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Searching for mastery in dyeing: Blackish blue on Estonian and Finnish textile finds from the 11th–15th centuries

Riina Rammo, Krista Wright and Mervi Pasanen

Abstract

Estonian archaeological textile finds only became abundant starting in the 11th century. Between the 11th and 16th centuries, one of the dominant colours used on textiles in rural communities seems to have been a blackish-blue. Preliminary analysis indicates that the main compound used for blue dyeing was woad (*Isatis tinctoria* L.), which was probably not cultivated in Estonia or Finland at the time (although it now grows sporadically in coastal areas). Chemical analysis clearly indicated that the dye recipe was more complicated than just one dyestuff. Woad dye was often mixed with local lichens (possibly *Lasallia pustulata* L.), creating purple hues to achieve the desired colour. The aim of the complex dyeing process was probably to achieve as dark a hue as possible. This paper explores how the mixed vat dying process may have functioned using woad and lichen, and how this impacted the final colors.

Keywords: wood, lichen dyes, HPLC, Cielab, experimental archaeology

12.1. Introduction

Blue fragments are among the most common Estonian and Finnish archaeological textiles made of wool. Based on the finds, blue dyeing was an essential technique in local textile craft during the 11th to 16th centuries. This article discusses the possible dyeing sources used based on preliminary analysis of the finds and experimental archaeology, and outlines the time limits of this tradition. Preliminary analysis of the Estonian finds indicated that all nine visually bluish samples were dyed using indigotin-based dyestuff, likely woad (*Isatis tinctoria* L.). Moreover, seven of the samples were notable because the spectra also indicated unidentified peaks of probable lichen colourants (Proaño Gaibor 2017). Comparable materials to these Estonian colourants were found on the other side of the Gulf of Finland, in five 11th century Finnish archaeological textiles which also contain probable lichen colourants (Vajanto and van Bommel 2014; Vajanto 2015: 74–76).

The similarities between Estonian and Finnish materials may indicate a common dyeing tradition. Considering the chemical analysis, modern reference material (Proaño Gaibor 2011; Vanden Berghe 2012; van Bommel 2014), local species, and the broader European dyeing history (Cardon 2007), we

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suggest that the lichen used as the source for orchil dye might be rock tripe (*Lasallia pustulata* L.). In this paper, we use the term 'orchil' to denote dyestuffs deriving from any lichen producing this purple dye, regardless of the vernacular name (Hofenk de Graaff 2004: 274; Cardon 2007: 489; Degano et al. 2009: 378; cf. Diadick Casselmann 2001). These ideas led us to conduct an experimental test to produce reference threads and experience the dyeing process.

For context, we should mention that the analyzed textiles are mainly from inhumation graves. The Estonian fragments were discovered in the Raatvere (Lavi 1986, 1988), Küti (Indreko 1930), and Jõuga (Peets 1993) cemeteries (Table 1). Of the Finnish finds, the Perniö Yliskylä textiles were published by Appelgren-Kivalo in 1907, while the Kaarina Kirkkomäki textiles and their dye analysis was previously discussed in several publications and reports (Riikonen 1990; 2003; 2006; Walton Rogers 2001; 2004a; Kirjavainen and Riikonen 2005; 2007; Asplund and Riikonen 2007). Only one fragment in the data set comes from a wealthy deposit found in Pudivere (Rammo and Tamla 2022).

All textiles from the deposit except one are related to the deceased's clothing. Most of the fragments are woven fabrics (Figure 1); only three samples come from ribbons (Figure 2). The present colour shades vary slightly, but it is often almost blackish blue. In addition to the dye compounds, both the Finnish (Vajanto and van Bommel 2014; Vajanto 2015) and the Estonian textiles were probably produced locally and represent a similar technological tradition used in these countries (Rammo and Tamla 2022). For example, the loom-woven textiles are generally crafted using wool from double-coated sheep, show a preference for various 2/2 twill weaves, and are woven with a plied warp (Szz) and z-spun weft (Figure 1). Therefore, comparing these finds is well justified. As the source material is scant and biased, the conclusions drawn in this survey are preliminary.

