

The Unprecedented Discovery Of The Royal Purple Dye On The Two Thousand Year-Old Royal Masada Textile

Zvi C. Koren

ABSTRACT - Nature has endowed certain murex sea snails with the precursors to the most noble, sacred, and expensive of all the natural textile dyes used in antiquity. High-performance liquid chromatography (HPLC) on the purple pigment extracted from a two thousand year-old fabric from King Herod's palace at Masada, detected the presence of brominated indigoids. The chromatographic and spectrometric results indicate that the most probable molluskan source of this purple was the hypobranchial glandular fluid of *Murex trunculus* gastropods. Based on the history, archaeology, religion, and marine zoology associated with this molluskan dye, the significance of the discovery of murex-purple on this fabric is three-fold: (1) This is the first time that a murex-purple fabric from ancient Israel has been discovered, and it is among the oldest 'true purple' textiles discovered anywhere in the world; (2) The fabric found undoubtedly belonged to the western Herodian palace at Masada and may have been part of the royal cloak or mantle of that king; (3) The color of this fabric was most likely that of the biblical Argaman dye.

1. INTRODUCTION

Royal Purple, or Tyrian Purple, as this rare pigment is known, was produced in antiquity from the precursors contained in the colorless, whitish, or yellowish fluids of hypobranchial glands of certain Muricoidea mollusks (figure 1). As described by Greek and Roman historians (Aristotle and Pliny), the dyeing of wool and silk with this chemically reduced pigment, or with its precursors, was undoubtedly one of the oldest and most complex of biochemical technologies in the ancient world. During cer-

tain eras, this precious dye was worth more than twenty times its weight in gold (Bridgeman 1987), which is no wonder, as experiments performed by the author have shown that approximately 10,000 such snails were needed to dye just one cloak! The scarcity of this animal dyestuff and the majestic beauty of murex-purple dyed textiles endeared kings, emperors, caesars, and ecclesiastics. History has recorded that this purple was the fashion of royalty in the empires of Assyria, Babylonia, Persia, Greece, and Rome. Military generals and nobility were also permitted to adorn at least part of their garments with this imperial dye.

Though the Aegean theory of purple-dyeing conjectures that the Minoans of Crete originated this industry almost four millennia ago

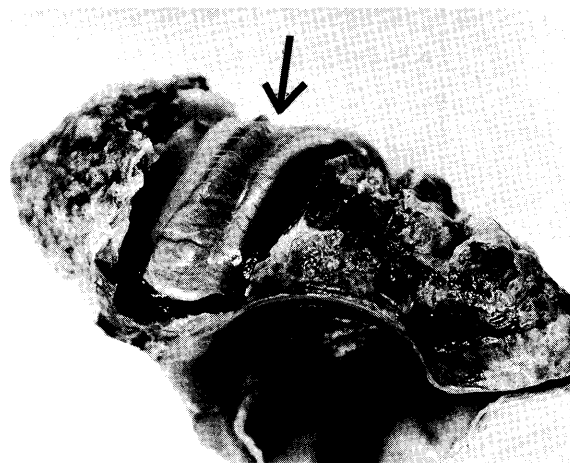
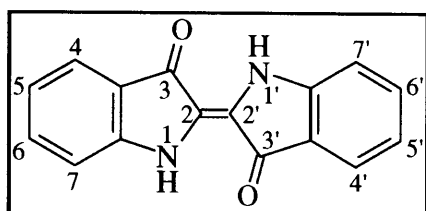


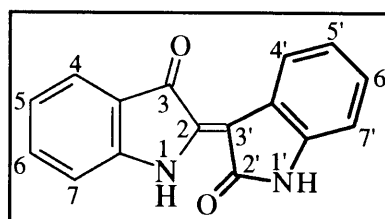
Figure 1. The exposed hypobranchial gland (see arrow) of a *Murex trunculus* snail caught in the shallow waters of Akhziv Beach in northern Israel.

(Stieglitz 1994), history has nevertheless credited the foremost traders and merchants of the ancient world - the sea-faring Phoenicians - with perfecting this craft. The textile dyeings produced by this exclusive industry, whose people were centered at Tyre and Sidon, were prized above all others (Strabo). The preeminent role that the Phoenician craftsmen enjoyed, and the high esteem in which these purple dyers were held, is evident from the 'Tyrian Purple' appellation that history bestowed on these purple goods.

