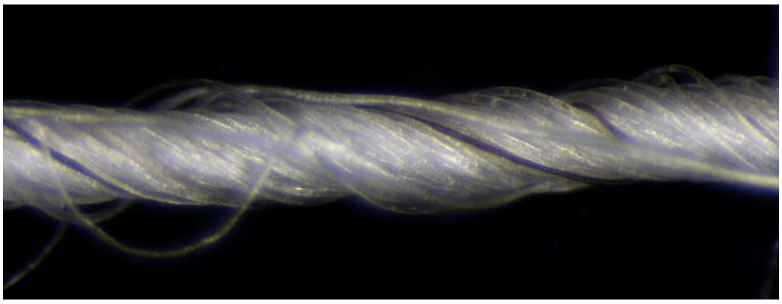
Untangling Wool

Fibre preparation for woollen threads in Dutch Early Bronze Age to Middle Iron Age



BA thesis Archaeology, Leiden University

J.B.C.M. Nobelen

Upper picture: step two of four in the carding process

Middle picture: Combed Shetland Fibre yarn, sample 7

Picture below: step two of two in the combing process

TITLE PAGE

Untangling wool

Fibre preparation for woollen threads in Dutch Early Bronze Age to Middle Iron Age

Jasmijn (Brechtje Chloë Margje) Nobelen, 1422367

First reader: Dr. R. Jansen

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PREFACE

During the writing of the experiment proposal for the BA2-course Experimental Archaeology by dr. A.L. van Gijn, I encountered the problem that not much research has been done regarding fibre preparation during the Metal Ages in the Netherlands or contemporary (European) ethnicities/material cultures. For most archaeological textile related tools and techniques, hypotheses or theories of use exist. However, almost nothing is known about tools for fibre preparation.

As a textile archaeologist in training at the Textile Research Centre Leiden (director: Dr. G. Vogelsang-Eastwood), I often encounter articles written by non-textile oriented specialized archaeologists writing about textile production where it seems if they have never even spun a thread or woven a cloth. This is one of the reasons that drive me to write a BA-thesis on woollen fibre preparation.

Since academic experimental data is missing, hypotheses and theories are sometimes copied wrongly by reenactors and (archaeological/historical) educational organizations. This could create a faulty view of the past. It is impossible to imagine a world without textiles, even to this day. We regard this material to be so important, because it is always present, that people tend to forget to appreciate fabric. In an industrial time such as ours, we also forget the time it took to produce a garment. The appreciation for the crafts is lost.

Taking this all into account, understanding the production sequence of textiles, from fibre to fabric, will surely enhance the search for a truthful, complete view of the past. This will not only be available to researchers. Everybody is allowed to gather a truthful viewing of the past through the different educational organisations having the correct, more complete information of the daily life of the past.

Luckily, I am not the only one who feels this need and passion. A few of the fellow enthusiast have helped me during the writing of this BA-thesis. Drs. D. Olthof and MA M. de Nijs functioned as second readers. A. Reurink reviewed this thesis using his practical knowledge as a master craftsman. He also helped with the experiment, as did dr. G. Vogelsang-Eastwood, drs. A. Verbaas and T. Stikkelorum. For the analysis of the experimental and archaeological material I thank E. Mulder and dr. I. Joosten.

1 INTRODUCTION

1.1 The Importance of Archaeological Textile Research

Several steps should be taken to understand the complete production process of fabrics. First, all possible production steps should be thoroughly researched. A scheme of all possible techniques used during the La Tène period to produce textiles has been published by Grömer (figure 1). This thesis will focus on the first step 'preparation', more specific the possibility of woollen fibre alignment before spinning.

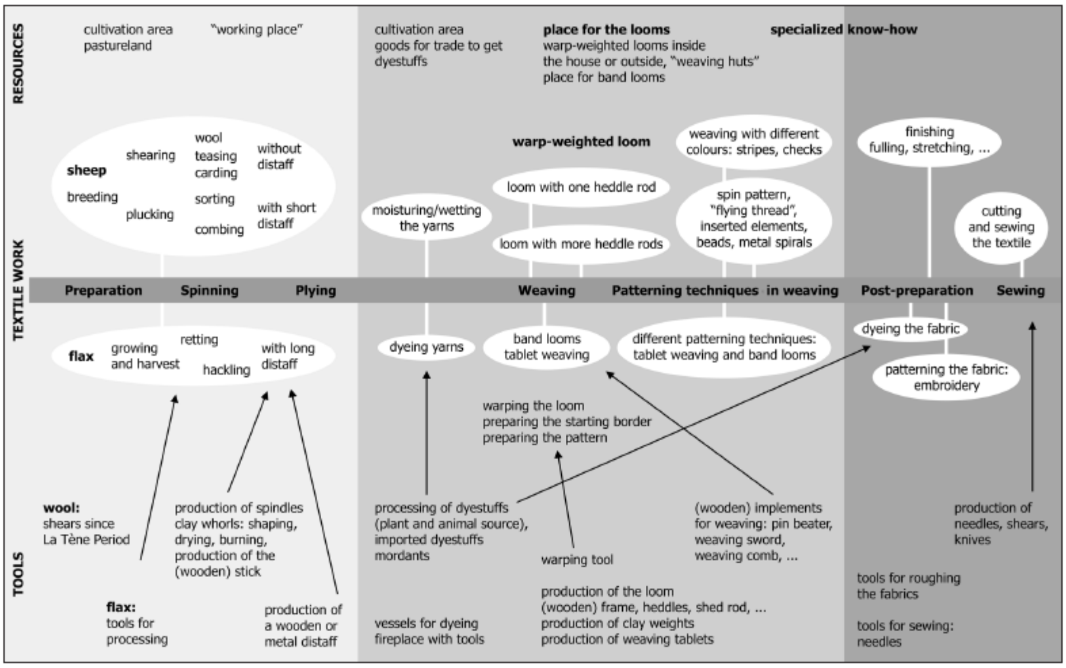

Figure 1
"Scheme of textile techniques, resources and tools (@ K. Grömer)"
Belanová-Štolcová and Grömer 2010, 9

The results can be combined by analysing all steps in a sequence and the relations between them. Every previous step influences the next and what the final product is to become influences all previous steps (Andersson-Strand 2010, 2). To understand the steps taken, the archaeological (final) product can be analysed. Bender Jørgensen (1991) started and Ingenegeren (2010) finished a database on Bronze and Iron Age textiles found during archaeological excavations in the Netherlands. By starting with making a database and focussing on one aspect, in the end all research could be bound together into one theory about textiles in general. From this forward, cultural and other human aspects of clothing and other textilia become clearer and better understandable. This will complete the reconstruction of the past.

There are three reasons why wool is chosen to be the subject of this thesis. First, due to limitations of a bachelor thesis only one type of fibre could be analysed. Second, most textiles found in the Netherlands and dating from the Bronze and Iron Age are made of wool. Third, the fibres are a personal favourite to work with.

1.2 Problems In Archaeological Textile Research

Textiles in archaeological context are rarely found (Bender Jørgensen 1991, 42) and the ones we have, have only been looked at to determine only a standardized selection of techniques, such as the weave and spin. Other techniques, such as fibre preparation, are rarely part of the research. To understand the sequence of production, every aspect has to be thoroughly researched, often with the use of experiments. This helps to understand the process as a whole, the individual techniques and how it affected the final product (Hammarlund 2005, 88-89). For example, to understand the thought behind the thickness of the fabric, the researcher also has to understand how different thicknesses were made. He or she has to have knowledge of the production of thread diameters and weaves. Every aspect and choice of the complete process influences the end product.

Therefore, documenting research methodology should become a standard part of textile analysis. For example, as has been stated in the article by Belanová-Štolcová and Grömer (2010), Ryder has looked at the Hallstatt textiles and wrote down if the yarn was made by teased or comb wool. Rast-Eicher worked on the same materials, checked Ryder's data and concluded the preparation of the fibres could be traced back by analysing the threads microscopically. Now the use of the microscope is documented, the methodology does not have to be invented before every research.

Results could be interpreted differently, when the same methodology is not followed. The production sequence could be falsely reconstructed, altering the interpretation of how textiles were seen and treated in the past. The view on the life of one individual or a whole group could be altered, when the sequence and the product is understood (Good 2001, 219; Andersson-Strand 2010, 2). Textiles have always been and still are an important piece of the daily lives of everyone (Good 2001, 209).

1.3 Definitions

This thesis will only use the word *fabric*. Here, fabric is a produced cloth without a meaning of use. Before the production, the maker would have an idea about what to do with it, but the final idea is not realised. Therefore, the fabric does not yet have a definite meaning of use. The meaning can be altered during, after production and during the lifetime of the, then, *cloth*. Also, the finished fabric is without meaning of use and has to be processed again to give it a meaning and could be used immediately as it was intended for. A dress would be a meaningful textile, because of its function (clothing). The meaning of use could also change into something the maker did not intent. After this dress is worn out, the material could be processed into another meaningful cloth, such as a cleaning rod. This purpose was perhaps intended by the maker of the fabric. Therefore, fabric does not have a meaning of use before it is processed into a textile with a definite meaning. This definition is also practical for the incorporation of findings which show different stages of process as well, such as balls of yarn. These could have been intended to be made into a garment, but they could also have ended up in a domestic textile, such as a rug or tapestry.

In addition, meaning and traditions behind fabrics and the different production techniques have been left out. Because of this, (decorative) stitching and repair techniques do also not have a part in this thesis. This BA-thesis will only focus on the technical aspect of creating a fabric, more specific the woollen fibre preparation techniques carding and combing.

Therefore, no hypotheses about dress and identity will be made in the following chapters. Those aspects could be understood when the researcher has a grasp of the craftsman's knowledge of the textile production sequence. The problem is that dress and identity focussed research is often lacking the technical aspects of fabric production because not only the final product is important, but also the way it is produced. Even without having knowledge of the meaning(s) of the final product, the maker would have had an idea and he/she or his/her predecessor deliberately chose to produce the fabric with certain techniques. These choices can be withdrawn from the archaeological artefacts, including yarn, fabrics and tools.

1.4 Period and Region

The Early Bronze Age to the Middle Iron Age (2000-250 BC) has been selected as a time frame for this BA-thesis with current borders of the Netherlands as region. At first, the Bronze Age (2000-800 BC) was selected. But short research showed little material has been found during settlement and burial excavation in the Netherlands. The Early and Middle Iron Age have been added to enlarge the usable archaeological data. The choice to not incorporate the whole Iron Age (800-1 BC) has been made, because direct contact between the Dutch farmers and the Romans has not been established as a fact. They possibly bring new ways of producing fabric, coming from the Mediterranean Sea, Near East or even further (Bender Jørgensen 1991, 43). By choosing not to use Late Iron Age (LIA) materials, the experimental and archaeological data would represent the local traditions. However, this thesis does not rule out the possibility of previous contact with the Mediterranean. Future research can verify or rule out the possibility by comparing the local traditions.

1.5 Goals and Questions

The two goals of this thesis research are stated below. On the next page, the three research question can be found. These will be answered in the concluding Chapter 6.

1) The production process of woollen fabrics is a complex process. This BA-thesis focuses on the fibre preparation of woollen fibres as could have been used in Bronze and Iron Age textilia found during excavations in the Netherlands.

2) The research methodology will be documented. This will be analysed on what presents the most reliable information about the preparation of woollen fibres.

This BA-thesis focuses on the preparation of woollen fibres before spinning of archaeological textiles. The aforementioned goals will be research by answering the following questions:

1) Which fibre preparation technique was used to produce woollen fabric in the Dutch Metal Ages, ca. Early Bronze Age to Middle Iron Age?

2) How can the fibre processing techniques be traced microscopically in experimentally produced threads and samples? What is the difference between unsorted teased fibres and the sorted fibres?

