the dead were noticeable; cremations and in-flesh burials, both of which included a careful 'decoration' of the dead with various copper ornaments, beads, mica, as well as textiles. Mills (1909) and Shetrone and Greenman (1931) suggest that the cremation practice of the Seip population included the placement of the textile in direct contact with the body and its associated artifacts before the body was burned. With the in-flesh burials, textiles were often found beneath the copper breastplates which were laid underneath the head and neck of the dead.

The cremation practiced by the Seip population would produce charred textiles which closely resemble charcoal as described by Cooke (1964). According to Cooke (1964), humus and charcoal are different in that the former is the result of the long-term deterioration ofthe plant residues in the micro-environment, and the latter is the result of a high temperature combustion by fire. It seemed obvious that the 'blackened' Seip textiles were products of the cremation practice among the Seip population whereas the 'unblackened' Seip textiles represent the association with the in-flesh burials.

Other than the blackened effect, different types of fabric structure also separated the Seip textiles into different groups. Four different fabric structures were found among the Seip textiles. They are spaced alternate-pair weft-twining, spaced 2-strand weft-twining, interlacing, and oblique interlacing following Emery's (1980) terminologies. Previous research (Song et al., 1996) identified that 117 of the total Seip textiles were all constructed with the spaced alternate-pair weft-twining technique, whereas the remaining 15 textiles were constructed with either spaced 2-strand weft-twining, interlacing, or oblique interlacing techniques. All the blackened textiles were constructed with the spaced alternate-pair weft-twining method. All of the 15 textiles constructed otherwise are unblackened. The Seip textiles constructed with the spaced alternate-pair weft-twining technique were grouped and labeled as the Alternate group, and the Seip textiles constructed otherwise were grouped together and were labeled as the Pooled group.

Hypothesis

From the above description of the Seip textiles and the assumption of cumulative fiber degradation, the researcher conjectured that beyond other treatments which the Seip textiles received during their life, different burial practices would have caused the most difference in the degree of fiber degradation. As a result, one may expect to see a difference in the cumulative degradation between the group of Seip textiles which had been involved in the cremation practice and the group of Seip textiles which had been involved in the in-flesh burials.

Although not as apparent as the degradation incurred by different burial treatments, the difference in the fabrication structures, another more readily recognizable difference, might also have an effect on the different degrees of fiber degradation. Thus, the hypotheses were designed for the comparison between first, the Blackened and the Unblackened textiles, and second, the Alternate and the Pooled groups of textiles. The research hypotheses for this study were as follows:

Hypothesis I: There is a difference between the cumulative fiber degradation of the Blackened group of Seip textiles and that of the Unblackened

group of Seip textiles.

Hypothesis II: There is a difference between the cumulative fiber degradation of the Alternate group of Seip textiles and that of the Pooled group of Seip textiles.

The degree of cumulative degradation in fiber morphologies was defined as the sum of the IBFM score obtained through the microscopic analysis.

Samples

As noted earier, the Seip textiles were in most cases mounted between two rectangular glass plates. Each piece of textile fragment within the glass plate as well as the ones on the copper breast plate were counted as individual piece. From the 226 Seip textiles, textiles which were smaller than $3\times3\,cm^2$ were excluded from the sampling frame. And the textiles which showed other visual characteristics than the blackening and the unblackening were also excluded. As a result, 45 textiles were selected as the sample textiles. From each of the 45 textiles, a yarn smaller than 1.0cm in length was cut out from three different areas within a piece for the microscopic examination. From the prepared yarn samples, the yarns containing rabbit hair fibers only were excluded again, not to be included in the hypotheses tests. Therefore, the total number of samples with which the hypotheses tests were conducted were 132, and these will be labelled as the 'yarn samples' in the following text. Among these, 75 samples belonged to the Blackened group and 57 samples in the Unblackened group. When the same yarn samples were grouped again in terms of fabric construction, 117 samples were in the Alternate group and 15 samples were in the Pooled group.