Vestiges of ancient Phoenician purple dyeing installations are found today along the northern Israeli and southern Lebanese coasts. Instrumental analyses of residual pigments on remnants from ancient dyeing vats have shown the presence of, primarily, the purple 6,6'-dibromoindigotin dye (figure 2). These investigations include analyses of a 13th century B.C. purple pigment on a potsherd from Sarepta (Lebanon), by means of proton-induced X-ray emission (PIXE) spectroscopy, electron spectroscopic chemical analysis (ESCA), and dif-



Indigoids



Indirubinoids

Chemical class Dye (<i>abbreviated symbol</i>)	C.I. Constitution Number ¹	Substituents	
		R ₆	R _{6'}
Indigoids			
Indigotin (<i>IND</i>)	75 780	H	H
6-Monobromoindigotin (<i>MBI</i>)		Br	H
6,6'-Dibromoindigotin (<i>DBI</i>)	75 800	Br	Br
Indirubinoids			
Indirubin (<i>INR</i>)	75 790	H	H
6-Monobromoindirubin (<i>MBIR</i>)		Br	H
6'-Monobromoindirubin (<i>MBIR'</i>)		H	Br
6,6'-Dibromoindirubin (<i>DBIR</i>)		Br	Br

¹Dye classification number according to *The Colour Index*; The Society of Dyers and Colourists: London, 1971; 3rd edition, Vol. 4; p. 4639; Vol. 8; p. 8133.

Figure 2. Chemical structures of the indigoids.

fuse reflectance Fourier transform infra-red (FTIR) spectroscopy (McGovern and Michel 1984, 1985). Spectrometric and chromatographic analyses on ancient artifacts from Israel include IR spectrometry performed by Edelstein and Abrahams on purple potsherd pigments from 9th to 8th century B.C. Tel Shiqmona (Karmon and Spanier 1988); visible spectrophotometry of a dark stain on a limestone from 6th century B.C. Tel Dor (Koren 1993a); and high-performance liquid chromatography (HPLC) on a 7th century B.C. Tel Kabri purple potsherd pigment (Koren 1995). The HPLC analysis mentioned above also showed the presence of 6-monobromoindigotin, dark-blue indigotin, and a fourth unidentified dark-red colorant, which may be 6,6'-dibromoindirubin (figure 2) (Koren 1995). These four dye components are also the ones that have been discovered in the purple pigment produced from the hypobranchial gland of the *Murex trunculus* gastropod (Koren 1995).

Tyrian Purple has been identified on ancient textiles excavated from the following archaeological sites: 1st century B.C. Asia (Black Sea coast) via HPLC (Wouters 1992); 1st century B.C. to 1st century A.D. Cyprus via visible spectrophotometry (Daniels 1989); 1st to 3rd centuries A.D. Palmyra (Tadmor) (Pfister 1934, 1937, 1940) and 3rd century A.D. Dura Europus (Pfister and Bellinger 1945), both in today's Syria, via visual colorimetric analyses; 3rd century A.D. Egypt via HPLC (Wouters 1992); 3rd to 4th centuries A.D. Egyptian Coptic textiles via mass spectrometry (MS) (Michel et al. 1992); a painted Paracas cotton textile from pre-Columbian Peru via visible spectrophotometry (Saltzman 1986); Peruvian textiles via MS (Michel et al. 1992); and an unidentified textile from a Cologne museum collection via HPLC (Wouters 1992).

In this study, the HPLC method is utilized

to analyze the purple dye extracted from a small thread that was excised from a two thousand year-old fabric excavated at the palace-fortress complex built by King Herod atop the Judean Desert cliff known as Masada. This HPLC method has been previously used for the analysis of an archaeological residual pigment from a 7th century B.C. clay fragment, which was part of a large Tyrian Purple dyeing vat (Koren 1995).

2. SAMPLE ANALYZED

The textile that was analyzed is shown in figure 3, and was excavated along with other textiles and artifacts in an expedition at Masada led by the late Yigael Yadin, the dean of Israeli archaeologists, between 1963 and 1965 (Yadin 1984). The irregularly shaped woolen textile fragment (number 1132/3) investigated, whose maximum measurements were approxi-



Figure 3.

