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FIBRE ANALYSIS OF LATE IRON AGE, EARLY MEDIEVAL AND MODERN FINNISH WOOLS

Abstract
This article compares archaeological Late Iron Age – Early Medieval Period wools found in Finland to the modern wools of Finnsheep and Finnish Jaalasheep. The archaeological finds originate from three female inhumation graves and two shipwrecks. The aim of fibre analysis is to shed light on the provenance of textiles and on wool processing. According to the analyses the archaeological textiles were made of *Hairy*, *Hairy medium*, *Generalized medium*, and *Medium* wools and one intermediate type. Moulting spring wool of modern sheep was found to be similar to the wools of some archaeological finds. It is suggested that some archaeological yarns were possibly spun directly from shed underwool staples without hand sorting.

Keywords: archaeological textiles, shipwreck textiles, Jaalasheep, Finnsheep, wool

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INTRODUCTION

The aim of study

This article compares the wool types of some archaeological woollen fragments found in Finland to the modern wools of Finnish Jaalasheep and Finnsheep. The aim is to shed light on the provenance of finds and on wool processing through fibre analysis of archaeological and modern wool samples.

The studied archaeological textile fragments have been found in Eura Luistari, Halikko Rikala and Mikkeli Tuukkala inhumation cemeteries, but represent only a very small proportion of all textile material at these sites. In addition, this article discusses textile finds from Lapuri and Egelskär shipwrecks (Fig. 1; Table 1). The textile fragments have been dated from the Late Iron Age, i.e. from the Viking Age (c AD 800–1025) and Crusade Period (c AD 1025–1055/1300), to the Early Medieval Period (c AD 1155–1300), but are discussed together here because the transition from one period to the next was not sudden.

Wool combs have been identified in Europe as essential tools in processing primitive wool (Christiansen 2004: 14; Gleba & Mannering 2012: 7–8) but such finds are unknown in the Finnish prehistoric material. It is possible that wool combs were made of materials that have perished or that their remains have been misidentified – or possibly wool was processed in some other way in Finland. Modern reference material is used here to understand how wool could have been processed during yarn production in prehistoric Finland.

Finnish sheep wool and native breeds

Earlier research has shown that *Hairy* and *Hairy medium* wool types predominated in the Late Iron Age in south-western Finland, and that *Generalized medium* wool was used in smaller extent. At that time pigmented brown and skimlet wool with grey, black, and white fibres were dominant (Ryder 1978; Kirjavainen & Riikonen 2005: 38; 2007: 137–8) but during the Middle Ages white was the most common colour (Kirjavainen & Riikonen 2005: 38; 2007: 137–8). Wool was plucked during the spring moulting both in the Iron Age and the Medieval Period, although shearing wool became more widespread during the Middle Ages

(Kirjavainen 2003: 268–9). Unfortunately, there are no Iron Age staple finds from Finland which would help to understand the amount of sorting and processing of wool performed during yarn production.

Finnish Iron Age sheep were probably the ancestors of Finnsheep breed, a northern short-tailed breed approximately 1000 years old (Ryder 1978; Kantanen & Tapio 2000: 22). In addition, Finland has two more native breeds, Kainuu Grey and Åland's sheep; all three are endangered species. All these breeds are genetically close to each other, but the double-coated Åland's sheep has also connections to Swedish native breeds.

The wool of modern Finnsheep and Kainuu Grey (i.e. Finnish Grey Landrace) is soft and relatively homogenous. The Finnsheep wool has a mean fibre diameter of 22.6–39.7 μm; the wool is free of kemps and the level of medullation is low (Puntila et al. 2007: 125). The *Semi-fine* wool quality has been achieved by breeding Finnsheep within the last 200 years (Vohlonen 1919: 4–5, 36–7; 1927: 63–6). The wool type of Finnsheep has been defined as a curly version of *Generalized medium* wool (Ryder 2000: 8), but the finest grade is described as *Merino* quality (Ryder 1983: 524), which is a *Fine* wool type. Today the wool of Finnsheep is white, black, grey, or brown. In general, the wool types of modern Finnsheep and Kainuu Grey are too homogenous to be used as reference material for archaeological textile finds. The mouflon coloured, double-coated Åland's sheep does not moult.

In 2005, a small and very isolated flock of Finnsheep was found in the municipality of Jaala in southern Finland (Kantanen 2007). These so-called Jaalasheep had retained archaic features, including double-coated wool with underwool, hairs and even kemps, spring moulting and more colours and patterns than modern Finnsheep (Vajanto 2011). Moulting of these sheep lasts 1–2 weeks and is not a result of nutritional changes, because in Finland the sheep are fed continuously through the winter and the moulting animals are not on the verge of starvation. The moulting habit is stronger in some genetic traits of Jaalasheep. Because of the archaic features the wool of Jaalasheep was considered as the best reference material for studying primitive wools and a parallel to archaeological wools found in Finland.

MATERIALS AND METHODS

Archaeological wool samples

Samples 1–4 were taken from twill fragments (KM 18000:2071 and KM 18000:2084) that were found in female grave 95 in the inhumation cemetery of Eura Luistari (Lehtosalo-Hilander 1982: 111–3, 402–3). The grave has been dated to the Viking Age based on the typology of bronze jewellery (Lehtosalo-Hilander 1982: 295). The textile fragments might originate from a cloak because of the coarse thread count of 6–8 yarns/cm. The fragments were found in direct contact with bronze bracelets (Kivikoski 1973: 101, Table 83).