3) Which differences are microscopically noticeable in the archaeological material?

1.6 The Experiment: A Short Introduction to the Methodology

1.6.1 The tools and fibres

The experiment was executed by myself at the Textile Research Centre (TRC) Leiden. The knowledge and experience was obtained during the attendance at several courses given by the TRC[1] and PRAE[2] and training based on the courses at home. Some threads have been been spun by expert spinners G. Vogelsang-Eastwood and A. Reurink to compare if the (un)sorted fibres would react differently to spinners of various levels.

The used wool was of *Ovis aries* (=sheep) Icelandic (long fibres) and Shetland (short fibres) breed. Two modern wool types were used, because the prehistoric breeds are extinct. The prehistoric breeds have been altered by selective breeding, for both the food and wool production. It is unknown which breeds were used in this region during the Metal Ages. In addition, the used fibre types, and therefore the properties of the fibres, are unknown[3]. Because of this, a long and a short breed have been selected to see if the lengths reacts differently to the preparation methods.

For the carding *Louët KP0110 Handkaarden 10x10 - 110 tpi* carding boards were used and for the combing *Louët KP0113 Mini-wolkammen enkel* combs[4]. Too

1 http://trc-leiden.nl/
2 http://www.prae.biz/
3 See Chapter 2.1 for woollen fibre types
4 For both types of tools see price list Louët: http://www.louet.nl/images/PDF/nl_verkoop.pdf

little research has been done on prehistoric tools and techniques to use replicas. In addition, no archaeological tools have been found in the region indicating use for explicitly the combing or carding of wool. This could also indicate that no preparation technique was used. The teasing of wool has been added as a variable to conclude more reliably whether the archaeological fibres show preparation of alignment and reduction of crimp, or show no preparation at all.

One type of tool is found in great numbers: spindle whorls. Especially at Iron Age sites, spindle whorls are found throughout the layers of settlements. Therefore, replicas were used during the experiment. These replicas were based on randomly chosen whorls found at Oss, dating Iron Age. Because the spindle sticks have never been preserved it is unsure how these whorls were placed on the stick. In the experiment, three options are tried out (figure 2). The question is if the position on the stick would influence the result of the fibre preparation experiment. However, the focus of the experiment is on the fibre preparation. Other experiments focussing on these whorls, using exact replicas, bring forth more reliable conclusions about the use of the tools.

Figure 2
L: top, middle and bottom VO6374ker replica drop spindle
R: top, middle and bottom VO1694ker replica drop spindle

1.6.2 The sampling of the experimental fibres and threads

Both types of wool were first split into two groups: carding, combing and teasing. Each group was split into twelve samples. In all cases, the Icelandic wool was processed and spun before the Shetland wool, the carding came before the combing, and the combing before the teasing. In addition, the Icelandic combed material was both carded and combed, to see if there would be differences visible if different methods would have been used on the same sample.

Each processed sample was put in a zip-lock bag. Following the steps on the standard form, each breed would have twelve samples per preparation technique (appendix 2). Each sample was spun by a bottom, middle or drop spindle, using either whorl VO1694 or VO6374 (figure 2; appendix 1). The samples have been either spun in the z- or s-direction (figure 3). The two breeds and three preparation techniques make a total 72 spun samples. In addition, twelve threads have been spun by two expert spinners and a total of six samples have been taken of the unspun fibres of each breed and preparation technique[5].

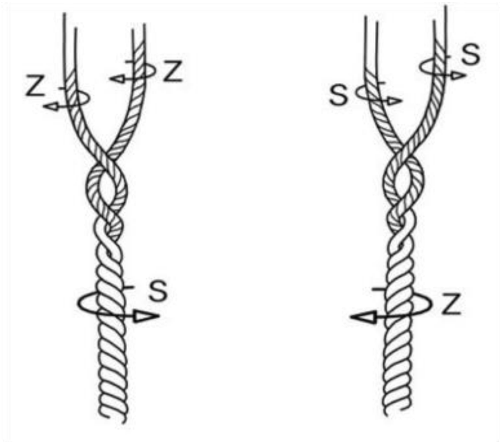

Figure 3
Left: the twist of the single thread is done in a z-spin and the plying in a s.
Right: the twist of the single thread is done in a s-spin and the plying in a z.

The twists are called z and s because the diagonal of the twist fits either in the z- or s-diagonal.

http://historicaltextiles.org/2015/08/31/den-viktiga-traden-the-crucial-thread/, accessed on 1-4-2016

After spinning, the 72 threads and unspun samples of all variable sorting techniques (appendix 2) were analysed with the use of a Leica M80. The twelve threads spun by the expert spinners were analysed in the same way as the experimental samples. All observations are compared to numerous samples of archaeological textiles from this region dating between EBA-MIA. First, the balls of yarn from Roswinkel and Smilde-Ravensmeer and then seven samples of the *Vorstengraf of Oss* were analysed with a Leica JSM5910LV (Ingenegeren 2010, 102-5; appendix 4; table 1 and 2). A larger magnification was used due to the small size of the archaeological samples. Five experimental threads have also been analysed with the same Variable Pressure Scanning Electron Microscope (VP-SEM) (appendix 3.9.1-11).

5 Expert spinners: Vogelsang-Eastwood and Reurink

Table 1: information about samples from Roswinkel and Smilde-Ravensmeer

sample	origin	date	soil	condition
BWV	Smilde-Ravensmeer	LBA	High moore peat	waterlogged/ acid
BW1, BW2	Roswinkel	MBA	High moore peat	waterlogged/ acid

Table 1
Short overview of the samples taken from the archaeological thread from Roswinkel and Smilde-Ravensmeer after Ingenegeren 2010; van Vilsteren 2008; personal correspondence van Vilsteren and Joosten.

Table 2: information about samples from Oss

sample	origin	date	soil	condition
A22, B2, C1A2, C2A2, E2	Oss	EIA	Sandy: Hn21(g)[6]	Corrosion product surrounding fibres/threads

Table 2
Short overview of the samples taken from the archaeological thread from Oss after Ingenegeren 2010; Jansen and Fokkens.

6 Jansen and Fokkens 2007, 17

2 TEXTILE PRODUCTION

This chapter includes the methods used to produce a woollen fabric made of sheep's wool in the prehistoric Netherlands. It is necessary to know the complete production process and its complexity (figure 1) before introducing the experiment. The choices being made in the previous step has effect on all other steps and the final product. In addition, these choices have probably been made beforehand, when the fibres were still part of the fleece of the sheep. In other words, the thought of what the final product was to become influences all steps in the production process.

2.1 The Three Types of Woollen Fibres

The woollen fibre is made of long-chain protein molecules. Due to this natural structure formed by the polymerisation of amino acids, the fibre is stretchy and will return to its former length because of its elasticity (Gordon Cook 1993, 115-166; Morton and Hearle 2008, 48). The fleece of a sheep does have different fibres as well. First of all, there is a distinction between short and thick kemp, long coarse hair and fine underwool fibres. Then, there is a difference between skin fibres and shed fibres in the staple. This means, once fibres are shed at different points during the year, they staple on top of the skin fibres still attached to the follicle (Ryder 1978, 10-12). There is also a difference between crimp: "the waviness of a fibre" (Morton and Hearle 2008, 146).

The thicker, often chalky-white, fibres with a medulla (a hollow space inside of the fibre) are kemps with a width between *c.* 50-100 microns (Grömer 2016, 65). These grow for a short period of time and are shed off after a few months, irregularly during the year. The hollow space inside the fibre probably functions as isolation, possibly why it is shed off so often to become part of the staple (Ryder 1978, 10-12; Wildman 1954, 64). Hairs could also have medullas, but these often are of a smaller width of around 80 microns. Hairs are longer than kemps, because they grow for a longer period of time (Ryder 1978, 7-10). Also, hairs have scales, whereas this is not a necessary feature of kemp.

The fine underwool fibres are the thinner scaled skin fibres without a medulla, where *c.* 30-60 microns would be medium and less than 30 microns fine (Grömer 2016, 66). These are shed once a year, growing from early summer to early summer the following year. When they are shed they are called 'dead' fibres, together with the hairs (Ryder 1978, 6-13). It is not fully understood which factors play a role in the shedding off of different hairs during different periods throughout the year and what correlation there is between the shedding of all fibres (Wildman 1954, 66). All shed fibres form the staple above the skin, and thus, consists of all kinds of different lengths and widths. The width depends on the season, diet and possible diseases. During spring, it looks as if the fleece has grown, because the thinner winter fibres have risen above the skin due to the excess of wool grease (Ryder 1978, 11-12; Wildman 1954, 66). Also, the shedding and even the existence of the different fibre types are not always the same as the prehistoric breeds had. These natural causes may have been influenced by humans, such as by domestication and sheltering.

Which fibres are used depends on what kind of fabric the maker wants to create. To make a coarser woollen fabric with a bristly feel, one should use more hairs and kemp than when you intend to make a very fine, soft woollen fabric made of underwool fibres. The thickness of the cloth has, next to the weave, to do with the thickness and 'spinnability' of the fibres. Kemp cannot be spun without use of spinnable fibres, because of its shortness relativity to its thickness and stiffness, and due to that it breaks fairly easily under pressure (Barber 1992, 21). It can be spun when it is mixed with hairs and underwool. The coarser the material, the easier a thicker thread can be spun (Andersson-Strand 2010, 14). Contradictory, not too many underwool should be used either, because it would produce a very fine thread vulnerable for opening up easily and to irregularities (Mårtensson *et al*. 2006, 5). However, fine wool was desired, reducing the kemp of most of the now living domesticated breeds (Grömer 2016, 56).

These choices based on the available fibre widths and lengths was already possible during the Bronze and Iron Age. From the Late Neolithic period, woolly sheep were known in Europe (Grömer 2016, 55). During the Metal Ages, medium to long haired sheep arrived, providing more choice in fibre types.

2.2 From Fleece to Processed Raw Wool

By examining fibres, it is possible to tell which species it derives from and what its condition was during the life of the animal (Østergård 2009, 42-43). It also tells something about the (cross-)breeding of sheep breeds and whether the sheep was domesticated or not. This research could be combined with the analyses of bones by zoo-archaeologist. This combination of different fields of research could give an insight in the environment, animal behaviour, local production traditions and thoughts of peoples in the past. From local phenomena, such as treatment of (domesticated) animals, to connectivity between groups or cultures (Rast-Eicher and Bender Jørgensen 2013, 1234; Frei 2010, 63-64).

There are different methods to gather woollen fibres from a sheep. The first method is to pluck (=rooing) the staple of shed fibres off from plants and bushes where the sheep left their dispensable fleece (=hedgerow wool) or directly from the sheep itself. This is most efficient during late spring when the sheep is moulting (Rast-Eicher 2013, 170). The usable material are full-grown skin fibres and kemp, both with a root (Wildman 1954, 66).

Another way to gather the shed hairs is to comb the sheep or skin the animal and bury the material to pluck off all hairs in a later stadium. To get the same effect as the plucking and combing of wool, the fibres can also be plucked off a skinned sheep. The skin will be put in a closed environment where it will decompose After the desired time for decomposition has passed, the skin is taken out to easily pluck of the woollen fibres without much force, not damaging the fleece and skin[7]. This is called bloat wool.

The sheep's fleece could be sheared or cut off. Now, both staple with roots and skin fibres without roots are taken. This information can tell whether a shear/knife/other cutting device was used during that period of time. The earliest shears in Europe date about 350 BC (Rast-Eicher and Bender Jørgensen 2013, 1238), but it is unknown when this technique was picked up on in our region. What could be concluded is that, if the marks left by this technique are found, flock management started or improved, because domesticated sheep will not shed their fibres (as much). The sheep grow accustomed of people taking care of their fleece. In comparison with the rooing and combing, the farmer can now plan the removal of the fleece himself, instead of waiting on the harvest period (Rast-Eicher and Bender Jørgensen 2013, 1236). But the researcher has to take into account that the cut marks of the fibres are similar to damage marks (Rast-Eicher 2013, 170).