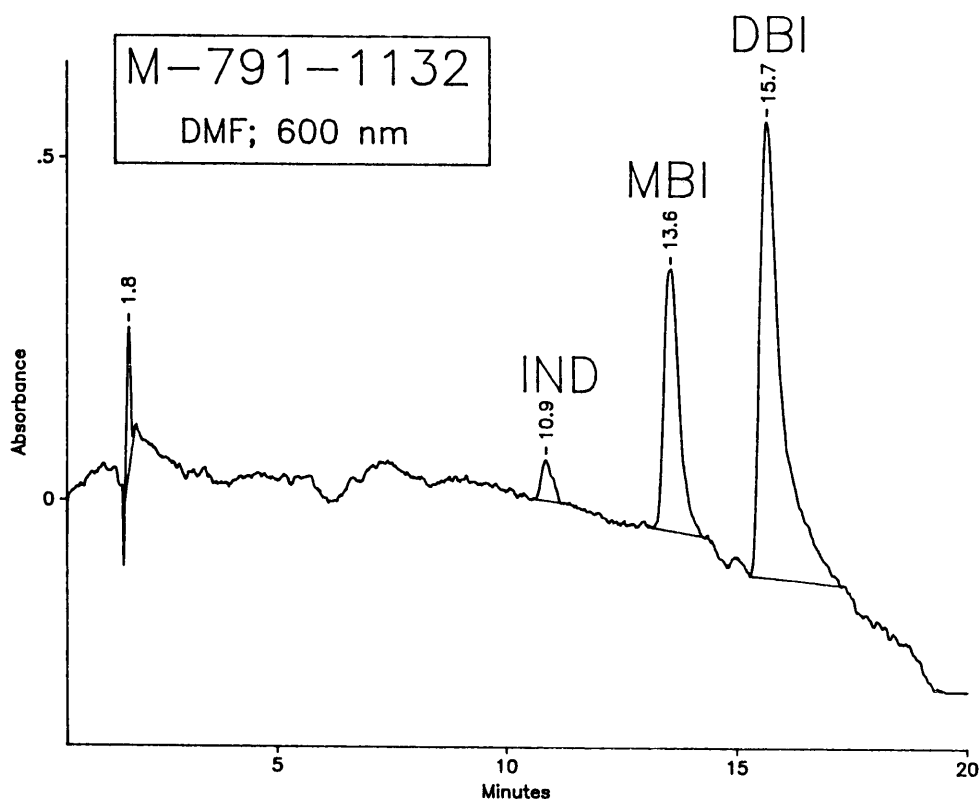


Figure 4. The chromatogram, obtained with a detector wavelength set at 600 nm, of the eluting indigoids from the HPLC analysis of the extracted purple dye from the excavated fabric. Indigotin (symbolized as IND) is the first eluting colorant, followed by 6-monobromoindigotin (MBI), and then by 6,6'-dibromoindigotin (DBI).

mately 2 x 4 mm, was unearthed in an area (locus 791) that was part of the refuse dump of the western palace and was situated at the northeast corner of that edifice (Netzer 1991). That this fabric belonged to the Herodian period (1st century B.C.) is based on the archaeological dating of the other artifacts found with this textile (Netzer, E., personal communication).

3. EXPERIMENTAL DETAILS

The dye analysis scheme consists of dye extraction followed by chromatographic and spectrometric detection, which are described below.

3.1 DYE EXTRACTION

The purple dye from about a 3 mm thread from the textile fragment did not extract from the textile fibers with the hydrochloric acid-metha-

nol system that is effective for direct and mordant red, yellow, and brown dyes (Koren 1993a, 1994). This indicated that the reddish dye was not an anthraquinonoid, such as alizarin or purpurin, which is generally obtained from the roots of the madder plant (*Rubia tinctorum* L.), the most popular red dyestuff in the ancient world (Koren 1993b). Subsequently, the dye began to extract in room-temperature N,N-dimethylformamide (DMF) for one minute, yielding a blue solution which is indicative of an indigoid vat dye. The extraction continued at a near-boiling temperature (150° C.) for another three minutes, producing a deep blue solution.