Another twill fragment (KM 12690:168) was found in female grave 11 in the inhumation cemetery of Halikko Rikala, dated to the 11th–12th centuries AD (Hirviluoto 1992: 86; Mäntylä 2011: 223). The fragment possibly belongs to a bronze spiral ornamented cloak (Riikonen 2007: 17). Sample 6 was taken from the warp, and samples 5 and 7 from weft yarns.

Samples 8 and 9 (KM 38090:682) were found in female grave 11 in the inhumation cemetery of Mikkeli Tuukkala. The cemetery has been dated to the 14th century AD based on the typology of bronze objects (Mikkola 2009: 182, 184). The textile fragments were situated in direct contact with a bronze shoulder brooch and probably belonged to a brooch fastened *peplos* type dress typically worn by Finnish Iron Age women. Sample 8 from the 2/2 twill was tightly z-spun, but it was not possible to determine whether it was a warp or a weft yarn. The yarn seemed to be strongly orange in colour. This sample was sent to the Royal Institute for Cultural Heritage (IRPA/KIK, Belgium) for High-Performance Liquid Chromatography with Diode-Array Detection (HPLC-DAD) dye analysis to distinguish between dyeing and natural pigmentation. Sample 9 was a loose find, s-spun or untwisted, and followed the course of fibula's bone needle.

Sample 10 came from the wreck of Medieval clinker-built ship of Egelskär (SMM 1657, 342006:16). The shipwreck was found in the Finnish Archipelago Sea, but vessel's port of departure and destination harbours are unknown. The Egelskär find has been dated to the early 14th century AD based on the ship's stoneware ceramic cargo (Wessman 2007). The cargo included also a

barrel containing iron bars, which were covered with wool fibres. The fibres were identified as sheep's wool based on the scale pattern, but the find was interpreted as fleece because of the lack of any textile structures.

The remaining three samples, 11–13, were taken from two textile fragments (SMM 2592:8 and SMM 1393:27) found in the wreck of clinker-built Lapuri ship; they have been radiocarbon dated to the late 13th century AD (Mökkönen 2006: 44, 58). The wooden, oaken parts of the boat might be of foreign origin due to the fact that oak is rare in Finland (Mökkönen 2006). The textile fragments were found as filling between the planks (Hölttä 1993: 12–3), and probably belonged to the same fabric based on the strong similarity of warp and weft systems. The fragments had been woven in three-shafted twill, using tightly z-spun yarns (warp?) in one system and Sz-plied (weft?) in another. One of the fragments (SMM 2592:8) had been heavily repaired with brown loosely z-spun yarn.

Fig. 1. Places mentioned in the article.

Table 1. The Finnish Late Iron Age/Early Medieval archaeological textile fragments discussed in this article.

Sample	Find	Size (cm)	Structure	Function	Twist	Thread count/cm
1.	Eura Luistari KM 18000:2071	1.5 x 2	2/2 twill	warp	Sz	7–9
2.	Eura Luistari KM 18000:2071	"	2/2 twill	weft	z	6–8
3.	Eura Luistari KM 18000:2084	11.5 x 8	2/2 twill	warp	Sz	7–9
4.	Eura Luistari KM 18000:2084	"	2/2 twill	weft	z	6–8
5.	Halikko Rikala KM 12690:168	5 x 4.5	2/2 twill	weft	z	9
6.	Halikko Rikala KM 12690:168	"	2/2 twill	warp	Sz	9–10
7.	Halikko Rikala KM 12690:168	"	2/2 twill	weft	z	9
8.	Mikkeli Tuukkala KM 38090:682	2 x 3	2/2-twill	warp or weft	z	7–9/7–9
9.	Mikkeli Tuukkala KM 38090:682	0.2 x 0.4	loose yarn	decorative?	s*)	–
10.	Egelskär SMM 1657, 342006:16	3 x 3	fibres	fleece	-	–
11.	Lapuri SMM 1393:27	4 x 8	2/1 twill	warp (?)	z	5–7
12.	Lapuri SMM 2592:8	10 x 25	2/1 twill	weft (?)	Sz	6–7
13.	Lapuri SMM 2592:8	"	stitching	repair yarn	z	2

*) or untwisted

Key: KM= National Museum of Finland, SMM= Maritime Museum of Finland

Table 2. The modern reference wools.

Sample	Personal name	Breed	Age	Sex	Length of staple	Crimps/3 cm
I	Muru	Jaalasheep	adult	ewe	underwool: 6	underwool: 12
					outer coat: 10	outer coat: 2
II	Mustasilmä-Susanna	Jaalasheep	adult	ewe	underwool: 6	underwool: 12
					outer coat: 15	outer coat: 0,5
III	Velho	Jaalasheep	adult	ram	underwool: 5	underwool: 12
					outer coat: 15	outer coat: 0,5
IV	Jokke	Jaalasheep	adult	ram	underwool: 6	underwool: 12
					outer coat: 10	outer coat: 2
V	Sioux	Jaalasheep	lamb	ram	underwool: 4	underwool: 12
					outer coat: 10	outer coat: 2
VI	Sioux	Jaalasheep	adult	ram	underwool: 6	underwool: 12
					outer coat: 10	outer coat: 5
VII	Eva's ewe-10	FInnsheep	adult	ewe	7	8

Modern wool samples

Seven wool staples were shorn from one single flock of sheep – samples were taken from the shoulder area, which produces the best quality wool (see Vohlonen 1927: 57). The sampled sheep were selected to represent typical wool structures of Jaalasheep and Finnsheep (Table 2). A sampling of two ewes was done before lambing in order to get full staple instead of low quality after-lambing wool. One ram lamb was sampled at the age of 4 weeks and later as an adult to observe the growth of fleece to full scale. In addition, one ram was sampled before the spring moult and another during the moulting. To simulate the sorting of wool, underwool was removed from two staples (samples IIb and IIIb) by pulling the short and fine underwool away from the long outer coat hairs by hand.