Table 1. Archaeological samples and modern reference yarns. (Abbreviations: RCE: the Cultural Heritage Agency of the Netherlands; UT: the University of Tartu, Institute of Chemistry; AI: Tallinn University Archaeological Research Collection; KM: the National Museum of Finland)

Estonian archaeological samples					
No.	Site	Date	Textile	Place of Analysis	Grave no.
1	Raatvere (AI5259: 194)	11th c.	2/2 diamond twill	RCE	Grave 26
2	Raatvere (AI5259: 196c)	11th c.	2/2 broken twill	RCE	Grave 26
3	Raatvere (AI5259: 196c)	11th c.	2/2 broken twill	RCE	Grave 26
4	Pudivere (AI4194: 16)	11th c.	2/2 broken twill	RCE	-
5	Küti (AI2731: 14)	12–13th c.	2/2 broken twill	RCE	-
6	Küti (AI2731: 14)	12–13th c.	Tablet-woven band	RCE	-
7	Jõuga (AI4008: XXII: 213)	14–15th c.	Tablet-woven band	RCE	Grave 22
Finnish archaeological samples					
8	Perniö Yliskylä (KM2912:53)	11th c.	2/2 twill	RCE	Grave 1
9	Kaarina Kirkkomäki (KM12687:H1:20)	11th c.	2/2 twill	RCE	Grave 1
10	Kaarina Kirkkomäki (KM27025:H27:168)	11th c.	2/2 twill	RCE	Grave 27
11	Kaarina Kirkkomäki (KM27025:H27:203)	11th c.	2/2 twill	RCE	Grave 27
12	Kaarina Kirkkomäki (KM27025:H27:230b)	11th c.	Ribbon	RCE	Grave 27
Reference yarns					
13	Rock tripe	modern	Sz yarn	RCE, UT	-
14	Rock tripe + woad	modern	Sz yarn	UT	-

Figure 1. Dark blue fabric fragment from Pudivere deposit find. The fabric is woven in broken 2/2 twill, with plied warp (Sz) and single weft (z). (Photograph: R. Rammo)

12.2. Analytical methods

Most of the archaeological sample threads, both Estonian and Finnish, were analyzed at the Cultural Heritage Agency of the Netherlands (Table 1). The dye analysis was conducted with a UHPLC (ultra-high-performance liquid chromatography), coupled with a PDA (photodiode array) detector. A two-step extraction method (DMSO, methanol, and HCl) was used (Proaño Gaibor 2017). The reference samples were analyzed at the University of Tartu's Institute of Chemistry. In addition to the HPLC-DAD, mass-spectrometry (MS) was added in order to identify unknown compounds (Peets 2020: 29) using a similar pre-treatment method as was used at the RCE (Peets 2020: 27; Peets et al. 2020: 21).

Secondly, both modern reference threads were measured in the CIELAB colour space to obtain objective measurement data on the colour (Vajanto 2014: 68). Measurements were performed with the Konica Minolta CM 2300d Spectrometer, the Spectra Magic programme and the D65 illuminant (Trotman 1984: 548). The measured area was 8 mm in diameter.

12.3. Reference dyeing and experiments

Archaeological experiments can be conducted in different ways to solve various research problems. The purpose of an experiment can be, among other things, to produce a replica, to restore a technology, or to test the functionality of an item (Coles 1979; Mathieu 2002). Our aim was foremost to produce

Figure 2. Tablet-woven band fragment from grave 22 (14th–15th century), Jõuga cemetery. The bluish yarn was sampled for dye analysis. (Photograph: J. Ratas)

a reference thread for chemical analysis, as well as to experience the functionality of the mixed woad and orchil vat. Although the cognitive aspects are subjective and not measurable, documenting and reflecting on such experiences during the dyeing process are also important (Howes 2006).