Data collection and Analysis

Materials: Fiber sample for microscopy was taken from each yarn sample either by cutting a micro-sized fragment from each yarn sample or by collecting the fiber mass from the sample vial in which the yarn sample was stored. Each fiber specimen for transmitted light microscopy was mounted with water on a glass slide. For some yarn samples in which the surface and innerstructures were difficult to observe with the water mount, Zinc Chloro-iodide stain was applied. For reflected light microscopy, fibers were dry mounted on a preprepared nonreflective black microscopic slide. Fiber specimens for SEM were mounted either on carbon planchettes or on aluminum stubs with Pelco colloidal silver paste and were gold coated using the Denton Vacuum Desk II sputter coater.

Equipment: A Zeiss Axioplan Research microscope equipped with MC100 camera and 10X eyepiece, 10X, 40X, and 100X objective lenses was used for the light microscopy. All the unblackened Seip textiles were examined using the transmitted light microscope. All the blackened Seip textiles were examined under reflected light since the blackened fibers prohibited the transmission of light. A JEOL JSM-820 Scanning Electron Microscope was used for the scanning electron microscopy (SEM). SEM was conducted on selected samples when the surface structure of the fiber was not clearly observable by means of the light microscopy.

Collection of data: During the microscopic observation each yarn sample was examined regarding the degree of bundle separation, presence of twist, lengthwise striation, transverse striation, surface folds, fibrillation, and crack. As a result, each yarn sample was given its own score of IBFM.

Data analyses: The data were analyzed using the SPSS for MS WINDOWS version 6.0. The difference in the cumulative score of IBFM between the groups was compared using the independent samples t-test at .05 alpha level. In order to minimize the possible errors in the hypothesis test, and

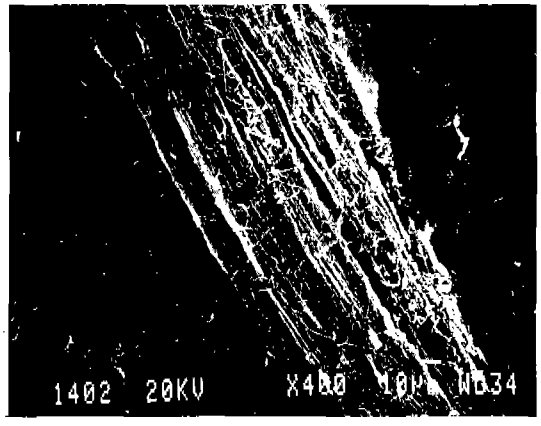

Fig. 1. Fibrillated fiber bundle in Seip 1402, SEM at 400X.

Fig. 2. Transverse Cracks in Seip 1901, SEM at 400X.

to control the possible inequality of variances between the two populations of textiles, Levenes test for equality of variances (F value) was carried out prior to the t-test (Koh and Kim, 1992). Depending on the F value and the corresponding probability, the appropriate t-value between the t-value for equal variances and the t-value for inequal variances was chosen.

Results

The bast fibers of the Seip textiles were found mostly in bundle form, differing in the degree of separation into smaller bundles. In many cases, the fibers showed numerous lengthwise or transverse striations, some leading to fibrillation (Fig. 1) in the lengthwise direction or cracks (Fig. 2) in the opposite direction.

The microscopic analysis of fiber samples based on the Index of Bast Fiber Morphology is summarized in Tables 3, 4, 5 and 6. Tables 3 and 4 shows the frequency distribution of yarn samples in the Blackened, the Unblackened, the Alternate, and the Pooled groups regarding different score levels of 6

Table 3. Frequencies for Each Score Level of 6 Morphological Features in the IBFM: The Blackened and the Unblackened Groups

		Blackened		Unblackened		Total	
		Frequency	%	Frequency	%	Frequency	%
Separation of Bundle	0	0	0	3	5.3	3	100.0
	1	7	9.3	18	31.6	25	
	2	39	52.0	15	26.3	54	
	3	29	38.7	21	36.8	50	
Lengthwise Striation	1	4	5.3	8	14.0	12	100.0
	2	71	94.7	49	86.0	120	
Transverse Striation	1	53	70.7	23	40.4	76	100.0
	2	22	29.3	34	59.6	56	
Surface Folds	1	54	72.0	28	50.0	83	100.0
	2	21	28.0	28	50.0	49	
Fibrillaion	1	63	85.1	42	73.7	106	100.0
	2	11	14.9	15	26.3	26	
Transverse Crack	1	70	93.3	30	52.6	100	100.0
	2	5	6.7	27	47.4	32	
Column Total		75	100.0	57	100.0	132	