The names of individual sheep were registered, as personal parameters are important in tracing descent lines for breeding and in researching the heritable variations of rare wool types. Thus, the sampled sheep are introduced here by names. Ewe I, *Muru*, had mostly white and very shiny underwool mixed with black hairs, smoky-bluish overall appearance and dark belly. Ewe II, *Mustasilmä-Susanna*, had white underwool, black outer coat and dark belly wool. Ram III, *Velho*, had mostly black underwool and white outer coat; he was piebald. Ram IV, *Jokke*, had mostly white underwool and white covering wool, mixed with black hairs; he was piebald with black patches. Ram V, lamb *Sioux*, was patched in white, brown and black; in addition, he had an orange overall appearance. Ram VI was the same animal, *Sioux*, as an adult; his adult wool was generally white with some orange coarse hairs.

Finnsheep's wool has been well described in research literature (Brax 1951; Ryder 1981a: 393–4; 1983: 524; Puntila et al. 2007) and therefore only one new staple, sample VII, was taken. It came from a brown Finnsheep ewe, *Eva's ewe-10*. The wool had no distinct outer coat and was crimpy, like Jaalsheep's wool. The studied flock had been shorn twice a year and the length of sampled staple was a result of five months' growth.

Fibre analysis

Fleece of sheep evolved from primitive double-coated type of wool, containing fine underwool, hairs and kemps, into true homogenous wool with only fine wool fibres. In southern Europe, soft, homogenous, self-coloured and even white wool existed as early as 2000 years ago. In northern Europe, such wool appeared 500–1000 years ago (Nakhlik 1963; Ryder 1983; 1984; 1987; 1988; 1990a; Bender-Jørgensen & Walton 1986; Maik 1990; Walton 1988; 1989; Kirjavainen 2005a; 2005b; Rast-Eicher 2008). According to historical sources, the practice of plucking wool and the transition to shearing followed the evolution of fleece in the south (Moeller 1976: 10–11; Pliny, NH VIII: lxxiii, 190).

The coarsest fibres define the wool type (Ryder & Gabra-Sanders 1985: 128). The most archaic wool type is the *Mouflon* type, which has very fine underwool and hairy outer coat with coarse brittle kemps. In addition, there are *Hairy, Hairy medium*, *Generalized medium*, *Medium*, *Semi-fine* and *Fine* wool types (Table 3). There is slight variation

in the names used of different wool groups, but this research follows the names created by M.L. Ryder (1981b: 21; 1984: 20; 2000: 4–5).

Ryder's wool categories have been criticized because the method does not take into consideration the natural variance of wool of one single sheep (Christiansen 2004: 11–8; Rast-Eicher 2008: 153–5; Brandenburgh 2010: 48). It has been suggested that the wool types found in the yarns do not directly indicate the evolution of wool, but rather the wool manipulation and the level of quality the spinners set on the yarns (Christiansen 2004: 16). If the promising strontium isotope research (Frei et al. 2009) will be found suitable for Finnish textile research it can be applied to the provenance studies in the future, but for the time being Ryder's method, despite its problems, is the only available method for wool provenance studies.

Critique has also been directed towards the incomplete and patchy information the fibre analysis produces – in practice, all fibres or yarns in a single archaeological find can never be sampled. According to Ryder (2000: 4), at least 100 wool fibres need to be measured for a valid fibre analysis. In archaeological samples it is sometimes impossible to measure more than 50 fibres due to the poor condition of decomposed fibres or the desire for non-destructive analyses. It has been estimated that 50 fibres can still give quite reliable results (Kirjavainen & Riikonen 2007: 135), but that the results of 20 analyzed fibres should be considered an approximation (Schjølberg 1992: 156).

For this research, a sample of 0.2 mm was taken from each archaeological fragment. The fibres were placed on an objective slide with distilled water as a medium. The fibres were examined with Leica DMLS (DFC 420) transmitted light microscope without dyeing. Measurements were made with Leica LAS Core V 3.6 program. Very dark fibres were defined *black*, densely pigmented brown fibres *brown*, less pigmented brown fibres *beige*, and colourless fibres *white*. Reddish-coloured fibres were defined *orange* (Ryder 1990b: 137). In addition, the existence of medulla was observed. The plied yarns in samples 1 and 3 were opened and measured independently, but the other plied yarns were too tight or mineralized and thus both threads were analysed together.

RESULTS

Hairy wool was found in archaeological samples 4 and 8, while samples 1, 6, 7, and 10 contained *Hairy medium* wool. The threads in the plied yarns 1 and 3 were made of wool types similar to each other. An intermediate type between *Hairy medium/Generalized medium* types was identified from samples 2, 3, 5, 9, 11 and 12. Sample 5 was heavily degraded and only a small number of fibres could be measured. Sample 13 contained *Medium* wool, but was difficult to interpret due to the small sample size. In most samples, the proportions of pigmented and medullated fibres were low, apart from sample 13. No hair roots were found (Table 4 & Appendix 1).

Sample 8 from Mikkeli Tuukala twill (KM 38090:682) contained fibres, of which the intermediate long fibres had a strong orange colour. The colour was not present in all fibres, so it was not a result of contamination with soil. According to the HPLC-DAD dye analysis, no organic dye was present or the content of dyestuff was too low to be detected (Vanden Berghe 2012). The samples from Eura Luistari and Halikko Rikala had a bluish tint and were possibly dyed.