We prepared a woad vat using 1.5 kilograms of fresh leaves for the experiment, as no woad balls were available. We extracted the indigo precursors for 30 minutes using 10 litres of hot water, splitting this between two buckets (vat 1: lichen and woad; vat 2: woad only); the leaves were squeezed to extract their sap in the vat.

Vat 1 was enriched with three litres of a three-year-old lichen vat, which contained rock tripe and human urine. This vat was dark purple in colour; it still contained the lichens. Once the lichens were sieved out, the lichen vat was added to the woad vat. We also added three litres of old human urine, and stirred vigorously for fifteen minutes. After this step, we added two dl of sourdough starter, two tablespoons of honey, and one litre of wood ash lye to increase the pH value to 10. Altogether, 50 grams of white, non-mordanted Finnsheep wool was added to the vat. The vat was kept at +30 °C for one week. The pH value varied between 8 and 10, and an alkaline pH was maintained by adding 2–5 dl wood ash lye every day. The colour of this vat remained dark blueish-purple throughout the entire process. After two days, the first test yarns were lifted out of the vat and oxidized. Their colour was initially green, although this turned to dark blue with a purplish-grey tint. After seven days, darker purplish-blue yarns were obtained (Figure 3).

Vat 2 contained woad, three litres of human urine, one litre of wood ash lye, two dl of sourdough starter, and two tablespoons of honey. Altogether, 50 grams of white, non-mordanted Finnsheep wool was added to the vat. After four days, the vat was bubbling fiercely, with a horrible smell and white foam on the surface. The first test yarn was removed, and exhibited an uneven turquoise colour. After five days, the vat was yellow with some indigotin spots on the surface. The vat was kept at +30 °C and wood ash lye was added frequently to maintain the pH at ca. 10. After one week, the vat produced dark blue yarns, although they slowly started to turn grey (Figure 4). If we compare Vat 1 (lichen and woad) with Vat 2 (woad only), it is clear that the woad-only vat was more challenging to control.

The lichen and woad vat remained active for over eight months. After that period, two test yarns were lifted from the vat. One had been pre-mordanted with alum (12%) and cream of tartar (4%) (Hassi 1978), and this sample turned greyish-purplish. The non-mordanted yarn turned bluish. This vat was still active as low as +16 °C, which saved energy and decreased the work load because the vat did not need constant controlling and warming. These parameters would have been influential in the past, as they make dyeing easier.

Figure 3. Blueish yarn from Vat 1, which contained lichen and woad and natural ingredients. (Photograph: M. Pasanen)

Figure 4. Blue yarns from Vat 2, which contained woad and natural ingredients. (Photograph: M. Pasanen)

12.4. Analysis results

12.4.1 Chemical analysis of the archaeological samples

As stated above, woad was the most likely primary source for blue dyeing in the Eastern Baltic Sea region in the period under study. Indigotin, indirubin, and isatin were identified in all archaeological samples from Estonia, and most Finnish samples (Table 2). Additionally, several unidentified compounds were also identified. In the present paper, we focus on those compounds that were likely related to lichen.

Compounds called lichen blue/purples were repeatedly observed in the Estonian samples. Their retention time ranges between 31.8 and 32.8, and the max absorption is 567–577 (Figure 5, Proaño Gaibor 2017). At the same time, in the Finnish 11th-century samples dyed in the woad vat, there are probable lichen-related blue/violet compounds in five woad-dyed yarns. It has been suggested that these peaks might indicate hydrolyzed compounds of lichen orchil (Vajanto 2015: 59–60). The retention time of the peak is approximately 16.42–17.68, and the max absorption is at 556–584 (Vajanto 2015: 59–60, Appendix 4: Spectra 13, 14, 16, 17). Because they belong to the blue/violet range, these spectra may refer to some local orchil dye. We suggest that these unknown lichen-related compounds indicate the same source and its different degradation products in both the Estonian and Finnish samples. Additionally, various unidentified oranges and red-orange compounds were also detected in these samples. Some of these generally appear in conjunction with probable lichen compounds (Proaño Gaibor 2017; Vajanto 2015: 50, 59; Vajanto and van Bommel 2014: 71), and as such it was suggested that some of them might originate from the same source (Vajanto 2015: 50). Regrettably, it is not currently possible to obtain an exact match for these spectra among the known references.