7 Personal correspondence Reurink

Nowadays, the fleece growing on different places on the sheep are already separated. According to Ryder (1978, 7), a system of the separation of different kinds of fleece between breeds, flocks and even sheep within the same flock took centuries to evolve. It would be quick to think that the prehistoric people did not know how to work with wool and used everything they could get their hands on to produce fabrics. Presumably, we possibly have lost the knowledge of fine quality production by hand when industrial mass production was introduced (Rast-Eicher and Bender Jørgensen 2013, 1224). Processing coarser fibres could have been tried to avoid during the Metal Ages, for example. The fine underwool was less coarse and could be used to produce a quality (=strong enough) thread (Morton and Hearle 2008, 135; Rast-Eicher and Bender Jørgensen 2013, 1227; Grömer 2016, 55). In addition, not every fibre on the sheep is useable. Fibres from underneath the tail would be very knotted and dirty, which would make it unusable to produce durable thread with equal width with[8]. It would be inefficient to try to unknot the impossible knots and wash out all the dirt and excrements, when there is enough fleece from the body of the sheep to work with. The sides, back and shoulders produce the best quality (=useable) fibres (Rast-Eicher and Bender Jørgensen 2013, 1227).

2.4 Fibre Preparation: Cleaning Fibres

After obtaining the fibres, the fleece is very greasy and has a lot of unnecessary natural products in it, such as knots, plants and excrements. The first step to clean the fibres is to wash most of the dirt out. After this, several methods can be applied to further clean and sort the wool. First, unusable fibre clusters, such as knots, could be teased out throughout the whole preparation sequence. In medieval Europe, the wool was further cleaned by a whipping technique (=smashing on the prepared fleece with light, small sticks to fluff the fibres and to let the dirt fall out). It is possible, this was used in the Metal Ages as well, however, the archaeological evidence is currently non-existent in the region. There are no indications of such practices known.

What probably was done was the re-greasing of the fibres before carding or combing. Dry fibres would break off more easily during spinning. If the fibres had not been cleaned and 'spinning the fibres right off the sheep', the fabric would be not as durable as processed fleece (Ryder 1978, 14-15) and, thus, would have been cleaned

8 Personal correspondence Olthof

so in prehistoric times as well (Rast-Eicher and Bender Jørgensen 2013, 1227). Dirty fibres produce a weaker thread, because the dirt would loosen the grip of the fibres during spinning or could break the fibres when sharp dirts, such as sand, rub against the fibres. In addition, the fabric could get mouldy and insects, such as moths, will be attracted to dirts as well[9]. The dirt could hold viruses, bacteria and smells of the sheep, which are uncomfortable or dangerous to humans. It could make the person wearing the fabric or using it for shelter (very) ill.

2.5 Fibre Preparation: Carding or Combing

The stages before this final preparation technique already started the job which carding and combing finishes: separating fibres in a certain way to be able to create the wanted fabric. This could be done by hand, but tools would make a great difference to separate the fibres in order to produce a more qualitative (=aligned) thread (Mårtensson *et al*. 2006, 5). These techniques are used to separate the different fibre lengths and widths if necessary and place them in a vertical or spiral order to produce a thread to their liking.

Presumably, at least either or both carding- or combing-like techniques were used during the Metal Ages in the Netherlands. At Hallstatt, Austria, the "skin samples were hairier and more variable than the fleeces used in the textiles" (Rast-Eicher and Bender Jørgensen 2013, 1228).

2.5.1 Carding

Carding is a technique for the sorting of wool with the use of a tool to align fibres of different lengths. A broad comb is used to draw the wool, placed on a similar board, out with a pushing motion (figure 4). A roll or rolag is made with a pushing motion holding the boards in the same position, teeth facing inwards (figure 5). A rolag is used to spin a thread from (Vogelsang-Eastwood and Nobelen forthcoming). The more air is trapped in the thread when drawing out of the rolag, the fluffier the thread (Hudson 2014, 5). The carding, the amount of crimp and the spiral form of the rolag are all factors which increase or decrease the 'fluffy feel'.

9 Personal correspondence Olthof.

Figure 4
Row 1
1) The wool is put on one card board, which is placed on the leg and, here, hold by the left hand.
2) A similar board will card in the opposite way across the board on the leg.
Row 2
3) The fibres get transferred to the board in the, here, right hand.
4) The boards are held in the same position with the wooden back facing outwards. In a rolling motion, the fibres are transferred to the other comb.

These four steps is counted as one session. These sessions can be repeated. When enough sessions have been done, rolag can be made in the same rolling motion in step 4 (figure 5). This can also be done by hand by carefully taking off the fibres of the, here, right board, placing it on top of each other and roll the tuft up into a spiral roll of wool.

Figure 5
Experimental rolag, sample bag 4 of carded Shetand fibres.

The fibres are rolled up in a s-spiral, preferred by the spinner. This direction will not interfere with the spinning process, which makes the direction of the twist definite. The fibres will be drawn out from either the top or the bottom of the rolag.

The possibility of this technique could at least be traced back to the Neolithic, considering a flax comb found in Switzerland (figure 6). The reconstruction of the implement looks similar to the modern card boards. This flax preparation tool could also have been used by the prehistoric people as a fibre preparation technique to create a roll/rolag of woollen fibres as well. Similar tools from the La Tène period have been found in Slovakia and Austria (figure 6). But the increasing use of flax could be the reason why similar tools have been found in IA Central-Europe as well (Belanová-Štolcová and Grömer 2010, 11).

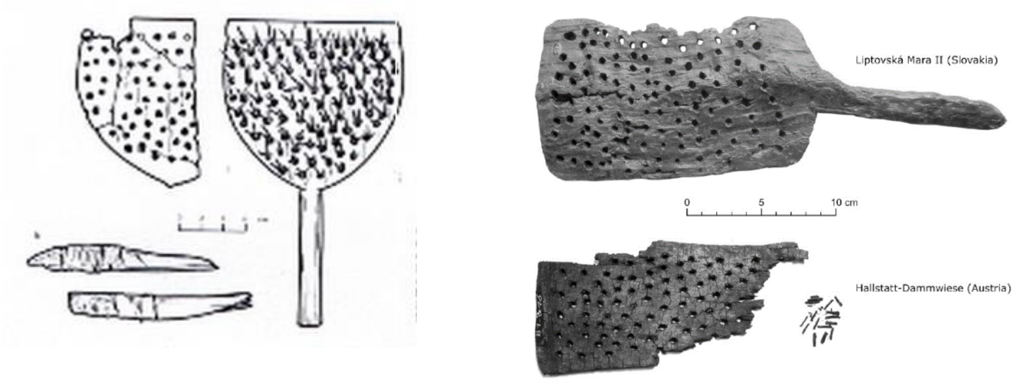

Figure 6
L: E. Vogt's reconstruction drawing of a Swiss Neolithic flax comb (Barber 1992, 14)
r: "Two similar La Tène Period tools used for raw material preparation (...)" (Belanová-Štolcová and Grömer 2010, 11)

2.5.2 Combing

Combing is a sorting technique to align and separate fibres of different lengths, where only medium to long fibres are used to form the staple for spinning. To do this, raw wool is kept still at one point and a comb with long teeth is drawn through the wool . Nowadays, the wool is usually held by another similar comb, but it can be held by hand as well (figure 7). The fibres would be pulled through the teeth of the steady comb, and later, the tufts (the longer fibres pulled off of the comb) are stacked on top of each other in the same direction, to produce a staple[10]. This aligns the fibres and reduces the crimp to produce a stronger, worsted thread which is often thinner in diameter than a woollen thread.

[10] See also Chapter 4.2.2 and figure 15

It is supposed that this was the most used technique at Hallstatt during the Hallstatt period (Belanová-Štolcová and Grömer 2010, 11). This has been concluded by the reduction of kemp found in the yarn, next to the alignment (Rast-Eicher 2013, 172).

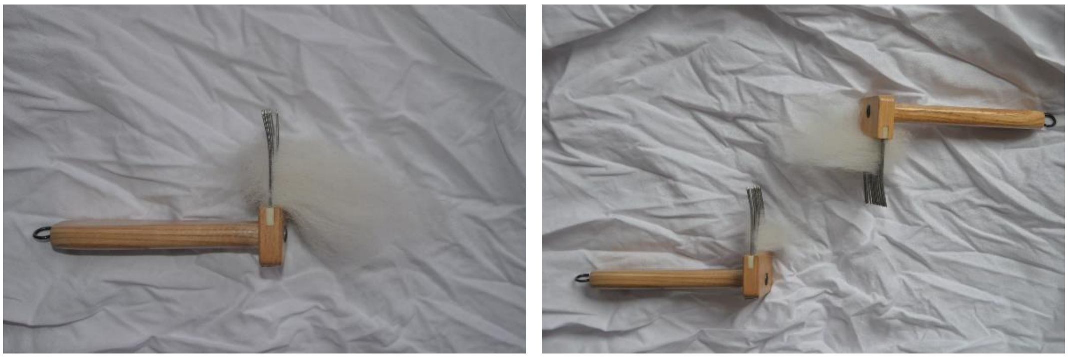

Figure 7 (step 1 and 2)
1) The raw wool is placed on the, here, right comb to be held steady. The wool can also be held in hand.
2) By a combing motion, the wool is drawn out by a similar comb. The long fibres are transferred to this comb. Short fibres and other remnants, such as knots and dirt, are still on the, here, right comb. This will not be used for spinning.

2.6 Spinning

There are various kinds of properties of the fibres which influence the final thread:

a) "Those that originate from the fibre itself, such as length, fineness or fibre diameter, crimp, absorbency, and abrasion resistance [and]
b) [Those] that originate from the spinning process, such as twist, twist direction, how the fibres are orientated in the yarn, and yarn diameter"

(Hammarlund 2005, 106).

Also, the heterogeneity or homogeneity of the used material has effect on the cohesion during twisting. The more homogeneous the fibres, the better the cohesion is, thus, the less twist is necessary. Also, the homogeneity helps with regularity of the yarn (Morton and Hearle 2008, 104). The regularity is the one of the most important features determining the level of the spinner.

This twisting technique is used to produce a thread to make yarn with, which made up of at least one thread (see further for 'plying'). A simple stick or weight function as a spinning tool, but threads can also be spun by using only one's hands. Because of the extensive amount of spindle whorls found at almost every site from the aforementioned period throughout the Netherlands, it is assumed that people used a drop spindle. This type would have a vertical stick with a whorl (a balanced weight) around it to produce a thread by the twisting of the stick and drawing of the prepared fibre out of the staple or rolag. Until now, no sticks specifically determined as spindle sticks have been found in the Netherlands. This could be, because these were not preserved together with the whorl, or the excavator would not have recognized it as a tool, because an unprocessed stick could already function as a spindle stick.

Spinning with a drop spindle can either be done clockwise (z) or counterclockwise (s) (figure 3). As stated by Bender Jørgensen (1991) both directions have been found in Dutch prehistoric textiles. However a trend seems to be noticed. Early Bronze Age groups prefer s-spin and Iron Age communities z-spin (Bender Jørgensen 1991, 42-43). Also plying has been done in order to create yarn. Plying is the spinning of already spun threads to create a new, thicker thread (figure 3). The plying is often done in the opposite direction in which the threads are spun, otherwise the thread could become unspun (Barber 1992, 42). However, this is not essential (figure 8). To create a thread it would take up more time to ply the already spun material again before using it to create an actual fabric. When a cloth is almost immediately needed, someone could leave the plying for what it is and begin working with the yarn made up of only one thread. Working with prehistoric material in Europe, plied yarn is rare. A reason could be, because it is more time consuming than directly starting on the weave or other type of fabric production technique.