Reference samples II, III and IV contained *Hairy* wool, while samples I, V and VI were of an intermediate type between *Hairy medium/ Generalized medium* wools. Samples V and VI, shorn from the very same animal but at different ages, presented the most remarkable difference in the proportions of medullated fibres and in the coarsening of fibre mean thickness. Sample VII, Finnsheep wool, was determined to be *Semi-fine* wool with no medullated hairs.

Type	Range	Mean	Distribution
Mouflon	5–20, 40, 70–190 µm	12 µm, 114 µm	bimodal
Hairy (H)	5–40, 50–120 µm	30–40 µm	skewed-to-fine
Hairy medium (HM)	10–130 µm	30–40 µm	skewed-to-fine
Generalised medium (GM)	15–55 µm	25 µm	skewed-to-fine
Medium (M)	20–60 µm	30–40 µm	symmetrical
Semi-fine (SF)	15–40 µm	25 µm	symmetrical
Fine (F)	10–35 µm	20 µm	symmetrical

Table 3. Wool categories.

The researched wool samples are presented in Figure 2. In this plotting, most archaeological textiles formed a group, which includes also the sorted modern wool (samples II and III), and moulted modern wool (sample IV). The wool of Jaalasheep, as well as the wool of Finnsheep formed separate groups. Samples V (lamb's wool) and 13 (containing a small count of measured fibres) fell outside these groups.

DISCUSSION

Provenance

The examined staples from Jaalasheep's outer coat revealed that the wool types, the number of crimps and the colours do vary in a single flock of sheep. Underwool and outer coat could be differently pigmented. The proportion of medullated fibres was found to be attribute, which varies between different sheep individuals, and a high proportion (53%) of medullated fibres can also be found in lamb's wool. The proportion of medullated hairs varied in the archaeological samples from 2 to 62%. In theory, all the researched archaeological samples could derive from local Finnish sheep, but only assuming that the flocks in the past did not produce uniform wool, and that the wools were sorted and mixed. Accordingly, the fibre analysis alone can give a false provenance determination. An imported product could be revealed by taking into consideration the archaeological context, possible atypical textile structures, and exceptional wool types.

Earlier fibre analyses made of Finnish archaeological materials had revealed that *Hairy* and *Hairy medium* wools were the most common types in the Late Iron Age Finland and that textiles were made of local wools (Ryder 1978; Kirjavainen & Riikonen 2007: 137). Samples 1 and 4 (Eura

Table 4. Statistical data of the measurements.

Sample	Type	Count of fibres (100%)	Medullated (100%)	Pigmented (100%)	Mean (µm)	Mode (µm)	VAR	SD
1a	HM	57	19	–	30	24	163	12.77
1b	HM	62	3	–	25	20	78	8.81
2.	HM/GM	87	18	–	30	26	167	12.92
3a	HM/GM	59	2	–	30	28	70	8.39
3.b	HM/GM	55	2	–	31	24	123	11.11
4.	H	61	2	–	24	20	46	6.77
5.	HM/GM	25	20	–	37	52	233	15.27
6.	HM	50	6	–	28	30	47	6.84
7.	HM	87	3	–	27	20	120	10.96
8.	H	93	4	12	24	22	84	9.18
9.	HM/GM	50	8	4	33	24	145	12.06
10.	HM	117	3	6	28	22	174	13.18
11.	HM/GM	105	14	10	36	30	249	15.78
12.	HM/GM	99	12	7	40	28	212	14.57
13.	M	26	62	38	41	42	128	11.31
I	HM/GM	88	11	26	35	32	268	16.36
II	H	113	27	38	41	22	581	24.11
IIb	H	103	4	16	29	22	155	12.47
III	H	91	18	55	34	22	292	17.09
IIIb	H	53	–	95	25	24	23	4.75
IV	H	62	3	5	27	16	136	11.66
V	HM/GM	96	53	58	37	16	278	16.69
VI	HM/GM	100	13	10	45	40	351	18.73
VII	SF	53	–	83	31	36	42	6.46

Key: VAR= variance, SD= standard deviation

Luistari; KM 18000:2071 and KM 18000:2084) as well as samples 5 and 7 (Halikko Rikala; KM 12690:168) can thus be defined as local products. The textile structure, which in Finland is the common 2/2 twill with plied warp and unplied weft (Bender-Jørgensen 1991: 96; Riikonen 2006: 14–5), supports this interpretation.

Samples 2 and 3 (Eura Luistari; KM 18000: 2071 and KM 18000:2084), sample 5 (Halikko Rikala; KM 12690:168), sample 9 (Mikkeli Tuukkala; KM 38090:682), as well as samples 11 and 12 (Lapuri; SMM 1393:27 and SMM 2592:8) were spun from an intermediate wool type between *Hairy medium* and *Generalized medium*. Previously this intermediate wool type has been found in Finland in the Late Iron Age textiles from the inhumation cemetery of Tampere Vilusenharju, dated to the 9th–13th centuries AD (Nallimaa-Luoto 1978: 240; Ryder 1978). These samples can be of local origin, though the 2/1 twill of the Lapuri fragments might refer to foreign origin (Tomanterä 2006: 45).

Only a little research has been done on the 14th century AD cemetery finds of Finnish inland, and it is unknown what kind of wool was available in these areas during that period. Sample 8 (Mikkeli Tuukkala; KM 38090:682) was defined to be most probably of local origin due to the *Hairy* wool. This kind of weather protective, double-coated fleece has been important to the northern sheep breeds (Christiansen 2004: 14). For example, in Greenland, contemporary archaeological yarns have been spun from the wool of double-coated sheep (Østergård 2004: 83–9) and *Hairy* and *Hairy medium* wools have also been found to be predominant in Medieval Turku in south-western Finland (Kirjavainen 2005a: 136–7; Kirjavainen & Riikonen 2007: 137).