12.4.2. Results of the reference dyeings

An in-depth analysis of the reference threads was performed at the University of Tartu Chemistry Institute in order to study the possible orcein-related compounds of rock tripe. The main aim was to use the MS to identify the possible dye source of these unidentified lichen peaks on the DAD spectra. Analysis of the reference thread dyed with only rock tripe enabled us to distinguish some of the amino- and hydroxy-orcein compounds and relevant peaks on the DAD spectrum, all of which are located in the area of the unknown orange peaks on the chromatogram. Regrettably, nothing appeared in the bluish/violet range. The second reference thread, dyed with the combined vat of woad and lichen orchil, produced ambiguous results. As the indigotin, isatin, indirubin, and probable woad flavonoid were easily observable, only tiny peaks which could be attributed to the previously-identified orcein-compounds can be seen. For example, the peak with retention time 34.17 could be the result of alpha-aminoorcein (Figure 6).

In addition to the dye analysis, the UV light tolerance of the reference yarns from the lichen and woad vat was tested on a sunny window for four months. There seemed to be only minimal changes in the visual assessment and CIELAB measurements (Table 3, Figure 7). The yarns faded slightly, but their tone did not change much, with a dE*ab value of 12.55. While it is well known that brilliant purple yarns dyed with rock tripe fade quickly in sunlight (Vajanto 2015: 63), this phenomenon did not occur in the reference yarns.

Table 2. Compounds detected in the samples (Proaño Gaibor 2017; Vajanto 2015: 59–60, Appendix 4: Spectra 8, 9b, 10, 11b, 12).

Estonian archaeological samples				
No.	Sample	Woad-related compounds	Lichen blues/ violets	Unknown orange and reddish compounds
1	Raatvere (AI5259:194)	Indigotin, isatin, indirubin, woad flavonoid	yes	Unknown oranges
2	Raatvere (AI5259:196c)	Indigotin, isatin, indirubin, woad flavonoid	trace	-
3	Raatvere (AI5259:196c)	Indigotin, isatin, indirubin, woad flavonoid	yes	Unknown oranges trace
4	Pudivere (AI4194:16)	Indigotin, isatin, indirubin, woad flavonoid	yes	Unknown oranges
5	Küti (AI2731:14)	Indigotin, isatin, indirubin, woad flavonoid	trace	Unknown oranges
6	Küti (AI2731:14)	Indigotin, isatin, indirubin, woad flavonoid	trace	-
7	Jõuga: AI4008:XXII:213	Indigotin, isatin, woad flavonoid	trace	-
Finnish archaeological samples				
8	Perniö Yliskylä (KM2912:53)	Indigotin, indirubin, isatin equiva-lent, isatin	yes	Unknown red and red-orange
9	Kaarina Kirkkomäki (KM12687:H1:20)	Indigotin, indirubin, isatin trace	yes	Unknown red and red-orange
10	Kaarina Kirkkomäki (KM27025:H27:168)	Indigotin, Indirubin, Isatin	yes	Unknown red and red-orange
11	Kaarina Kirkkomäki (KM27025:H27:203)	Indigotin trace, Indirubin trace, Isatin	yes	Unknown red-orange and reds and oranges
12	Kaarina Kirkkomäki (KM27025:H27:230b)	Isatin-probably	yes	Unknown red-orange