3.2 CHROMATOGRAPHIC AND SPECTROMETRIC ANALYSES

The HPLC analysis was performed via a reverse-phase linear gradient elution method de-

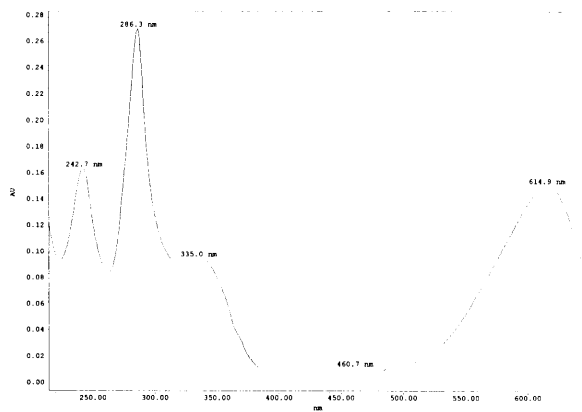


Figure 5a.

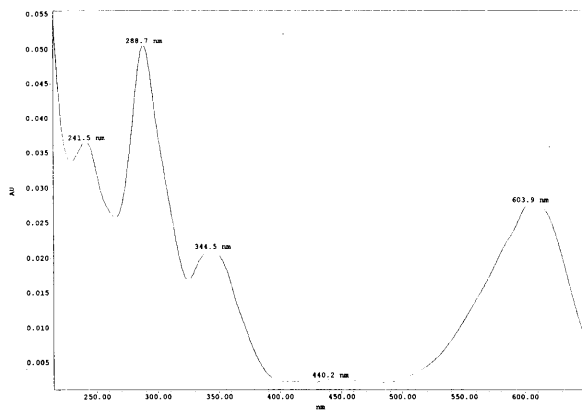


Figure 5b.

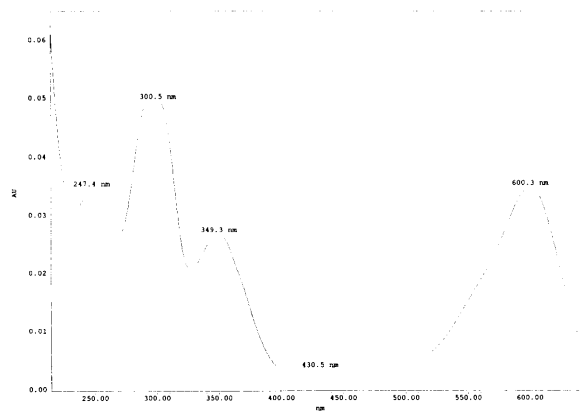


Figure 5c.

Figure 5. UV/Vis spectra of the three indigoids detected in the historic dyeing: (a) IND, (b) MBI, and (c) DBI.

veloped for the separation and detection of indigoids and indirubinoids. This chromatographic system, using a Varian chromatograph and separation method, have been fully described in a previous publication (Koren 1994). The spectrometric analyses were subsequently performed on a purple pigment produced from modern *Murex trunculus* snails caught off the Mediterranean waters in northern Israel. The HPLC system used for this analysis consisted of a Waters 600 Controller with a 996 Photodiode Array detector.

4. RESULTS AND SIGNIFICANCE

The chromatogram resulting from the separation of the ancient purple textile dye components is depicted in figure 4, which shows the presence of the three indigoids discussed above, and the UV/Vis spectra of these components are presented in figure 5. The relative compositions of these three ancient dye components are depicted in figure 6, and are very similar to those obtained from an archaeological pigment from an ancient clay dyeing vat, and to those obtained from a modern *Murex trunculus* purple pigment. Hence, it can be definitely established that this purple dye is of marine origin and that the most probable source of this dyestuff is the *Murex trunculus* mollusk.

The three-fold significance of the discovery of murex-purple on a royal fabric from ancient Israel and its biblical ramification is discussed below.

4.1 UNPRECEDENTED DISCOVERY.

One textile from the late Byzantine period (7th century A.D.) excavated at 'En-Boqeq, Israel, was analyzed in the early 1970s by means of x-ray fluorescence (XRF) and was reported to have been dyed with dibromoindigotin due to the reported presence of bromine in dark blue