Table 4. Frequencies for Each Score Level of 6 Morphological Features in the IBFM: The Alternateand the Pooled Groups

		Blackened		Unblackened		Total	
		Frequency	%	Frequency	%	Frequency	%
Separation of Bundle	0	3	2.6	0	0.0	3	100.0
	1	20	17.1	5	33.3	25	
	2	44	37.6	9	60.6	53	
	3	50	42.7	1	6.7	51	
Lengthwise Striation	1	5	4.3	8	53.3	13	100.0
	2	112	95.7	7	46.7	119	
Transverse Striation	1	72	61.4	4	26.7	76	100.0
	2	45	38.5	11	73.3	56	
Surface Folds	1	76	65.0	6	40.0	82	100.0
	2	41	35.0	9	60.0	50	
Fibrillaion	1	96	82.0	10	66.7	106	100.0
	2	21	18.0	5	33.3	26	
Transverse Crack	1	91	77.8	8	53.3	99	100.0
	2	26	22.2	7	46.7	33	
Column Total		117	100.0	15	100.0	132	

Table 5. Mean of IBFM Socre between the Blackened and the Unblackened Groups and the Results of T-text for Equality of Means (α=.05)

Morphology	Means of IBFM Scores		T-test Results		
	Blackened n=75	Unblackened n=57	df	t-value[1]	P<[3]
Cumulative Score	10.60	11.14	86.14	2.02(U)[2]	0.470*
Bundle Separation	2.43	1.84	130.00	4.35(E)	0.000
Lengthwise Striations	1.95	1.86	90.24	1.63(U)	0.106
Transverse Striations	1.29	1.60	115.62	3.60(U)	0.000*
Surface Folds	1.28	1.50	111.04	2.58(U)	0.011
Fibrillation	1.15	1.26	105.77	1.59(U)	0.115
Transverse Crack	1.07	1.47	77.07	5.59(U)	0.000*

[1]The t-values presented here are the absolute values of the test results.

[2]The (U) represents the t-values for unequal variances and the (E) represents the t-values for equal variances between the two groups.

[3]p-values with *are significant at alpha=.05.

Table 6. Mean of IBFM Socre between the Alternate and the Pooled Groups and the Results of T-text for Equality of Means (α=.05)

Morphology	Means of IBFM Scores		T-test Results		
	Blackened n=117	Unblackened n=15	df	t-value[1]	P<[3]
Cumulative Score	10.81	11.07	130.00	0.66(U)[2]	0.513
Bundle Separation	2.21	1.73	130.00	2.17(E)	0.032*
Lengthwise Striations	1.96	1.53	14.56	3.15(U)	0.007*
Transverse Striations	1.38	1.73	18.34	2.76(U)	0.013*
Surface Folds	1.35	1.57	129.00	1.62(E)	0.108
Fibrillation	1.19	1.27	129.00	0.70(E)	0.485
Transverse Crack	1.21	1.47	16.36	1.82(U)	0.086

[1]The t-values presented here are the absolute valuesof the test results.

[2]The (U) represents the t-values for unequal variances and the (E) represents the t-values for equal variances between the two groups.

[3]p-values with *are significant at alpha=.05.

morphological features in the IBFM. The mean score of each morphological feature in each group as well as the mean of the cumulative sum of 6 items is illustrated in Tables 5 and 6. The mean of IBFM score of the Blackened group was 10.61, where as the Unblackened group was 11.14. In the case of the Alternate and the Pooled groups, the mean of IBFM score of the former was 10.81, and that of the latter was 11.07.

The results of t-tests for equality of means between the Blackened and the Unblackened groups on the cumulative score and also on the 6 individual items is illustrated in Table 5. The t-value for the mean difference between the cumulative scores was 2.02 with the $p<.047$, slightly below the alpha level. The test did indicate that there was a significant difference between the textiles in the Blackened group and the textiles in the Unblackened groups in the cumulative score of the index at alpha=.05. Among the 6 morphological features, the degree of separation of bundle ($p<.000$), presence or absence of transverse striations ($p<.000$), surface folds ($p<.011$), and transverse cracks ($p<.000$) showed significant difference at the given alpha level.