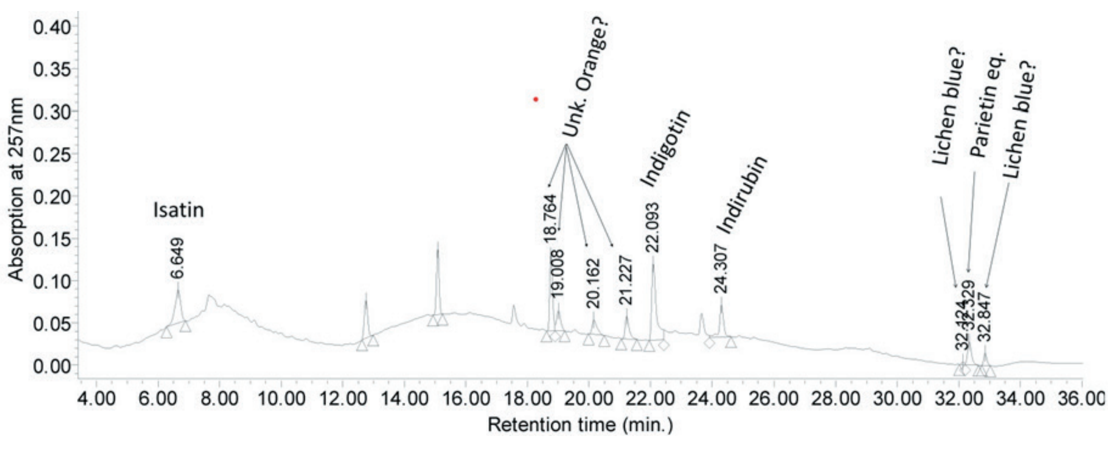

Figure 5. Chromatogram of Pudivere textile sample. (Image: A. Proaño Gaibor 2017)

12.5. Discussion

Given the historical background, the source for blue dyeing was probably woad. Woad was widely used as a source of blue in Europe since the Neolithic and the Bronze Age (Cardon 2007: 374; Hofmann-de Keijzer et al. 2013: 142). During the 11th–15th centuries woad was widely used in Northern Europe, including the Eastern Baltic. Another possible dye source, the *Indigofera* species, probably did not reach Estonia and Finland before the 17th century.

Woad grows as a wild plant in the coastal areas of Estonia and Finland today (Peets 1998: 294; Vajanto and van Bommel 2014: 69–70). While not native to the region, it spread in the past through seafaring or other activities. It is noteworthy that 19th century ethnographical records in Estonia and Finland do not mention native woad as a source for dyeing. An 18th century author describing the local dye plants in Estonia does not mention woad either (Hupel 1789).

Instead, in the 19th and beginning of the 20th century in Estonia and Latvia, imported indigo pigment obtained from tropical indigo shrubs was widely used for blue colour by utilizing a urine vat (Bielenstein 1935: 98; Vilbaste 1939: 51–53). Although there is no evidence that woad was cultivated in Estonia or Finland, Latvian folk songs claim that it was planted in Latvian gardens (Bielenstein 1935: 87; Pīgozne 2020: 169). In Finland, wild woad was identified by botanical surveys in the south-western archipelago in the 18th century (Gadd 1760a; 1789). Thus, woad cultivation was actively officially encouraged, but without success, as peasants lacked the know-how to grow woad and refine pigment from the leaves (Gadd 1760a; 1760b; 1789).

Table 3. CIELAB measurements of yarns dyed in the lichen and woad vat.

Blue not faded, no alum	Blue faded 4 months, no alum	Blue 6 months dyeing, no alum	Blue 6 months dyeing, with alum
L*= 29 a= -3.36 b= 12.05	L*= 40.72 a= -2.63 b= -7.64	L*= 42.38 a= 5.59 b= 0.07	L*= 51.28 a= 5.88 b= 9.12
dE*ab 12.55		dE*ab 13.21	