Sample 13 from the Lapuri textile (SMM 2592:8) was made of *Medium* wool, but the count of measured fibres was small and might give a misleading picture of fibre distribution. The sample can be of foreign origin; in Medieval Europe, the wools were mainly of *Generalized medium* and *Medium* types, and coarser wool existed only rarely (Ryder 1984: 26; Maik 1990: 123; 1998: 220–1). Furthermore, *Medium* type wool has been recognized in imported textiles from Medieval Turku (Kirjavainen 2005a: 137, 142–3).

Medieval raw wool staples found in Turku, most probably of local origin, were mainly skimlet with brown fibres. One completely white staple was also found, and, in addition, white wool existed in yarns (Kirjavainen 2005a: 136, 140). Thus the almost white *Hairy medium* wool sample 10 from the Egelskär fleece (SMM 1657, 342006:16) might derive from local Finnish sheep flocks. Alternatively, because of its archaeological context in a trader, the Egelskär fleece can be an imported product from some other part of the Baltic Sea coast where double-coated sheep were bred.

New insights from modern wool

Prehistoric lamb's wool probably differed from the wool of an adult sheep, but without prehistoric lamb and adult wool staples, ideally from *one single* sheep, it is almost impossible to determine the degree of change, and the observations might also reflect the non-uniform wools of prehistoric fleeces (Ryder 1978; 1988). When observing the fibres in lamb's wool in sample V, it was noted that naturally phaeomelanin-pigmented orange wool fibres could easily be misidentified as dyed fibres in visual microscopic examination – possibly also the orange fibres in sample 8 contained phaeomelanin, which still exists in some sheep breeds (Ryder 1983: 545; 1990b: 137, 148; 1991: 59).

Nowadays only ewe's wool is commonly spun, because ram's wool has a strong odor. However, it is possible that ram's wool was also spun in the past to diminish the amount of wasted wool. Ram's wool in sample VI has a mode of 40 µm in underwool, in addition to a few coarse hairs typical of *Hairy medium*/*Generalized medium* wool. In ewe's wool in sample I of the same wool type, the mode is 32 µm. Thus a non-typical histogram with coarse mean and mode could facilitate the identification of ram's wool.

Sorting experimentation made with the modern wool, samples IIb and IIIb (Table 4 & Appendix 1), revealed that it was possible to sort underwool (less than 50 µm) from outer coat with a high degree of accuracy. This sorted wool included only a few medullated hairs. Underwool consisted of approximately 70–80% of the total original fibres in the fleeces. The larger number of hairs in sample IIb could be explained by less careful sorting and this could also be the explanation for hairs in the archaeological samples. Alternatively, the hairs in archaeological samples could be explained to be a result of intentional preserving or adding of long hairs, which not only increases

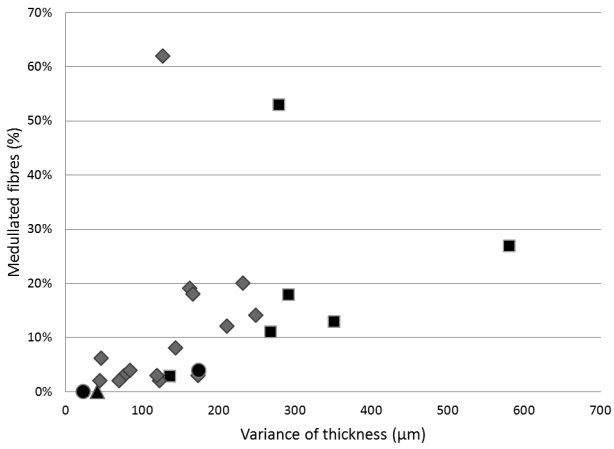

Fig. 2. Researched wools compared by variance and diameter range. Archaeological wool – grey rhomboid, reference wool of the Jaalasheep – black square, sorted wool of the Jaalasheep – black disc and wool of the modern Finnsheep – black triangle.

the warps' resistance to breakage (samples 1, 3 and 6), but also diminishes the amount of wasted wool (samples 2, 4, 5, 7, 8, 9, 11 and 12).

It has been suggested that the coarsest fibres were removed during the spring moulting period when different wool types could be plucked separately due to their different intervals of moulting (Ryder 1983: 49). Furthermore, Ryder (1993: 310) has described that in the sheep breeds of Orkney and Shetland the coarse hairs shed later than wool. Jaalasheep moult differently: first, the coarse hairs fall out, and then the finer fibres of underwool, as can be seen in sample IV.

The experiments raise a question, whether moulted wool was sorted at all by humans in the Late Iron Age and Early Medieval Finland. Perhaps the underwool was collected during moulting, after the sheep had shed the coarsest hairs. Especially archaeological samples 11 and 12 can be interpreted to have been collected during spring moult and spun directly from staple, i.e. according to a method suggested to be the most archaic manner in yarn making (Ryder 1969: 500) (Fig. 2 & Appendix 1).

Jaalasheep moult only once a year in the spring, but are shorn again in the late autumn. Traditionally, Finnsheep has been shorn 2–4 times per year; the autumn wool is of the best quality with the longest fibres (Vuorela 1975: 472). Until the beginning of the 20th century AD in eastern Finland, the shorn wools were mixed carefully and beaten with wooden sticks or an ancient tool called *savitsin*, which were later replaced by hand carders (Vuorela 1975: 472–3; Forbes 1987: 11). Fragments of Medieval wool beaters have been found in Finland, but no wool carders or wool combs have been discovered (Kirjavainen 2003: 269). Perhaps the Iron Age Finnish wool was plucked in the spring time during the moult of the underwool, which was ready for spinning per se. The wool shorn in the autumn got a different quality; it contained both the fibres from the underwool and the coarse outer coat hairs. The lack of wool combs suggests that the autumn wool was sorted by hand. Possibly the staples were not beat with savitsin, but with simple wooden sticks, which are easily perishable and difficult to identify from the archaeological material.