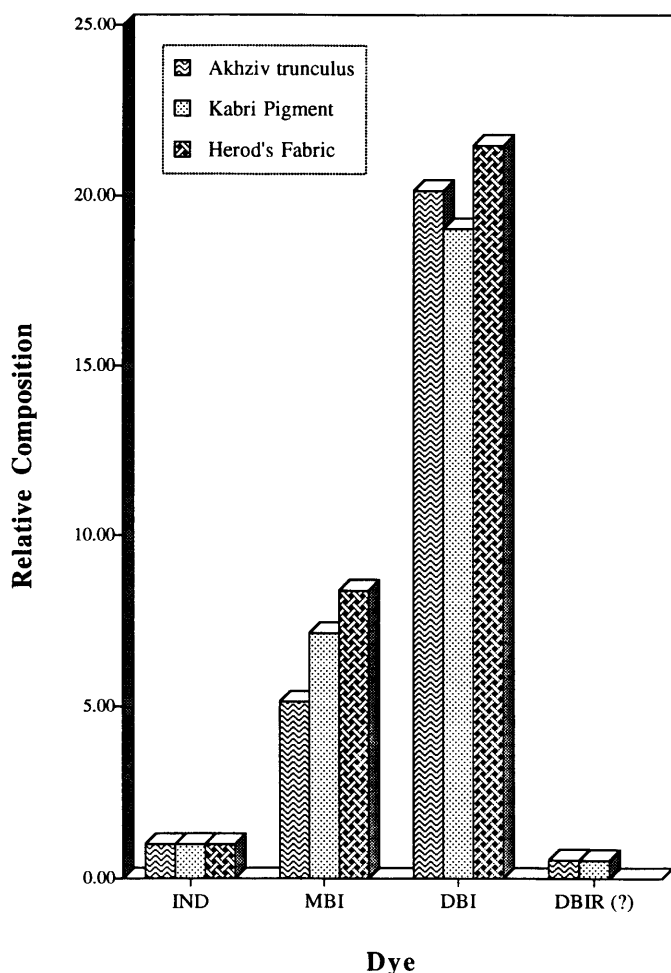


Figure 6. Comparison of the relative compositions, with respect to IND, obtained from absorbance data at 600 nm, which is near the visible λ_{max} of the three indigoids. The data for the archaeological and the modern trunculus pigments are from Koren 1995. DBIR? represents the fourth colorant, which may be dibromoindirubin.

textile dyeing (Masschelein-Kleiner et al. 1991). However, the elemental analysis performed with this technique only detects individual atoms, not whole molecules. Thus, this technique, which was used during the infancy of instrumental analyses of archaeological textile dyes, is not the most appropriate for the detection of the dibromoindigotin molecule. Subsequent XRF analyses recently performed by the author on the questionable 'En-Boqeq textile, and on a number of other fabrics from this site, all showed trace amounts of bromine.

This is not surprising in light of the location of this archaeological site; it is near the Dead Sea, which is rich with bromine, a major commercial product obtained from this area. In addition, the trace quantities of bromine reported on the 'En-Boqeq textile are virtually indistinguishable from the noise level produced from even more modern and sensitive instrumentation. The only colorant detected by this author via HPLC analysis of the dark blue 'En Boqeq dyeing was plant-derived un-brominated indigotin. The HPLC method is very sensitive - limit of detection is on the order of nanograms - and is able to detect trace quantities of residual brominated indigoids from photochemically debrominated turquoise dyeings produced from the dibromoindigotin dye (Koren, Z. C., unpublished). It can, thus, be conclusively stated that the 'En Boqeq textile was not dyed with the purple dibromoindigotin dye, a colorant that is only obtainable from a marine animal source. Hence, the Masada textile analyzed in the current study is, in fact, the first (and, so far, only) murex-purple dyed fabric discovered in Israel, and it is also one of the oldest textiles yet found anywhere that has been dyed with this pigment. Based on the qualitative and quantitative analyses of the purple pigments discussed above, the most likely molluskan dyestuff source is *Murex trunculus*.

4.2 HERODIAN FABRIC

To understand the historical significance of this find, one has to recall the two major historical periods associated with Masada: the Herodian and the revolt (or "zealot") periods. This fortress and palatial complex was built by King Herod, the Rome-appointed Jewish monarch of Judea, during the middle of his reign (37 to 4 B.C.). History recounts that he built the palaces and other structures at Masada as a fortress in case a retreat by him and his family was necessary. King Herod's short-lived dynasty was to be the last monarchy of ancient Israel. About a century later, as the Jewish-

Roman historian Josephus recounts, almost a thousand people, including leaders (and family members) of the Jewish revolt against Roman rule in Judea, occupied this fortress from 66 to 73 AD before committing mass suicide instead of being captured by the attacking army (Josephus; Yadin 1984). The western palace was the first of the two that were built at Masada and it served as an important administrative center (Netzer, E., personal communication). Further, a "throne room" was discovered in that palace in which four rectangularly arranged niches were found in the floor in a corner of this chamber (Yadin 1984). These notches were undoubtedly used for the supporting poles of a royal canopy in a room that was large enough for people to have an audience with the king.