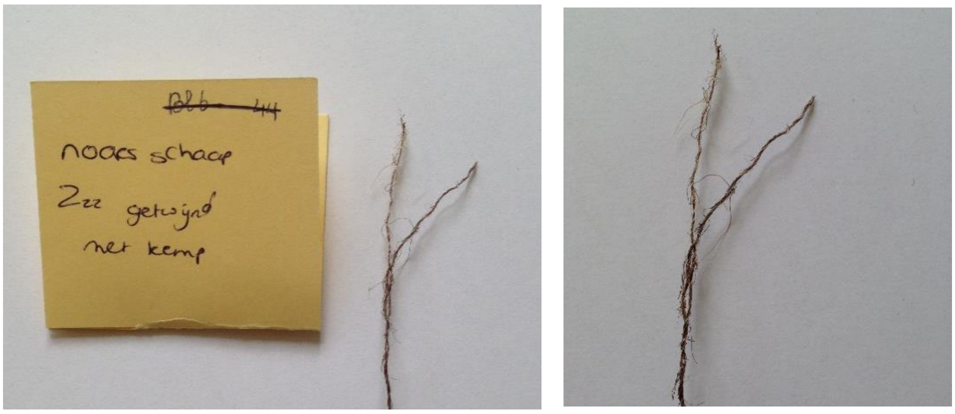

Figure 8
Zz-plyed thread, spun by A. Reurink. To create a stronger thread, the woollen threads were spun Zz. This does not work with all breeds, however, it does with this type of a Norse sheep breed.

The staple or rolag could also be held by a distaff. This method lets the spinner focus more on the process of the drawing out of the fibres and the spinning itself, because he/she does not have to hold the prepared fibres. It does also help to separate the spun threads from the raw wool, making sure it will not get spun on places where it should be (Andersson-Strand 2010, 12). In Central-Europe iconographical evidence is found of women using such tool. These have also been found in graves in Austria dating from the Hallstatt and Roman period (Belanová-Štolcová and Grömer 2010, 11). No evidence has been found in Dutch soils. This could be, because distaffs could be produced from a simple stick as well[11].

2.7 Weaving and Other Fabric Production Techniques

Asking laymen about textiles, they will always know the term ‘weaving’; the interlacing of thread to produce a fabric (Vogelsang-Eastwood and Nobelen forthcoming). Sometimes they also know there are different weaves. But many more techniques can be used to produce a fabric, such as tablet weaving, sprang, netting, nalbinding, diagonal plaiting, knitting and crocheting (*ibid*). The techniques used during the Metal Ages in the Netherlands will be further discussed in this subsection.

As mentioned above, weaving is the interlacing of threads by the use of a loom to keep the weave in place. The warp (vertical threads) and weft (horizontal threads) are used to create a weave, whereby the weft-thread is moving horizontally in order to create a fabric. This produces selvedge as the side edges. In between, an unlimited amount of patterns can be reached. Basics weaves to makes these patterns with are tabby (figure 9a), basket (figure 9b), twill (figure 9c), satin (figure 9d), brocade (figure 9e), damask (self-patterned weave with one warp and one weft in which the pattern is formed by a contrast of binding systems), gauze (figure 9f), tapestry (weft faced weave where the weft does not have to go from selvage to selvage) and velvet (warp-pile weave with cut open loops) (Vogelsang-Eastwood and Nobelen forthcoming; Burnham 1980, 3-163).

11 Personal correspondence Olthof

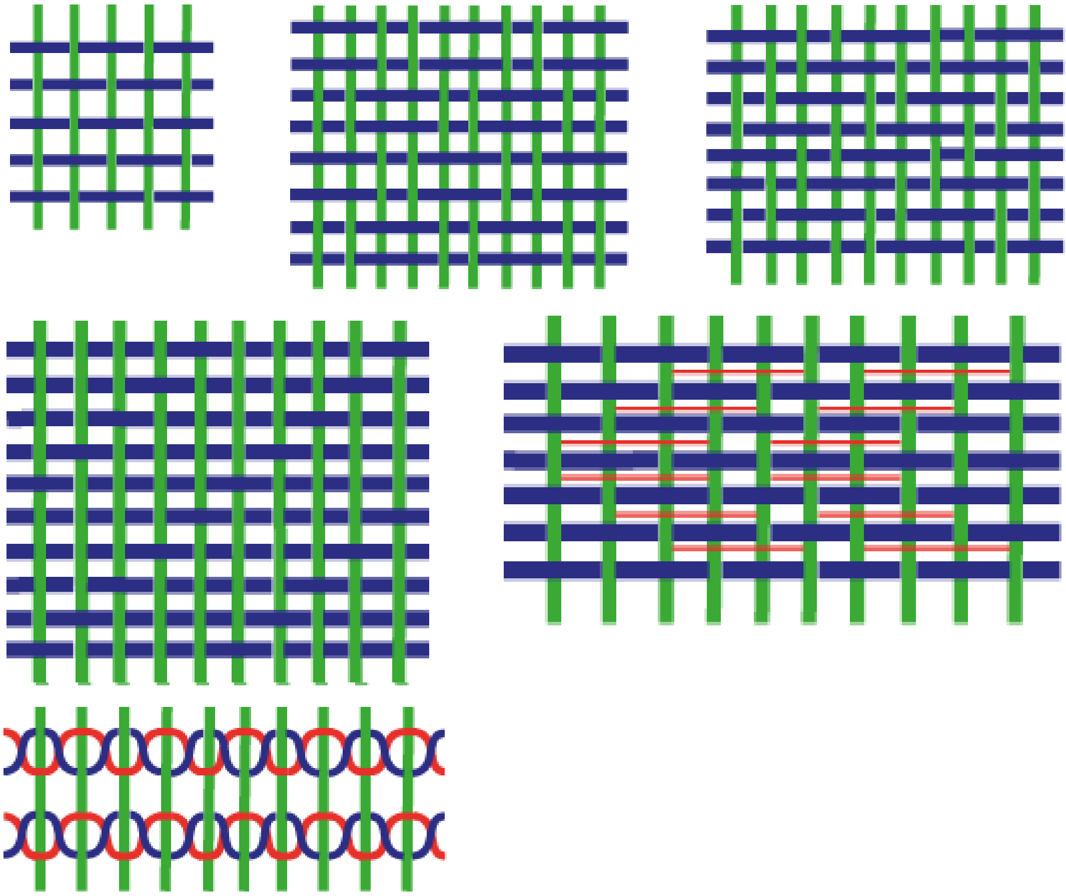

Figure 9
Row 1
a) tabby weave: one over, one under, one over
b) basket weave: extended tabby in either the warp or weft, or both
c) twill weave: 1st: row over/under/over – 2nd: row under/over/under creating a diagonal line
Row 2
d) satin weave: similar to a twill, but as less binding points as necessary of five or more threads in one unit
e) brocade weave: supplementary weft imitating embroidery
Row 3
f) gauze weave: weft function in pairs to hold the warp threads together creating an often loose weave

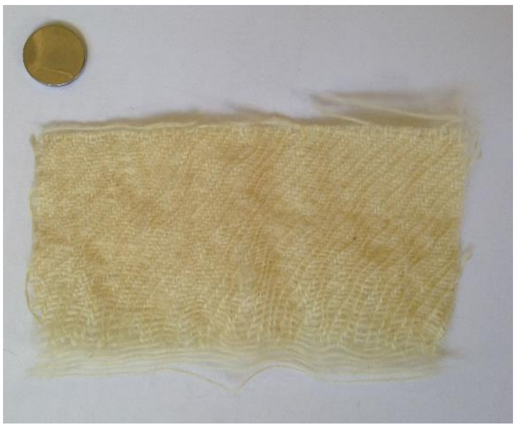

Figure 10
Shifted single twill weave of woollen Cotswold yarn, made by A. Reurink. Result of fulling after weaving.

The thickness of the thread and the density of the weave give the viewer different visual effects (Hammarlund 2005, 116). Some types of wool will only give the desired effect after the different fibre preparation techniques. For example, Cotswold threads are only 'weavable' when using both worsted and woollen threads. To produce a felted fabric, such as *laken*, the warp has to be made of worsted yarn and the weft of woollen yarn. The weave would just fall apart using only woollen yarn (figure 10).

Tablet weaving is called weaving, but it is actually the intertwining of threads woven into a small fabric with an invisible weft thread (figure 11). The tablets and threads are both lined up horizontally with each tablet having multiple holes. The tablets could either be held s or z, making a different pattern by twisting them forwards or backwards. Before one or more turn(s) a weft thread should be placed under the upper threads and above the under threads. One turn is equivalent to one side of the tablet, of which it has four, thus making each turn about 90 degrees.

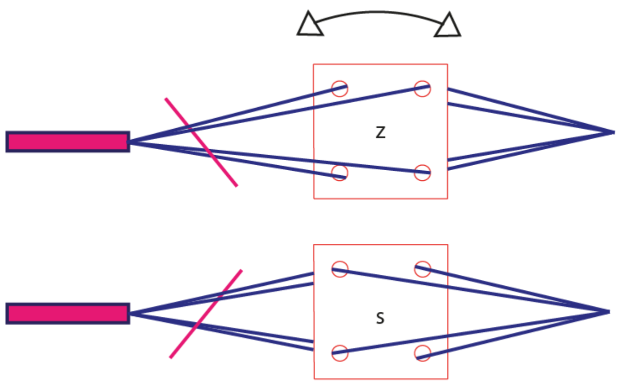

Figure 11
Tablet weaving
The lavender rectangle on the left is the weave and the stripe of the same colour the weft. The blue threads in front of the tablets make the weave when the tablets are turned, for example 90º degrees, either clockwise or counter clockwise. The tablets are hold horizontally in front of the weaver. The can be hold either in z or s position. This creates different pattern, next to the amount of holes are threaded and the colours of the yarn.

Another way of making fabrics is by sprang, which is also done by intertwining threads, but without the use of a weft thread (figure 12). All threads are placed on a vertical frame. The warp threads are twisted around each other in the middle to create a pattern. This twisting happens at the top of the frame and simultaneously at the bottom. The fabric is finished off with a weft thread in the middle of the sprang (figure 12). When finished, the fabric is stretchy.

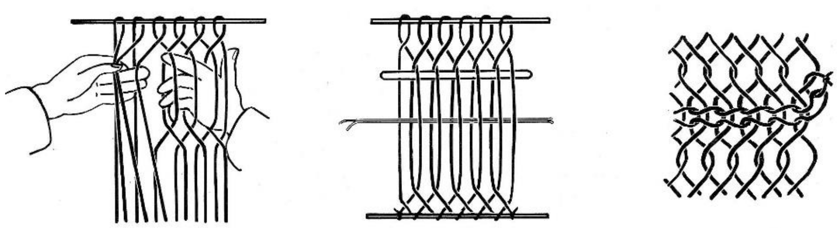

Figure 12
Sprang
left: the person is intertwining the warp threads
middle: the interlacing is seen on the bottom and the top in the same pattern. A weft thread is placed in the middle to keep the fabric in production in place when it is not worked on.
right: the top and bottom is what the interlacing should look like. By chaining the meeting line, the sprang could be secured, however, this is not necessary.
http://1501bc.com/files/sprang_technique.jpg, accessed on 17-04-2016

Netting is a technique that looks similar to sprang when it is stretched out, but is not as stretchy. This is because of the differences of the techniques. Instead of intertwining the threads, the intersections are knotted or looped in order to create a net (figure 13). The fabric will stay in place due to these knots or loops.