CONCLUSION

Some Late Iron Age and Early Medieval textiles found in Finland were examined in this study. The samples were found to contain *Hairy*, *Hairy medium*, *Generalized medium* and *Medium* wools as well as intermediate types between *Hairy medium/Generalized medium* wools. No clear evidence of the evolution of sheep fleece towards softer, homogenous modern wools was found.

The samples from Eura Luistari (KM 18000: 2071 and KM 18000:2084), Halikko Rikala (KM 12690:168) and Mikkeli Tuukkala (KM 38090:682) cemeteries were defined as being of local origin due to the presence of *Hairy* and *Hairy medium* wools and an intermediate type between *Hairy medium/Generalized medium* wools. These wool types have also parallels in other Finnish archaeological material.

The warp and weft yarns of the Lapuri fragments (SMM 2592:8 and SMM 1393:27), made of *Hairy medium/Generalized medium* wool, were defined as possibly local products, although the textiles are 2/1 twill, which is rare in Finnish archaeological textile material. The repair yarn

from one of the Lapuri fragments (SMM 2592:8), made of *Medium* wool, might be of foreign origin. The fleece from the Egelskär shipwreck (SMM 1657, 342006:16) was defined as *Hairy medium* fleece, either local or imported, because of its archaeological context in a trade vessel.

The fibre analyses revealed that the wool of modern Jaalasheep was comparable to the Finnish archaeological wools. What was notable in the wools of Jaalasheep was that the underwool and outer coat could be differently pigmented; the proportion of medullated fibres varied between individuals; and a high proportion of medullated fibres could also be found in lamb's wool. In the wool samples taken from one single Jaalasheep, orange wool was found in both adult's and lamb's wool. The orange fibres in archaeological textiles might thus contain the rare pigment of phaeomelanin, especially when no dyes can be detected in the HPLC-DAD analysis. Double-coated wool with relatively coarse underwool could indicate the use of ram's wool.

The presence of hairs in the archaeological textiles could be explained by a lack of careful sorting. In addition, the hairs can be seen as a sign of intentional preserving or adding of long hairs, which not only diminishes the amount of wasted wool, but also increases the yarn's resistance to breakage. An alternative explanation comes from the modern reference staple collected from naturally moulted wool with a distribution close to the hand-sorted staples. Accordingly, some prehistoric wool material could have been collected during moulting time after the shed of hairs and spun directly from staples; some wool that was shorn in the autumn may have been sorted by hand.

Experimental work with modern reference wool offers a rich source of possibilities for wool manipulation research starting from plucking. Such research can also provide new insights on wools and yarns from archaeological contexts.

ACKNOWLEDGEMENTS

I would like to thank the Alfred Kordelin Foundation and the following people: Ina Vanden Berghe (IRPA/KIK, Royal Institute for Cultural Heritage, Belgium), Riina Suominen (sheep owner), Juha Kantanen (MTT, Agrifood Research Finland), Esa Hertell (University of Helsinki, Finland), Stefan Wessman, Esa Mikkola and Ulla Klemelä (National Board of Antiquities, Finland).

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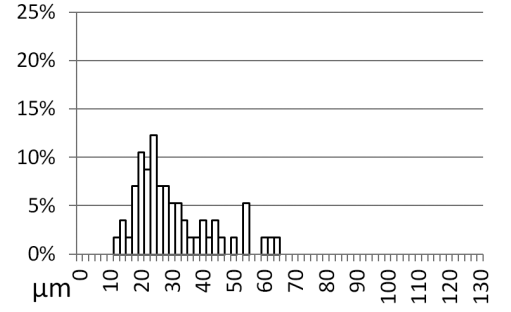
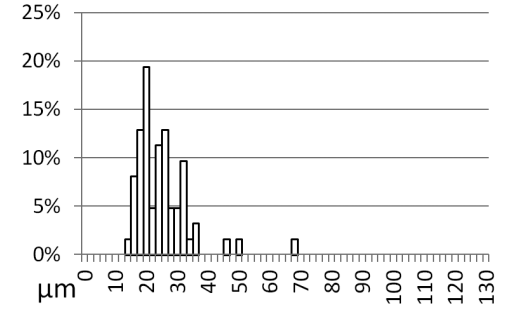
APPENDIX 1. MEASUREMENTS PRESENTED AS HISTOGRAMS

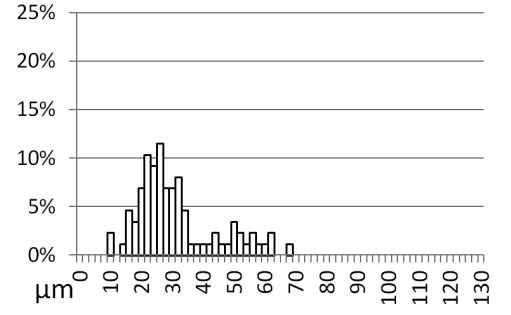
Sample 1a.



Sample 1b.



Sample 2.