Contrary to the above result, the t-tests for equality of means between the Alternate and the Pooled groups illustrated that there was no difference between the textiles in the two groups on the cumulative score of IBFM (Table 6). The t-value for the mean difference between the cumulative scores was .66 with the $p<.513$, far above the alpha level. Among the 6 morphological features, the degree of separation of bundle ($p<.032$), presence or absence of lengthwise striations ($p<.007$), and the presence or absence of transverse striations ($p<.013$) showed significant differences at the given alpha level.

Discussion

Statistical analysis showed that the difference in cumulative degradation existed only between the textiles in the Blackened and the Unblackened groups and not between the textiles in the Alternate and Pooled groups. The probability of the t-test between the Alternate and the Pooled groups was high enough to be certain of the no-difference result. Since the two hypotheses in this research deal with the two different phases in the life of the Seip textiles, phases of the textile fabrication and the burial discard, the result implies that more variation in fiber damage occurred during the phases of burial discard than during the phase of textile fabrication.

As noted earlier, the Seip burial practices included both cremations and in-flesh burials, and the Seip textiles with either blackened or unblackened appearance were good proofs of these burial practices. The result shows that the two different burial practices imparted differential degrees of fiber degradation on the respective textiles. Furthermore, the means of IBFM score of the Blackened group and that of the Unblackened group indicate that fibers of Blackened Seip textiles were damaged less than the fibers of Unblackened textiles. Such a result seems to coincide with Hearle et al.'s (1989) theory about a carefully burned textile which could be protected from most of the biological attacks after burial.

Similar results as above were observed among the three morphological features which showed statistical differences. When the means of IBFM scores of four morphological features are compared between the Blackened and the Unblackened groups, except for the degree of separation of bundle, the means of Blackened textiles were smaller than those of the Unblackened textiles. It is probable that Hearle et al.'s theory on burned

textiles also holds for degradative morphologies such as transverse striations, surface folds, and transverse cracks. However, following this theorem, the difference in the degree of bundle separation between the Blackened and the Unblackened groups is difficult to explain since the mean score of bundle separation of the Blackened textiles (2.43) was larger than that of the Unblackened textiles (1.84). It is probable that the higher degree of separation of fiber bundle among the Blackened textiles originated from the brittleness of burned textiles.

Between the Alternate and Pooled groups, the mean of the Alternate group (1.38) was smaller than that of the Pooled group (1.73) for transverse striations. For both the degree of bundle separation and the presence of lengthwise striations, the Alternate group (2.21, 1.96) had a larger mean value than the Pooled group (1.73, 1.73). However, the results obtained from the Blackened and the Unblackened groups seems to have had a direct impact on the statistical results of the Alternate and the Pooled groups, since all the Blackened textiles belong to the Alternate group. Nevertheless, the t-test for the equality of means between the Alternate and the Pooled groups on the cumulative scores of IBFM do support the fact that the most difference in the degree of fiber degradation aroused from different discarding activity rather than from different fabrication methods.

Conclusion

This research was aimed to investigate the differences between the two visual groups of the Seip textiles on the cumulative effect of the morphological degradation of fibers using the microscopic analysis. It was found that the textiles which had been part of a cremation practice exhibited a lower degree of fiber damage as a whole than the textiles which had been part of the in-flesh burial. As suggested in previous literatures, the result obtained from the analysis of the Seip textiles imply that the partial carbonization aids the preservation of cellulosic textiles during the long-term burial environment. In the case of the Seip textiles, the different burial practices seem to have had a higher effect than the different fabrication methods on the degree of morphological degradation of fibers.

Some of the limitations to this study include the lack of other analytical approach such as a microbiological test between the textile groups or a tensile strength test which virtually measures the result of fiber degradation. However, it is doubtful that a microbiological test will provide a reliable result as to the microbes which actually adhered to the textile during burial, since there is more than sixty years of elapsed time from the point of excavation. Any microbes which may be identified among the sample would mostly have originated from the storage environment rather than from the burial itself when only the latter can explain the degree of microbiological degradation during burial.

In the case of the Seip textiles, limited size of the textile fragments and the overall fragility of the textile prohibits the practice of tensile strength test despite the fact that tensile strength can be a direct measure for comparing the degree of textile degradation. Future research on the Seip textiles should also focus on topics such as the degree of crystallinity in fibers and fiber length measurement as measures of ageing and fragility of bast fibers.

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