Microscopic analysis of the structure of the woolen fabric showed purple threads in one direction and Z-ply threads in the other. The presence of plying is indicative of the warp as it would allow for heavier loom weights to be used so as to produce a tighter weave (Sheffer, A., personal communication). The weft consists of purple woolen threads and each plied woolen warp thread contains an undyed yellowed yarn and a purple-dyed yarn. The plying in the warp is very distinctive and suggests that the textile, from which only this minuscule fragment survived, had purple weft throughout. This is because the weaver of this fabric would not have used a warp with purple in it if he/she had been weaving a ground of another color and using purple weft only in restricted areas, such as clavi, gamma motifs, etc. (Granger-Taylor, H., personal communication). Hence, although the sample analyzed was less than 8 sq. mm, the weave indicates that the entire fabric was purple.

Another unique feature of this fabric is its reddish nature, where the other ancient purple-dyed fabrics discovered so far and mentioned

above were more bluish or violet in color.

The function of this textile, lacking further evidence, cannot be unambiguously determined. However, the fact that the entire textile was surmised to be purple and that, as indicated previously, a completely purple garment was the franchise of the sovereign of the land, it can be conjectured that this purple fabric was from the royal cloak or mantle of King Herod. That this fabric may have been part of a garment and not just a palatial furnishing is consistent with the texture and structure of the weave. Although very few plied-warp textiles have been discovered so far at Masada from any period, one Z-ply warp fragment suggests an item of clothing (Sheffer and Granger-Taylor 1994). It is interesting to note that although this purple textile belonged to royalty, the weaver was still intent on sparing the owner unnecessary expenses by plying with undyed wool. This undyed wool was not particularly visible to the naked eye within the overall weft-faced reddish matrix.

4.3 BIBLICAL ARGAMAN DYE

The true color of the biblical textile dye Argaman has not been definitely established. The discovery of this fabric, however, can now shed light on this subject. The only direct evidence of the nature of this dye is from the Septuagint, the translation of the Bible into Greek that was commissioned from about seventy rabbis by Ptolemy II (Philadelphus), the king of Egypt, in about 250 B.C. In that work (Rahlf's 1935), the biblical Hebrew Argaman is translated as porfuran, which is the well-known Greek term for the purple dye (or dyeings) derived from certain Mediterranean murex and related sea snails. As various passages in the Book of Exodus indicate, the biblical Argaman was used in various sacral vestments worn by the Israelite High Priest Aaron and in the textiles that surrounded and covered the Tabernacle in the Wilderness about 3,300

years ago. Additionally, the Book of Esther and Daniel, for example, also associate that dye and its bluish-colored chemical relative, Tekhelet, with royal garb and palatial furnishings. Historically, the Herodian monarchy is contemporaneous with the beginning of the mishnaic period, a scholarly era that presented rabbinical interpretations of biblical ordinances in the religious, civil, and agricultural spheres. Thus, it is probable that the biblical royal tradition associated with Argaman was continued into the Mishnaic period by the palace of Herod, King of the Jews. Hence, the reddish purple (or 'bordeaux') color detected on this archaeological royal fragment seems to be the authentic color of the biblical Argaman.

5. CONCLUSIONS

The Masada textile analyzed in the current study is the first (and, so far, only) murex-purple dyed fabric discovered in Israel, and it is also one of the oldest textiles yet found that has been dyed with this pigment. Based on archaeological, historical, religious, and chemical data discussed in this paper, the following thesis regarding this textile can be proposed: this royal fabric may have been part of the mantle of King Herod, the patriarch of the last monarchy of ancient Israel, and it was dyed with the biblical purple colorant known as Argaman.