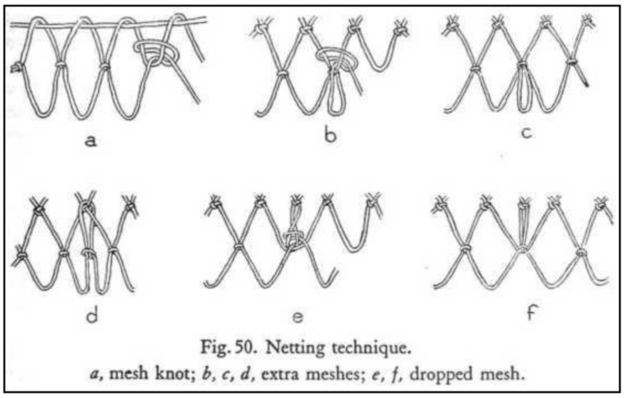

Figure 13
Examples of netting. In all cases, the fabric is hold together by the tightened loops.
http://nzetc.victoria.ac.nz/tm/scholarly/BucTheC-fig-BucTheC213a.html, accessed on 01-05-2016.

Nalbinding creates a fabric by making spiraling loops in one continuous loop, which the use of yarn which is not too long to pull through the loops effectively (figure 14). Because of working in a spiral, no seams are necessary to complete the round fabric. It is also possible to nalbind back and forth creating a flat, straight fabric.

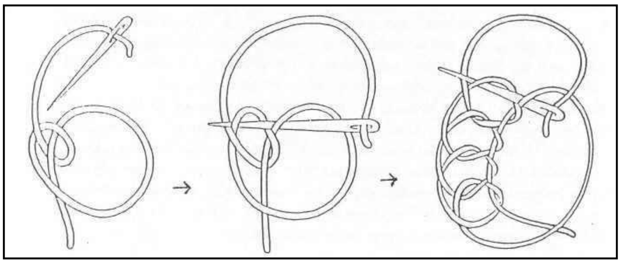

Figure 14
Nalbinding
The fabric is created in a spiral by continuously making loops inside of the previous loops with the help of a needle. The new loop can be made in either one or more of the previous loops. The technique cannot be done with a continuous string of yarn.
http://www.ars-replika.de/1__Jahrhundert/1__Jh__Handwerk/Textilhandwerk/Nailbinding/Nalebinding_1_komplett_klein.jpg, accessed on 17-04-2016

3 PRESERVATION OF WOOLLEN FIBRES

In this short chapter, the preservation of wool in archaeological context will be discussed. Dutch soils differ throughout the landscape and some conditions are almost perfect for preservation, such as at the peat soils in the northern provinces. During and after the excavation the fibres degrade fast (Good 2001, 217-8). Information about the fabric and its production sequence, and landscape and environment could be lost quickly. Not only hold the spun and woven threads the key to understand the process, pollen and other organic material from the moment of spinning could be 'trapped inside' the thread.

Different fibres are found at different locations. For example, linen and woollen textiles have never been found in the same context due to the chemical processes and the different substances it is made of. Wool is made of protein-chains and will survive better in acidic conditions, whereas flax, a cellulose fibre, will survive in alkaline soils (Vogelsang-Eastwood and Nobelen forthcoming). Both humic and tannic acid attack plant tissue, whereas it would decrease the oxygen levels in such way the unharmed animal fibres are preserved. It works the other way around in alkaline soils. Here, the minerals in the soil chemically react to the acidic molecules, whereas the cellulose fibres are unharmed (*ibid*).

Next to the type of soil, three conditions play a part:

1) dry conditions, such as deserts, caves and salt-mines;
2) wet, semi-wet or moist conditions;
3) frozen conditions.

Information of the fabric, yarn and production could also be preserved as impression, as pseudomorph (="mineral formed by chemical or structural change of another substance, though retaining its original external shape")[12], as metal corrosion product or after indirect contact with fire (=carbonization) (Vogelsang-Eastwood and Nobelen forthcoming; Good 2001, 213-5). In all conditions, the atmosphere has to be constant, because irregularities will activate fungi and bacteria, destroying the fibres (Vogelsang-Eastwood and Nobelen forthcoming).

12 Source: http://www.britannica.com/science/pseudomorph, accessed on 12-04-2016

Because of this, most prehistoric woollen textiles in the Netherlands are preserved by the acidic soils at *terpen* (=artificial dwelling mounds), in inhumation graves and around bog bodies in acidic peat, such as sphagnum[13] and oligotrophic peat (Ingenegeren 2010, 12). All Bronze Age textiles come from the northern provinces of the Netherlands, whereas the Iron Age textiles are found in the south, where conditions are different (Bender Jørgensen 1991, 42). For example, the location of the *Vorstengraf* at Oss unexpectedly preserved remains of woollen Early Iron Age textiles (Jansen and Fokkens 2007, 81-83). Normally, animal material would not survive in relatively wet and sandy soil. In addition, the location got very tempered throughout the years, because of human interaction with the landscape (Jansen and Fokkens 2007, 16-17). In some way, the conditions of the exact location were consistent enough for the fibres to get mineralized by the corroding metals of and inside the *situla*.

Although there are many cases in which materials could be preserved, this does not happen often, because of the irregularities that could have occurred in 4000 years of time. As mentioned previously, these irregularities are fatal for the preservation of fibres. There irregularities bring the materials in contact with oxygen, starting various processes.

13 Personal correspondence Olthof and Mol.

4 EXPERIMENTAL METHODOLOGY

4.1 Before the Start of the Experiment

At first, a standard form was made to understand which variables would be relevant and what the quantity of samples would be (appendix 2). 72 threads were produced, made from two different breeds, three different preparation techniques, and spun in both s- and z-direction using two different spindle whorls in three different positions on the stick. As mentioned in 1.6, twelve additional threads were spun by expert spinners. They spun all prepared fibre types once using a bottom drop spindle with the replica of whorl VO6374ker.

To see if fibre lengths have effect on the reaction of fibres two different breeds have been chosen: a long (*Ovis aries* "Icelandic") and a short (*Ovis aries* "Shetland") fibre. The choice of the specific breeds was made due to availability at the Textile Research Centre Leiden. Both samples were already washed and re-greased, ready to be processed. But, the raw wool still had some irregularities. Especially the Icelandic variant had a lot of knots, which has to do with the fibre length in combination with the crimp. The shorter Shetland fibres were dirtier than the Icelandic, but had almost no knots[14].

4.2 Execution of the Experiment

4.2.1 Carding

The experiment started by carding the long Icelandic fibres. Afterwards, the short fibres of the Shetland raw wool was put on the cleaned carding boards. To produce the necessary threads a rolag was made and put in different zip-lock bags to be able to transport the samples[15]. Each bag contained one rolag, made up of two sessions, whereby the Icelandic wool was pulled in half in order to use the other half for the combing. Each rolag was used to produce one thread. The amount of wool per bag was based on personal experience. Counting the fibres is not possible or necessary and would take up too much time. Weighing the experimental wool and threads, and archaeological threads or weaves would have been an option, but the effect of this measurement is unknown. Too many variables could play a part in the weight of the

14 Dirt: seeds, pieces of twigs and pieces of hay.
15 See Chapter 2.5.1. for rolag

spun thread. Therefore, the amount of wool for each rolag was based on personal experience of spinning and preference of how much would fit on the boards.

To produce a rolag different steps have to be taken. The following explanation of the carding process makes use of a right-handed carder (figure 4). First, the fibres have to be applied onto the left carding board by hand, by pulling the raw wool softly through the teeth to place it on the board. By holding the boards in opposite directions, teeth facing inwards, the fibres are transferred from the left board to the right. When most of the fibres are transferred, the remnants on the left board are put on the right board by make the same rolling motion, holding the boards in the same direction, instead of the opposite, teeth facing inwards. Then, repeat the process, transferring everything from the right to the left comb. This marks the end of one session and was repeated four times. This number of times was chosen, because this way both ends were processed two times. When the fibres are transferred from the right to the left board, the upper part becomes under and vice-versa.

When the carding process is finished, the processed fibres are taken off by hand. Normally, a rolag would be made using the boards, but more processed wool than fitted on the boards was necessary for the experiment. In order to put the carded material on top of each other, it had to be removed carefully by hand. Two processed pieces were put on top of each other and rolled up at the sides of the fibres. The fibres were pointing left-right and rolled clockwise. The rolling has no influence on the thread, because the z-s-spin will give the final effect.

The aforementioned pulling of the rolag would have no effect on the spinning of the carded and to-be-processed combed thread. The pulling was done in the same manner the wool would be drawn out of the rolag in order to spin a thread from it. In the case of the combed Icelandic wool, which was first carded and then combed, the function of the rolag is lost. The fibres get sorted again, and are aligned straight instead of aligned in a spiral.

4.2.2 Combing

The combs were held in opposite directions with the nails pointing up and down. This is the safest way to execute this technique. Another way is known by holding the steady comb with the nails pointing away from the body. The nails of the moving comb always point down in both techniques. Further references to holding the combs left and right are again because the person who combs was right-handed.

The process started with putting fibres on the comb in the left hand and were transferred by the moving comb in the right hand. When most of the longer fibres were transferred, the combs were switched at least once. After this, the medium to long fibres were pulled off the right comb in between comb-motions. When the fibres could not be pulled off anymore, the remnant fibres were taken off the combs and put on the left comb again. The process started again to make sure most medium to long fibres are used. The remnant, such as short fibres, dirts and knots, were thrown away (figure 15).

The tuft were placed on top of each other with the fibres pointing in the same direction, creating a staple[16] (figure 15). These were put in one of the twelve bags without rolling it up first, as had been done with the carded material. The tips of the fibres were either pointing up-down or left-right, depending on how the tuft fitted in the bag.

Figure 15
Above and on the combs: remnants of Shetland fibres after combing.

The combed product in placed on the bag with the fibres pointing north-south. This tuft is formed by two combing sessions, pulling off the longer fibres of the combed and stapling it.

4.2.3 Teasing

Twelve samples of raw, unsorted Icelandic and Shetland wool were teased instead of being carded or combed. This could be seen as a 'control group', because no

16 See Chapter 2.5.2 for 'tuft' and 'staple'

preparation using tools would have taken place. When the archaeological samples would not show similarities between the carded and combed threads, it might show similarities with the teased material, when no preparation method has been used during the Metal Ages in this region.

As can be read in 2.4 teasing is used for the cleaning of the wool. Getting rid of dirt was also the focus during the teasing. The knots and bigger pieces of dirt are pulled out by hand. The wool becomes cleaner, and often also a bit fluffier. This method did not cover all smaller pieces of dirt, which have been removed during the combing or carding process. Mostly material stuck inside of curls and other locks of fibres could not be filtered out by hand. In contrast, the ground was much cleaner after the teasing. Carding also mingled in a little of the dirt, stuck between the nails. Combing removed all excessive material.

4.2.4 Spinning

Before spinning unprocessed samples were taken from each fibre type and sorting technique. This in order to be able to document the reaction of unspun fibres as well. Each unspun sample was taken from sample bag 8 of each technique and breed. Although the techniques were seemingly of equal level for each bag, it is expected that by the time sample 8 (out of twelve) was processed, the technique is of an expert quality.

The replica spindle whorls are based on whorls found at the site Oss-Horzak in 2004. These were made with the same exterior looks with the use of modern Darwi classic clay. The size and type whorl is the same, but the type of clay, the weight and the diameter of the whorl hole differs from the original archaeological Iron Age spindle whorls. Because the research would not be focussed on tools, it was not necessary to track down the used clay in order to produce an exact replica. What was of importance are the rotational characteristics of the spindle whorl. These characteristics influence the rotation and balance, thus influence on (the spinning of) the thread (Verhecken 2010, 258-260). Both spindles were balanced enough to easily spin a thread of an equal width. VO6374ker worked best as a bottom drop spindle and VO1694ker as a bottom and middle drop spindle. Both whorls did not have the balanced out to be used as top drop spindles[17].