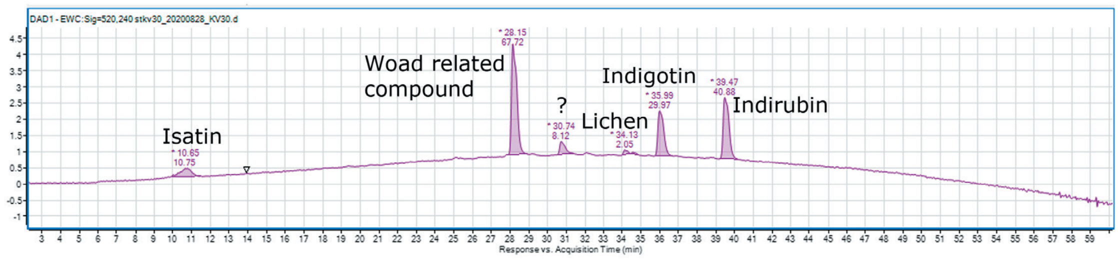

Figure 6. Chromatogram of reference thread dyed with woad and rock tripe. (Image: P. Peets)

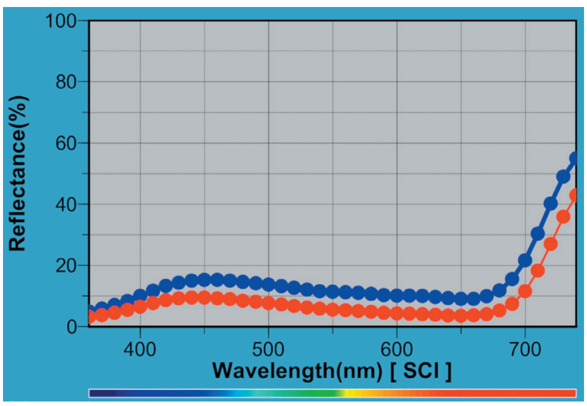

Figure 7. CIELAB graph of the yarns dyed in the woad and lichen vat and faded for four months. (Image: K. Wright)

Therefore, it was assumed that despite relatively wide use, locally cultivated woad was not a local resource in the Eastern Baltic during the 11th–15th centuries (Peets 1998: 294–297). It was probably an imported dyestuff, for example, transported as dried balls from western Europe in the High and Late Middle Ages. Indigotin-based textile dyes may have already reached the study area prior to this period. The earliest blue-dyed textiles found in Finland are from the 4th century AD (Vajanto et al. 2016) and those found in Latvia were dated to the 5th–6th centuries (Pīgozne 2020: 72). The provenance and exchange mechanisms of early trade to the Eastern Baltic is obscure. Some researchers have suggested that tropical indigo pigment may have reached the shores of the Finnish Gulf from the east during the Viking Age (Peets 1998: 297). Woad seeds have occasionally occurred in the Eastern Baltic in the 3rd–5th century (Aalto 1982). Due to the prevalence of cremation burials, textiles are very rare in Estonian archaeology prior to the 11th century, by which time blue dyeing with woad already seems to be a well-known craft.

In addition to woad, various unidentified compounds may indicate the use of local lichen-based dyestuff, possibly orchil, in the Eastern Baltic area. Orchil is obtained through treatment in ammonia, which transforms the precursors present in the lichen (orsellinic acid) into orcinol; further treatment leads to a complex mixture of dye compounds (phenoxazone structures) (Serafini et al. 2018). The end product, orchil, is a direct dye. Initially, orchil was a dyestuff extracted from the *Rocella* species in the Mediterranean as early as antiquity (Hofenk de Graaff 2004: 275). In Western and Northern Europe, several lichens can produce many purple shades, with the best-known species being *Ochrolechia tartarea* L. and *Lasallia pustulata* L. The chemical analyses of archaeological textiles indicate the presence of orchil-dyed textiles in Europe from the Iron Age onwards (Banck-Burgess 2012: 145; Grömer and Rösel-Mautendorfer 2013: 436, 456–457, 471; Hofmann-de Keijzer et al. 2013: 150). Numerous examples have been detected among Viking Age and medieval textile samples from England, Ireland, Iceland, Scandinavia, and Greenland (Walton 1988a; 1988b; Walton Rogers 2004b: 63; 2004c: 89; Vanden Berghe et al. 2009; 2010). Both archaeological and written sources indicate that orchil was sometimes combined with other dyes such as woad (Kok 1966: 250, 267; Walton 1989: 403; Cardon 2007: 499–501).