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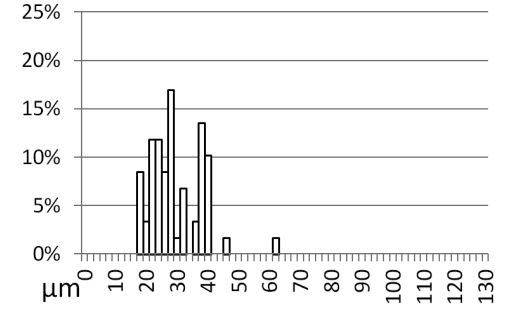
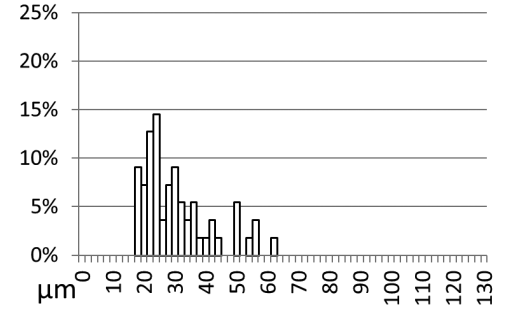
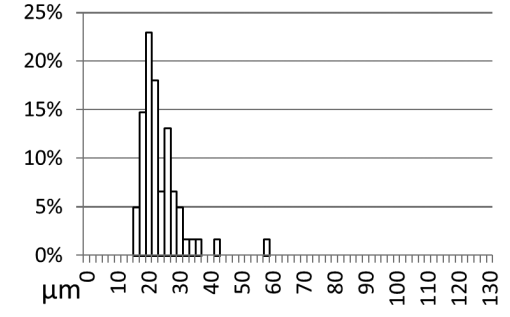


Sample 3b.



Sample 4.



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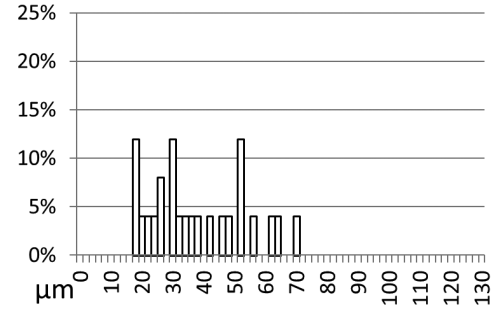

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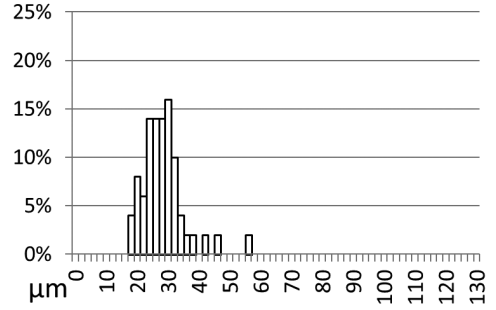

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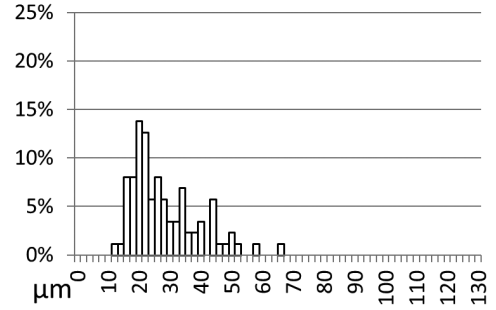

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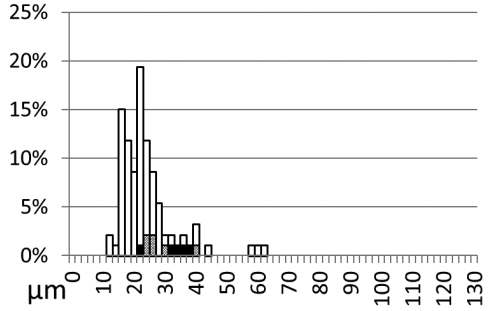

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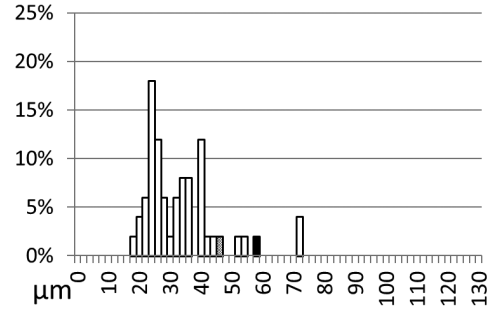
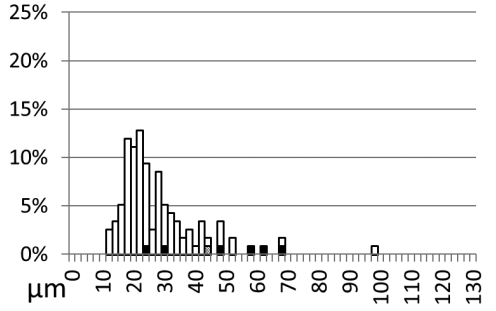


Sample 10.



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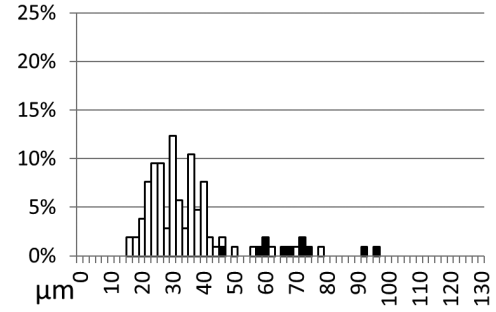
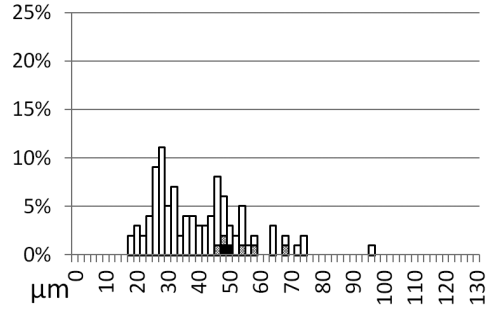
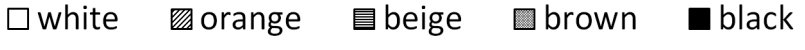


Sample 12.