There is a reason why these replicas were used instead of modern spindles, as was with the tools for the carding and combing. It is unknown if different spindles or their whorls would have an effect on the reaction of the prepared fibres. By using replica spindle whorls a more reliable outcome is possible. The reason why this is not done with the carding and combing is because there is too little evidence of tools used for this process. In the case of pierced through ceramic balanced weights, it is almost certain these artefacts were used as spindle whorls during the Bronze and Iron Age in the Netherlands.

The position of the whorl is a question unanswered until the sticks are found. Therefore, the experiment was executed whereby both whorls are used as top, middle and bottom drop whorl spindles (Barber 1992, 43; figure 2). It is unknown if the position of the whorl has an influence on the fibres or if it all depends on preference and experience. To keep the whorls placed on the stick, the hole had a diameter of 7.5, corresponding with the width of the stick[18]. A measurement tape was used to place the whorls in the same position. The bottom whorl had its centre of centrifugal force (=flat side of VO6374ker and middle of VO1694ker) on 3 centimetres, the middle whorls on 9 and the top centre on 15 centimetres (figure 16). This, because the stick was 18 cm. in length in total, making the middle 9. The whorl could not be place on the exact top or bottom of the stick, thus 3 and 15 were chosen. Lower than 3 and the whorl could fall off, higher than 15, a thread could not be looped around the stick to continue spinning. If the looping was difficult, when, for example, the stick was to slippery, the hooked implement could be used (figure 16).

Figure 16
L: spindle stick with 3-9-15 centimetres and the hooked implement on the top half of the spindle.
R: detail of the hooked implement. Used for stability of the thread whilst spinning, but was not used during the experiment.

17 See figure 2 for the position of the used drop spindles
18 The wooden stick is made by fellow student and expert woodworker T. Stikkelorum

Based on practical knowledge by Hammarlund (2005) the way a spindle looks would have no effect whatsoever. According to the technical reports of experimental research by The Danish National Research Foundation's Centre for Textile Research Copenhagen (Mårtensson, L. *et al*. 2006; Mårtensson, L. *et al*. 2006) the weight, width and balance would have an effect regardless what the exterior would look like. Because of the results of these experiments based on expertise a heavier spindle whorl was used in this BA-experiment a well. It seems that a heavier, well-balanced whorl is less time consuming than lighter whorls (Andersson-Strand 2010, 13).

The 84 experimental samples were spun either in the z- or s-direction (figure 3). Both directions were used throughout Europe during the aforementioned period. In Early Bronze Age Hallstatt the s-direction was dominant, but changed to z during the Iron Age (Bender Jørgensen 1991, 42-43). Whether this was also the case in part of the Netherlands is unknown, because too little material has been excavated. It is possible that different directions have been used in one weave as well, because this would have influence on the strength and durability of the fabric, for example the Cotswold (Chapter 2.7)[19].

All 84 threads are around 1.50 meters. This was the most efficient, because 1.50 meters could be spun without winding the thread around the whorl to continue. The winding is done when spinning in order to produce yarn to make a fabric with, but it was not necessary to spin continuously for the experiment. After the desires length was reached, the whole thread was wound around the spindle stick to be transferred to two skewers (figure 17). This in order to keep the thread in place during transport. This winding up would have no effect on the analyses, because the threads were straightened before put under the microscope.

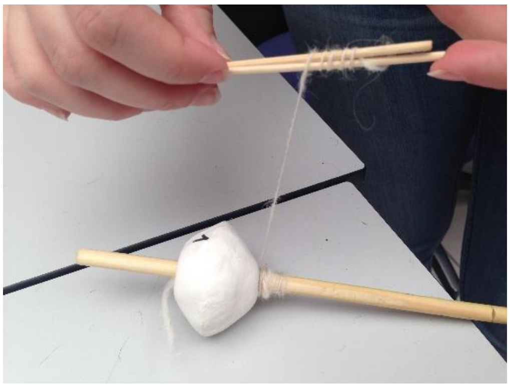

Figure 17
Yarn transferred from spindle to two skewers for transport. The yarn cannot get unspun when winded around the skewers. The beginning and end of the threads have been fastened between the two skewers.

19 Plyed yarn would also have influence on the fabric. Possibly, it can also influence the reaction of the fibres inside a thread. This would be another, perhaps additional, experiment and has therefore been excluded from this thesis. For 'plyed': 2.6

5 MICROSCOPIC ANALYSIS OF ALIGNMENT IN THREADS

5.1 Introduction

In this subsection, the archaeological material and suppositions and hypotheses will be introduced. As with every research, there is a hypothesis and there are suppositions about the outcome. The results in subsections 5.2 and 5.3 will show whether these suppositions are correct. In subsection 5.4 and 5.5, and Chapter 6, the suppositions will be corrected when necessary.

5.1.1 A short introduction to the archaeological materials

The total amount of textile remains from the Metal Ages in the region is small. As mentioned in Chapter 3, non-acidic soil types do not preserve organic animal material (very well). However, for example the textilia from the *Vorstengraf* is found in a sandy layer. Therefore, two different types of archaeological samples have been studied. Another reason for the choice for these samples is, because of the availability at RCE.

The first samples are of the balls of yarn from Roswinkel and Smilde-Ravensmeer (table 1). These textile objects are found in the acidic conditions of high moore peat of the Bourtangemoore. They date Middle to Late Bronze Age, fitting the time frame (Vilsteren 2006, 217).

Contradictory to expectations, woollen fragments survived in the sandy soil of Oss (table 2). Normally, corrosion product would only show impressions, which can be used for determining the weave and spin. Information about the fibres is lost. In the case of the *Vorstengraf* woollen fragments were preserved by the microclimate inside of the closed off situla (Jansen and Fokkens 2007, 81-82). The textilia probably survived, because the microclimate was constant.

5.1.2 Suppositions of the reaction of experimental fibres

Presumably, the woollen yarn[20] shows less alignment of the fibres and are more 'hollow' between fibres due to the preparation. The rolag has effect on the alignment as well as the carding itself, helping with the creation of these 'hollow' spaces. What also makes this difference is the fibre's crimp, which is not reduced by the carding.

20 =carded thread(s)

The length of the fibres would differentiate more in the woollen than in the worsted yarn[21] and these lengths would be more mixed than when using teased wool. Because of the better alignment of combed fibres, the thread would be less 'hollow' between fibres and would be more homogeneous in length.

The teased yarn would, firstly, possibly have more dirt in it than the woollen and worsted yarn. Secondly, the fibres could be less or not aligned, thus making the thread as 'hollow' as or more 'hollow' than the woollen yarn. The fibres could be less mixed than in the woollen yarn, because it came right off the sheep's staple in which the different fibre types do not have to be mixed.

Perhaps difference between the Icelandic and the Shetland fibres would be seen in the worsted yarn. Because of the length of the Icelandic, this would form a more aligned thread. The carding of this fibre type could have a slight effect on the outcome, such as having less crimp reduction than the Shetland fibres. The fibres would have more crimp.

Possibly, the different techniques leave markings on the fibres, such as breaking fibres when they were not aligned whatsoever in the raw wool (Morton and Hearle 2008, 149-152), or damaging the scale patterns. Presumably, the differences would be minimal.

5.1.3 Suppositions of the reaction of archaeological fibres

Before the experiment was analysed, the expectation of the archaeological material was that what could be detected in the experimental thread could also be seen in the prehistoric samples. After the analysis the hypothesis was revised. It was harder than expected to, to determine the preparation of individual yarn of the experimental samples. Because of the small archaeological sample size and actual size it would probably not be possible to recover the previous preparation technique. It would be possible to determine whether a technique has been used for the alignment. Something could be said about the fibre thicknesses, the space between fibres and their crimp, which would indicate a combing-like technique. If the material is not too weathered, the scale patterns could still be visible.

---

21 =combed thread(s)

5.2 Microscopic Analysis of Woollen Fibres in Experimental Threads

For the recording of all 84 experimental threads, a Leica M80 with a magnification between 2.5x and 5x. was used. After this thread analysis, six samples were randomly taken and put in the chamber of a Leica Variable Pressure Scanning Electron Microscope (VP-SEM) of the model JSM5910LV under a pressure of 30 Pa to see the most details on the fibres. The same microscope was used to analyse the archaeological material.

A difference between the analyses would be the 'checking' by feel. All experimental samples were felt to check if they would feel worsted or woollen and if this corresponds with the technique used. The visual representation of the preparation shows if, and if yes how, the 'feel' is represented in the alignment and crimp of the fibres in the thread. The feel could not be checked with the archaeological material, thus this was why it has been tried to see the feel of the thread represented in the microscopic pictures.

First, the z-spun threads (uneven numbers) and then the s-spun threads (even numbers) of the same type of sample were analysed. The recording started with the carded material, then the combed material and lastly the teased material. Icelandic fibres came always before the Shetland fibres. Never were the beginning and end of the thread used. An average of 20 centimetres was seen as unusable. The end could have been damaged during transportation. The middle and beginning of the threads would have been secured winded around the skewers. However, the beginning was spun by hand, instead of with a spindle, making these parts of the threads unreliable.

The exact middle was put in the middle of the 8 centimetres wide plastic holder. Always, three points of the thread on top of the plastic holder were recorded. 1 was always the exact middle, 2 was on the left of the holder on approximately 1 centimetre and 3 was on the right on approximately 7 centimetres. Only the most representative picture has been inserted in this thesis in appendix 3.

5.3 Microscopic Analysis of Woollen Fibres in Archaeological Samples

The archaeological threads were a lot thinner than the experimental yarn. Although a higher magnification was used, it was possible to get an overview of the threads due to their thinness and small size of the sample. The width of the threads is partially influenced by the thinness of the woollen fibres (figure 18). Other influences are the tightness of the spin (=more twists per centimetre); the fibre alignment; and products, such as dirt, hindering the tightness. The thickness could as well be influenced by personal preferences based on, for example, preference of feel or look, function of the textile, or cultural differences.

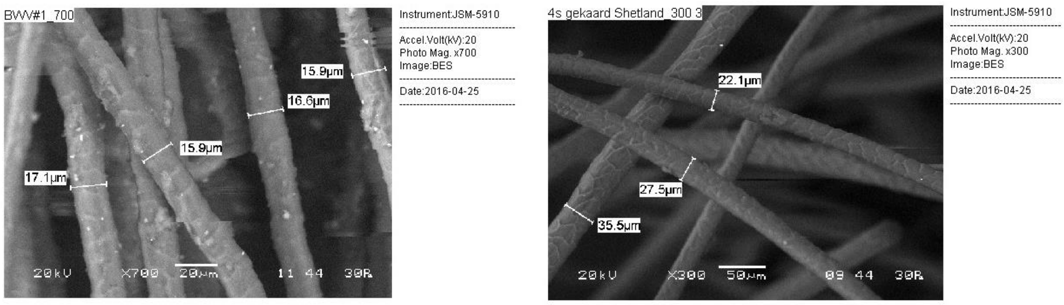

Figure 18
L: The archaeological woollen fibres differs from thickness. The archaeological thread (BWV1) has three different thicknesses measured, whereas the 17.1 µm could be another type of fibre. The scale pattern is unrecognizable.
R: The modern thread also shows differences in thickness between fibres and are much thicker than the archaeological ones. A carded sample is taken, to be sure of different type of fibres, based on the scale pattern. The smaller pattern (22.1 µm) is more aligned, than the thicker one (35.5 µm) in the back. The 27.5 µm as a more regular scale pattern, such as de 22.1 µm one.

The archaeological samples were of such small sample sizes that analysing them with the same magnification of the stereo light microscope was not possible. Therefore, it was chosen to look at these samples with a higher magnification with the use of a VP-SEM. More information of the mineralized fibres of Oss could be acquired with this type of microscope (Fischer 2010, 58). This also provides more details of the fibres instead of the yarn properties.