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El Descubrimiento Sin Precedentes Del Tinte Púrpura Real Sobre Un Textil Masada De Hace Dos Mil Años

Zvi C. Koren

RESUMEN - La naturaleza ha dotado a ciertos múrices y caracoles del mar con el precursor de uno de los más nobles, sagrados y costosos de todos los tintes textiles usados en la antigüedad. Este raro pigmento conocido con el nombre de Púrpura Real o la Púrpura de Tiro; es producido por los fluidos blanquecinos o amarillentos de las glándulas hipobranquiales de estos moluscos. Historiadores griegos y romanos, han descrito la tintura de lana y seda con este pigmento químicamente reducido o con sus precursores, indudablemente como una de las tecnologías bioquímicas ancestrales más complejas del mundo antiguo. Durante algunas épocas este precioso tinte valía más de veinte veces su peso en oro. No es de asombrarse, pues experimentos realizados en este laboratorio han demostrado que se necesitan aproximadamente diez mil caracoles para teñir solo una capa o manto imperial. La escasez de cantidades suficientes de la tintura de este animal y la majestuosa hermosura en el color del tinte del múrice sobre los textiles, cautivó reyes, emperadores, cesares y al mundo eclesiástico. La historia ha registrado que la Púrpura Real estuvo de moda en los imperios de Asiria, Babilonia, Persia, Grecia y Roma. A militares, generales y nobles se les permitió adornar por lo menos parte de su traje con este tinte imperial.

Conjeturas sobre la tintura de la púrpura a través del mar Egeo dicen que los minoicos de Creta crearon esta industria hace por lo menos cuatro mil años; sin embargo la historia ha acreditado a los más notables mercaderes y comerciantes del mundo antiguo - a los navegantes fenicios - con el perfeccionamiento del arte de teñir con múrice. Los tintes textiles producidos por esta exclusiva industria eran valorados sobre todos los demás. El rol de superioridad del cual disfrutaron los artesanos fenicios, y la alta estima en que estos tintoreros fueron tenidos, es evidente por la denominación de la "Púrpura de Tiro" que la historia le ha conferido a los materiales teñidos con púrpura. Vestigios de los antiguos talleres de tintura de los fenicios se encuentran hoy día a lo largo del norte de Israel y las costas del sur de Líbano.

Por primera vez esta rara tintura, la Púrpura Real, ha sido recientemente identificada en un antiguo textil de Israel. El textil fué excavado hace treinta y cinco años por la expedición a cargo del importante arqueólogo israelí ya fallecido, Yigael Yadin en la fortaleza-palacio edificada en un farallón y conocida como Masada. El sitio de Masada se identifica con dos periodos principales. El primero es el periodo Herodiano, llamado así por el monarca judío de Judea nombrado por Roma de 40 a 4 a. de C., quién edificó palacios y otros edificios en Masada, como una fortaleza en caso de que fuera necesaria una retirada de él o de su familia. La corta dinastía del rey Herodes fué la última monarquía del antiguo Israel. La última ciudadela judía

que peleó contra la dominación de los romanos sobre Judea ocupó este fuerte un siglo después. El historiador romano Josephus describió posteriormente que cerca de mil hombres, mujeres y niños se suicidaron en masa para evitar ser capturados por el ejército romano.

Los textiles de lana de forma irregular investigados, cuyas máximas dimensiones son de aproximadamente 2 a 4mm, fueron desenterrados en un área que formaba parte del basurero del palacio de oeste del Rey Herodes, el cual era el centro administrativo de Masada. El que este textil pertenezca al periodo herodiano (siglo I a. de C.) y no al periodo de rebelión un siglo después, se determinó por medio del fechado arqueológico de otros artefactos encontrados junto con los textiles.

El color majestuoso que produce este tinte rojo-púrpura sobre un textil es indudablemente también la tintura bíblica “Argaman.” Este color es mencionado en la biblia siguiendo el éxodo de los israelitas de Egipto, hace 3.300 años. “Argaman” es uno de los colores que fué posiblemente usado para las vestiduras del alto sacerdote Aaron y para algunos de los textiles que cubrieron el Tabernáculo del Desierto.

La ponencia discutirá varios aspectos de la tinturación con tinte púrpura, entre ellos el descubrimiento de este raro tinte real por medio de cromatografía de alta resolución (HPLC) llevada a cabo en este laboratorio. El textil de Masada analizado en el presente estudio es el primero (y hasta el momento el único) tinturado con púrpura mística descubierta en Israel, y es también uno de los más antiguos que se han encontrado hasta el momento tinturados con este pigmento. Los datos arqueológicos y químicos señalan una sorprendente conclusión acerca de este textil.