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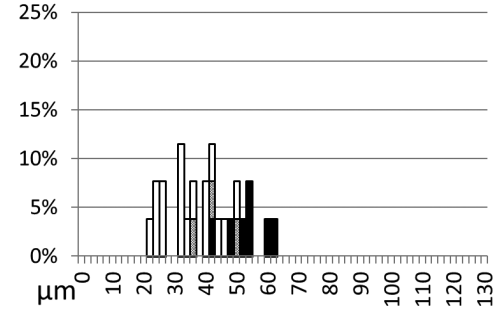
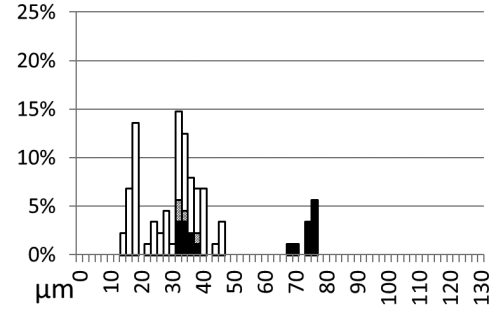
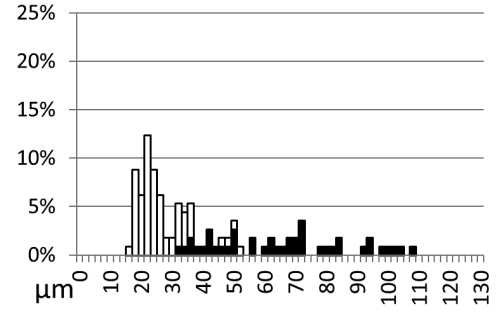


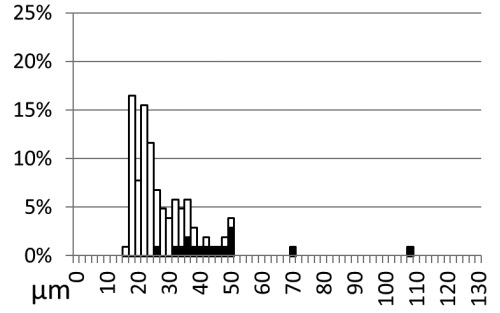
Sample I.



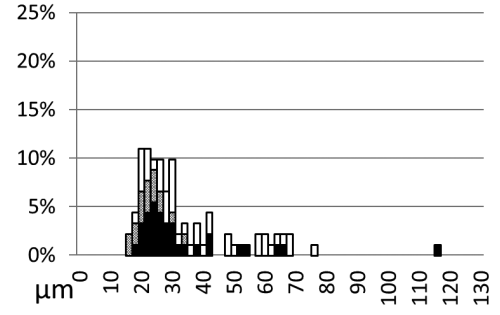
Sample II.



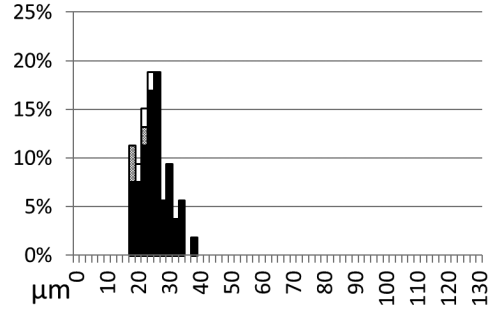
Sample IIb.



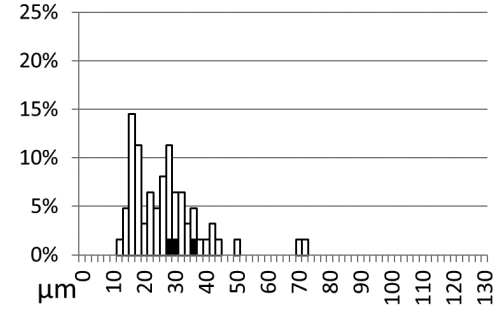
Sample IIIa.



Sample IIIb, sorted wool.



Sample IV.



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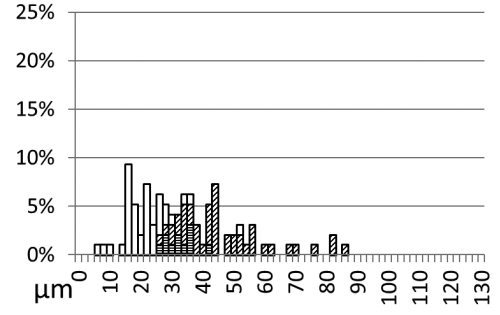
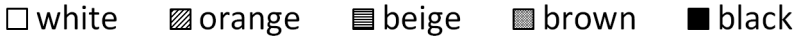
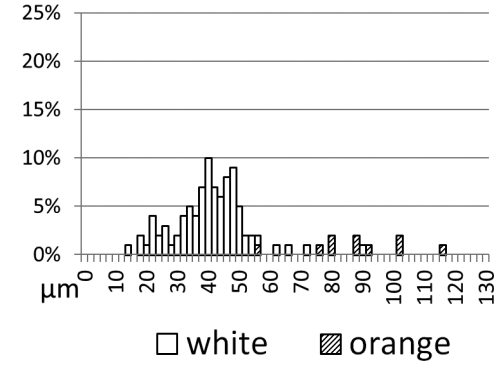




Sample VI.



Sample VII.