The archaeological samples were placed on magnetic strips (figure 19). The samples from Oss were very small, whereas the yarn samples from Roswinkel and Smilde-Ravensmeer was too big to fit on the strip. These samples moved due to the shooting of electrons, making it harder to focus[22]. This problem did not occur with the samples from Oss.

22 Personal correspondence Joosten

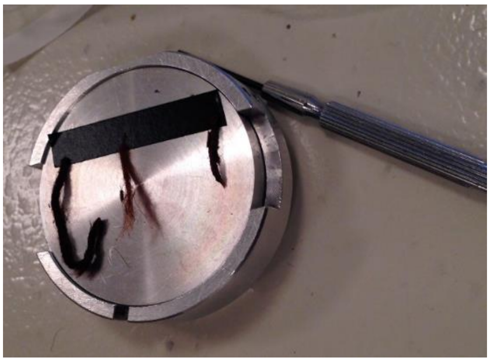 

Figure 19
L: fltr: BWV, BW1, BW2. These are samples of the three different balls of woollen yarn from Roswinkel and Smilde-Ravensmeer..
R: Fltr: A22, B2, C1A2, C2A2, E2. These are samples of Vorstengraf of Oss.

5.4 Results of the Microscopic Analysis of the Experimental Threads

5.4.1 The feel of woollen and worsted threads

During the analysis in the laboratory attention went to the feel of the thread. Because of the different processing techniques, the thread would feel different in the end. The woollen yarn should feel soft and fluffy, the worsted yarn stronger, harder and coarse. This difference could be felt in every worsted or woollen thread, except for worsted yarn 1 and 2 of the Icelandic fibres. Even when the carded material was spun tightly, the difference could be felt. The core of the worsted thread felt strong and coarse, while the exterior felt soft. What was interesting was that the combed Icelandic fibres felt like worsted yarn, but have a similar fluffy look as the woollen yarn (figure 20). The Icelandic teased material felt more like worsted Icelandic yarn was expected to feel like. The Shetland teased threads felt similar to the Icelandic combed material, but the threads were dirtier and more irregular.

This difference is explained by the use of the fibres. In woollen yarn, the different fibres of a sheep are mixed, making is softer due to the use of underwool. The worsted yarn makes use of more coarser fibres, which are less mixed and covered by the fine underwool. Perhaps, the hollow spaces between the fibres and the amount of crimp (see further) amplifies the softer feeling as well.

Using a 2.5x to 5x magnification, the expected differences could be seen better through the microscope, often corresponding with the feel of the thread. The sample size of the experimental threads was big enough to recognize the differences in more than half of the threads.

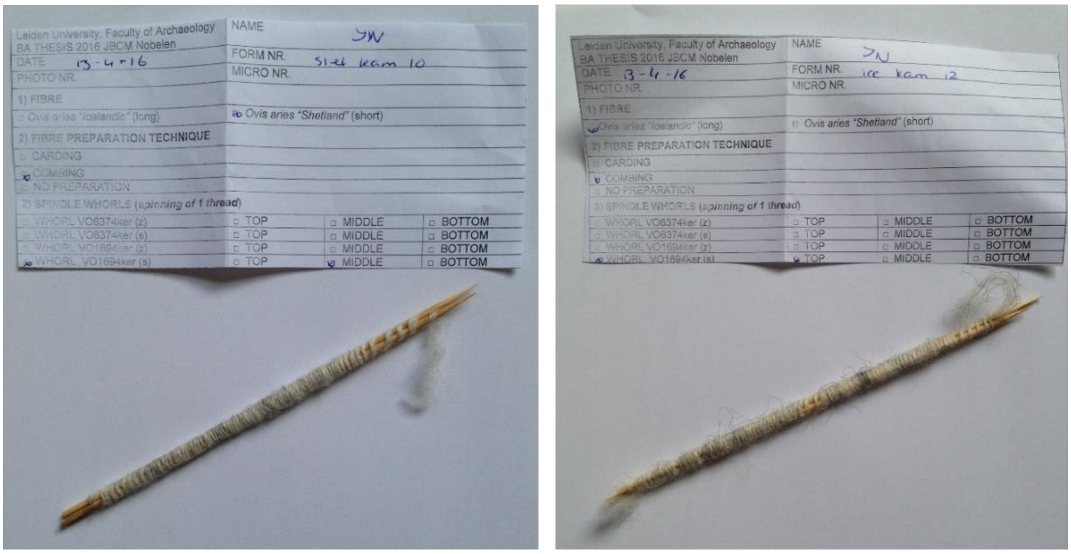

Figure 20
L: Combed Shetland thread 10 as an example. The thread looks less fluffy than the combed Icelandic thread, but both feel worsted.
R: Combed Icelandic thread 2 as an example. Although the thread feels like worsted yarn, it looks rather fluffy compared to worsted Shetland yarn.

All experimental sample were felt as part of the analysis to determine whether the thread was a woollen or worsted yarn. Needless to say, this cannot be done with the archaeological threads and textiles. Firstly, because the material is too brittle. Secondly, if it is possible to touch it with bare hands, the feeling could be tempered by wear, post-depositional causes and chemical changes.

5.4.2 The unspun experimental fibres: results

No remarkable differences can be seen between the carded and combed material and there are seemingly no differences between the fibre type of the two breeds. Remarkably, the Icelandic teased material actually looks to lay more aligned than the combed fibres. The picture of the Shetland teased fibres show a curly lock of fibres which could easily become tangled into a knot during spinning, making it harder to produce a thread of an even width. Mind the waviness of the fibres, the Shetland teased fibres do look aligned. After this it was thought that only the yarn of the teased fibres would be very aligned, although the combed material was expected to show that effect.

5.4.3 The carded fibres: results

The carded material of both the Icelandic and Shetland breed (appendix 3.3.1-12 and 3.4.1-12) were analysed. The samples look fluffy, because of the crimp of the fibres, the irregularity in the alignment and hollow spaces between the fibres. Even appendix 3.3.12 has the airiness that was expected, although one might argue that this thread might also correspond with worsted yarn when found in an archaeological excavation without many or any reference material. Because this is one in twelve samples, the reason for this seemingly odd, but feeling correctly woolly, Icelandic sample is that it was probably the fault of the spinner. This also does not happen in the Shetland samples, thus making it one outlier out of 24 samples. The Shetland samples do look even woollier, than the Icelandic ones, due to the shortness and amount of natural crimp.

5.4.4 The combed fibres: results

The first two threads of the combed Icelandic fibres felt woollen, 4, 5, 6, 10 and 12 felt soft worsted (=worsted basis of the spin, but softer, woollier feeling of the exterior of the thread), and 3, 7, 8, 9 and 11 felt worsted (appendix 3.4.1-12). The feeling was checked again after visual representation, because the soft worsted threads individually looked more woollen. Getting perspective by placing them in a list and compare this to the list of the carded material, the threads do look more aligned, less fluffy and the fibres closer next to each other. The Shetland fibres spun with VO6374ker (appendix 3.5.1-6) actually look more similar to the expected worsted threads, than the threads spun with VO1694ker (appendix 3.5.7-12). These threads look fluffier compared to the samples of the same breed. The fibres are still more aligned and closer next to each other, than the Icelandic material. This difference might be explained by the carded preparation of the Icelandic material, making it harder to comb the crimp out and mixing the soft underwool more than when combing raw wool.

5.4.5 The teased fibres: results

The teased material of both breeds (appendix 3.6.1-12 and 3.7.1-12) felt worsted or soft worsted in all cases. As mentioned in the previous paragraph about the unspun sample, it was expected that the teased material would look more like worsted yarn than the worsted experimental yarn. 42% of the Icelandic samples (appendix 3.6.3, 4, 7, 8 and 10) and only sample 6 of the Shetland fibres (appendix 3.7.6) show similarities to the combed yarn. The difference between combed and teased fibres would be hard to trace back based on fibre reaction alone. Still, there are similarities between the techniques, however not traceable in such a small view of one picture or in a small archaeological sample size. For example, the teased material would be expected to be much dirtier than can be seen on sample 9 (appendix 3.6.9). Also, it would be harder even for an experienced spinner to create a thread of an even width, because of the lesser alignment and crimp hindering the drawing out of the wool. This can be seen on sample 24 (appendix 3.7.12) which shows a thread broken by a jumpy, loosed curl or knot. In this case, the same type of fibres are spun, but it can also happen that all fibres are used in the threads. In the case of combed material, only the longer fibres would be used. A larger sampled view of the thread or of the whole thread is necessary to conclude this. Also, a larger magnification is recommended to see differences between the fibres (appendix 3.9.2, 7, 9 and11).

5.4.6 The spindles: results

Because no remarkable differences could be seen between the different spindle types and positions, the expert spinners were free to choose their preferred method of using a drop spindle[23]. Nonetheless remarks could be made about the pictures, keeping the sample size of one of each type in mind. Firstly, the carded Icelandic thread 1 looks worsted, but feels woollen and the combed Icelandic thread vice versa (appendix 3.8.1). This probably has the same reason as mentioned before with the Icelandic combed material; because of the carding before combing. Secondly, the combed Shetland sample by G. Vogelsang-Eastwood looks more fluffy because of the crimp of the fibres (appendix 3.8.11). Concluding remarks: different twists do not have effect on the visibility of the preparation; such a small sample size, which will be encountered archaeologically, would make it harder to determine the fibre preparation; the crimp of the fibres are probably the biggest factor making it hard to see differences. Notwithstanding this, comparing the samples of the experts to the other 72 experimental threads of the same sample bags, these do also not correspond

23 Both experts chose whorl VO6374ker and used it as bottom drop spindles. Reurink chose to spin in the z-direction and Vogelsang-Eastwood in the s-direction.

to the hypothesized outcome as the overview would do so. In other words, these experimental threads were either outliers or would be like the inconspicuous pictures in a list. Especially sample 6 of the combed Shetland fibres could be seen as woollen yarn, although they both feel (soft) worsted (appendix 3.5.4 and 3.8.11).

5.5 Results of the Microscopic Analysis of the Archaeological Samples

5.5.1 The condition of the archaeological samples

The balls of yarn are better preserved than the material from Oss. Samples 2, 7, 8 and 9 of the balls of yarn all show differences in scale patterns on fibres of different thicknesses (appendix 4.1.2, 7, 8 and 9). The Oss material is too weathered to see any scales (appendix 4.2.2), but sample 1 shows difference in fibre thickness (appendix 4.2.1). Because the amount of thicker fibres is much less than the thinner fibres, it could be concluded that either the sheep had many thin fibres (underwool?), or some sorting process must have been done in order to spin the thread more evenly.

5.5.2 VP-SEM comparison

Along with the archaeological material, six random experimental threads were put in the VP-SEM (appendix 3.9.1-11). More remarkable differences have been discovered. Firstly, most thicker Shetland fibres had 'pointy' scales when carded, which were not encountered in the teased and worsted yarn (appendix 3.9.4). Some thicker Icelandic fibres showed damage marks (appendix 3.9.7 and 11). Both breeds showed a better alignment of fibres when combed, following the twist (appendix 3.9.6, 8 and 10), but that was already determined in the pictures taken with the stereo light microscope (appendix 3.4.7, 8 and 3.5.7). The alignment differs immensely, from a jumpy carded sample (appendix 3.9.3) to a mixture of straight to almost horizontal alignment (appendix 3.9.5).