Rock tripe is native to the coastal area around the Finnish Gulf, and is a possible source for bluish-purplish lichen dye. According to Finnish folk recipes, it seems that lichen orchil was still used in dyeing, although relatively rarely, in the 19th century, while crottle (*Parmelia* species) was also very common (Vajanto 2015: 34). These recipes might have roots in the prehistoric lichen dyeing tradition, or be a result of the Industrial Revolution and subsequent increasing interest in utilizing local dye sources. Because of this interest, Finnish peasants (then part of Sweden) were encouraged to collect lichens (*Lasallia pustulata* L., *Cladonia digitata* L., *Parmelia* and *Ochrolechia* species) to sell to suppliers (Gadd 1789). Moreover, the orchil dyeing recipe is mentioned in a Swedish household book (Warg 1790) and a botanical book (Westring 1805). Although some lichen species, especially crottle, were mentioned as a dye source in Estonian ethnographic data, they were used as direct or mordant dyes for brown, yellow, and green (Vilbaste 1939: 47–49).

The experiment we conducted, dyeing with woad and rock tripe, was successful and resulted in blue yarns. Although processed orchil is a direct dye (Cardon 2007: 493) and woad is vat dye, it is relatively easy and practical to combine these dyestuffs in one process, as both orchil lichens and woad need pre-treatment and fermenting in an ammoniacal solution, for example, urine. Historical documents also suggest that in addition to 'bottoming' the indigo-blue with orchil, these two dyestuffs could be mixed in one bath (Cardon 2007: 499–500). Moreover, the alkaline environment of the vat would bring out a bluer shade in the orchil (Hofenk de Graaff 2004: 275–277).

However, so far our research has not provided a definite answer on whether rock tripe and/or the recipe used is consistent with those used in the Eastern Baltic area in the past. Chemical analysis did not give a definite answer, and additional analysis is required to better understand the role of the various different factors, particularly the degradation products. More experiments should be conducted, and different lichens should be tested. Despite insufficient knowledge of the dye sources, we assume that blackish-blue dyeing probably required a great deal of resources (Walton 1988a: 154), as it required an imported and expensive dyestuff and experience, with a limited distribution of knowledge. These characteristics may indirectly indicate some specialized dyeing craft (Rammo and Matsin 2015: 285).

12.6. Conclusions

Blue dyeing was an essential technique in local textile craft in the Eastern Baltic area between the 11th and 15th centuries. Based on dye analysis, the main compound used for blue dyeing was woad; while woad grows sporadically along the coastal areas of Estonia and Finland today, it was never locally cultivated for dyeing. Woad as a refined dyestuff (likely as woadballs) was probably imported to the Eastern Baltic area during the period under study. Chemical analysis clearly shows that the dye recipe was more complicated in order to achieve the desired colour. The aim of the complex dyeing process was probably to achieve as dark a hue as possible. The imported woad dye was often mixed with local lichens, resulting in purple hues. This lichen might have been rock tripe, although additional research and further tests with other species are necessary to produce definitive conclusions. Lichen dyes, and dying processes which mix them with woad, are not specific to this area but represent a more widely spread European tradition. The samples analyzed indicate that the heyday for such a dyeing method was probably in the 11th–12th centuries in the Eastern Baltic area. At least in Estonia, it was likely used until the 14th–15th centuries or later.

The dyeing experiment, which consisted of mixing woad with rock tripe, highlighted several advantages of the recipe. For example, local lichen may have helped to minimize the amount of imported woad dye needed. In practice, mixing these two alkaline vats saves time and energy, and the mixed vat was easy to control, remaining stable for more extended periods and tolerating cooler temperatures. The preliminary UV light tolerance tests of the dyed yarns showed only minimal changes. As such, the combination of lichens and woad seemed an excellent source for blue.

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Mervi Pasanen is independent researcher, author and craft specialist focused on Finnish Iron Age clothing and tablet weaving, and on medieval dress making. She has written books about ancient crafts such as nålbinding, tablet weaving and Late Iron Age clothing.

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