5.5.3 The alignment and crimp of woollen fibres in the archaeological samples

The fibres seem (very) aligned and show little to no crimp. The fibres of the z-spun thread from a ball of yarn follow the same twist, as can be seen on the first picture (appendix 4.1.1). Most fibres on picture 6 show straight alignment, whereas picture 5 of the same ball of yarn (BWV) shows more messy fibres in the s-spun (appendix 4.1.5

and 6). None of the threads of the Oss material (appendix 4.2.1, 3, 4 and 6) have any jumpy fibres and are very aligned in the twists of the threads. Also, the fibres do not have hollow spaces between them. The balls of yarn look more similar to the experimental material, which are more airy (appendix 3.9.8). This could be, because of the amount of crimp. Some fibres in the balls of yarn are a little wavy, instead of straight (appendix 4.1.1 and 6). However, comparing the archaeological material to the experimental samples put in the VP-SEM some preparation must have been done to the fibres, because the teased and carded fibres are a lot more wavy (appendix 3.9.1-11). Another reason for this difference can be thought of. Presumably, the crimp has been lost because of post-depositional causes aligning the fibres more perfect, such as the reduction of air between fibres and mineralization. This is substantiated by picture 4 of yarn sample 'BW2', which is also more damaged and dirtier than the other yarn samples (appendix 4.1.4). Here, the fibres are more aligned and closer next to each other. It is the question if this would happen if the fibres had never been aligned by a previous process. In other words, it is the question if post-depositional and chemical changes can straighten the fibres and align them more perfect in a thread, than before the fabrics became part of the soil archive.

5.5.4 Possible additional plant material in the woollen threads

Next to woollen fibres, (broken) plant fibres are to be seen in the samples of the balls of yarn (appendix 4.1.1 and 3). They follow the twists of the thread. This could mean that they have always been part of the thread. Botanical analysis could give more information about the plant fibre type and if this fibre could have any effect on the fabric.

As can be read in Chapter 3, plant and animal fibres are almost never found together in Dutch soils. If these plant fibres have been spun together on purpose, this could give more information about the textile production of this time. The plant fibres could also have been spun with the raw wool unknowingly at the same time, making a 'dirtier' thread. The plant fibres could still have become part of the thread after deposition and getting aligned together with the yarn, as would be concluded by the more damaged sample of the balls of yarn (appendix 4.1.4).

6 CONCLUSIONS

The concluding chapter will answer the three research questions raised in Chapter 1 in a different order. It is necessary to answer the questions about the experiment and the comparison with the archaeological material first. To have the results in context first, they can be placed in the picture of the past. The main question can be answered: Which fibre preparation technique was used to produce woollen fabric in the Dutch Metal Ages, ca. Early Bronze Age to Middle Iron Age?

6.1 The Experiment

<u>6.1.1 How can the fibre processing techniques be traced microscopically in experimentally produced threads and samples?</u>

Two different microscopes have been used to look at the material. First, a stereo light microscope with a magnification of 2.5x to 5x to see the fibres reaction in the twist of a thread. The VP-SEM was used to see more detail of the fibres inside of the thread with a magnification between 100x and 700x. Both techniques complemented each other. In general, microscopic analysis gives information about the reaction of the fibres on the spin, twist, amount of crimp, dirt and alignment, and it gives an overview of the thread properties. All of these together indicate different preparation techniques. More detail of the fibres, such as damage marks, scale patterns and alignment inside one twist, could be better determined with the use of a VP-SEM.

<u>6.1.2 What is the difference between unsorted, teased fibres and the sorted fibres?</u>

The experiments with the carding, combing and teasing of woollen fibres of the Icelandic and Shetland sheep breeds were done in order to be able to see differences. These experiments focussed on the three different preparation methods and then spun with two replica spindles and in the z- and s-direction. To answer the question if a preparation method could still be seen in the spun material, it is be important to know whether the fibres would react differently to spinning techniques before researching different aspects of the three techniques. This, because only spun threads from the Metal Ages have been excavated in the Netherlands. No account has been made of a pluck of wool being excavated in the region. Nevertheless, not many information could have been gotten from these plucks. As shown by the experiment, the unspun raw wool does not show differences between techniques. It only indicates whether a sorting technique was used, instead of which specific technique. In addition, when raw wool is found and no preparation method can be seen, it would not indicate that the people used unprocessed material for their fabrics. This raw wool could also have fallen off the sheep or still had to be processed.

No differences between the techniques could be detected in the unspun samples. Both the carded and combed material looked jumpy and tangled. The teased material looked different. The teased Icelandic fibres were fairly straight and were aligned. The teased Shetland fibres were aligned, but showed much crimp. A difference between using the sorted and unprocessed fibres is that there are more irregularities in the raw wool, such as curls and knots next to dirts, making it harder to spin a regular thread. These differences already existed in the raw material of both breeds.

No differences between spinning directions and spindles have been encountered during the analysis of the experimental data. If there would be a difference between the same type of fibres which are processed exactly by the same technique, it would be because of the expertise of the spinner and the balance of the spindle.

The feel of the processed threads corresponded almost always to what they should feel like. The carded material felt fluffy, soft and flexible. The combed material felt stronger, coarser and a bit stiffer. There were some threads that felt softer, however, the feel of their core would be like a worsted thread. This was also often the case with the teased material, surprisingly. The softer feel would be because of the fluffiness of the crimp and the better mixture of soft underwool. The teased and combed material would have these fibres less mixed through the thread than the woollen yarn would have.

The carded and teased threads often looked fluffy and messy, with jumpy fibres. This, because the crimp has not been combed out of the fibres. There are also differences. The dirt was combed and teased out of the carded material during the preparation, but would still be visible in the teased threads. The leftover dirt in the teased threads are too little to tease out by hand or were stuck inside a small knot or curls. This made it hard to spin a thread with an even width. This could already be seen by the naked eye, although concluding this with foreknowledge about the preparation of the fibres. Another difference would be the mixing of different fibre types in the carded material, compared to the teased samples. To determine this, a whole thread has to be analysed, instead of a few small samples. But what can be seen with only a very small sample is the scale pattern. Comparing the carded Shetland fibres to other samples, the scales look more pointy than other. This could be the damage done to the carding. However, only one sample showed this feature.

The combed fibres seemed more aligned, often just as the teased threads, laying the fibres closer next to each other. Because crimp would be reduced, the threads were less fluffy. This could be determined by the difference between the Icelandic and the Shetland fibres. The Icelandic samples were carded before they were combed. This made the thread look more fluffy, due to the slight reduction of crimp and mixture of different woollen types. The Shetland fibres were able to align better because they were only combed. In addition, looking at the unspun teased material, the Icelandic fibres seem to have been aligned and straight naturally. The carding seems to have increased waviness. However, new experiments executing the same technique or techniques using only the same type of fibre and breed will harden this conclusion.

6.2 The Experimental and Archaeological Comparison

6.2.1 Which differences are microscopically noticeable in the archaeological material?

The preservation of the balls of yarn was better than the mineralized weaves of Oss. Details of the fibres, such as scale patterns, could not be seen in the Oss material. These faded properties were seen on the fibres of the balls of yarn and showed the use of different fibre types. Also, the material looked more like the experimental threads. The fibres were as aligned as the combed material and some fibres showed crimp. This was not the case in the thread from Oss. These fibres were aligned and showed no crimp whatsoever. No jumpy fibres were to be recognized, it even looked as if bundles of fibres stuck together made the thread.

A few plant fibres in the yarn from the northern provinces were aligned together with the woollen fibres. It is the question whether this was intentional, accidental or became part of the thread after deposition. If the fibres would be of a plant fibre which could be used to make fabric of, perhaps prehistoric societies could have mixed different fibre types together.

As said in Chapter 5, the alignment and reduction of crimp in all archaeological samples could be have post-depositional cause. The soil or other chemical changes, such as the mineralization, could have reduced the airiness between the fibres, as would be expected of carded material, and knots, as would be expected in the unsorted fibres, could have been straightened. Little research is done, but presumably the fibres must have been processed in order to be preserved looking this aligned.

6.3 Metal Age Fibre Preparation

6.3.1 Which fibre preparation technique was used to produce woollen fabric in the Dutch Metal Ages, ca. Early Bronze Age to Middle Iron Age?

Concluding, in both cases, it seems that all archaeological threads were subjected to combing or another combing-like technique. The fibres have been aligned and most of the fibres are of the same, small type. A few thicker fibres, and perhaps plant fibres, were part of the thread, but more than half of the thread was spun with the smaller, perhaps softer, wool. The raw wool has been pulled through by a toothed object, either by hand or by another toothed object. The spinning was done with the use of the material aligned in the direction it would be spun to have as less air between the fibres. If the fibres had more hollow spaces between them before, it could not be seen in the material due to post-depositional causes. Even when the fibres would have looked as airy or fluffy, this could be achieved by making a rolag of the combed material. All sorts of slight changes in the process could have been made. But the sorting process of dirt from fibres, and of the fibres and their alignment is still visible in the archaeological material.

6.4 The Importance of Archaeological Textile Research

This thesis plays a part in the very large weave of the research of the production process of fabrics. By 'untangling' one very small aspect from the final product back to the raw material, such as understanding the woollen fibre reaction from microscopic analysed threads, every step and variable can be spun and woven into the existing web of the production process of fabric. Every very small aspect of fabric production can then be combined to make sense of the complexity and its influence. As mentioned in Chapter 1, meaningful fabrics will surely have been an important part of the past, as it still is to this day. To understand the workmanship, the time consumption and knowledge, archaeological might get a step closer to the understanding of all groups of people and cultures of the past. Although this thesis has used archaeological examples of Bronze and Iron Age threads, the results and conclusions are useful for every period of time. The view on textilia could change over time, but the importance is a constant woven through time.

7 REFLECTION OF LIMITATIONS AND FURTHER RESEARCH

No experimental research of the fibre preparation processes of Dutch prehistoric fibres was published before or during the writing of this thesis. Therefore, it was chosen to research various breeds; the carding, combing and teasing of the fibres; and to see if there are differences between spindles, because only spun threads could show the preparation.

Further experiments could focus on a lot of different aspects. A bigger sample size, using more breeds, corresponding with the ones living in that period and region. More techniques and tools could be explored. The use of more than one technique on the same raw wool, as has been done with the combed Icelandic fibres, could be researched. The variables could be altered, such as spinning from a rolag made up of combed wool, or spinning a staple of carded wool. The experiments could be timed to see if there are differences between this, especially when focussing on tools. The process could be extended, by focussing on the amount of crimp and sorting of the fibres. There could be more research done to the environment, such as temperature. For instance, if tools are warmed, the crimp is combed out more easily and the fibres would stay straight after contact with fluids (Morton and Hearle 2008, 482-483). This was done during the Middle Ages for example, but no evidence has been found in the prehistoric periods (Rast-Eicher 2013, 172). In order to check this experimentally is to use replica materials for the experiment and analyse the samples before and after contact with fluids.

Different tools could be used, such as replicas of 'combs', which might have been used for something else completely. In addition, experiments done with modern tools might provide the researcher with false data, especially working with prehistoric cultures. This was also pointed out by Grömer (2016, 70-71). Products of modern tools do not always correspond 100 percent correctly due to many different variables, such as other preparatory methods and spinning techniques.

The conclusions could be biased, because the threads were spun and analysed by the same person. Also, the level of spinning is of course a grey area, because there are many ways to spin and no standardization of the levels. Still, the regularity of twist and width of the thread gives a clearer view of the outcome of the experiment, because the data is more reliable. To make this experiment more reliable, the spinner could use an exact replica of the whorl and try out different positions on a drop spindle. If the spinner is more comfortable using another type of spinning, this could also be part of an experiment.

Also different people could be used for the sorting techniques, instead of one. It would be interesting to use both experts, people with little knowledge and laymen. Also, differences between these levels and the different preparation time before the experiment could influence the outcome. Perhaps differences inexperience could be seen in the, later, spun threads. Comparing it to archaeological material could tell if the fabric was made by someone with or without experience.

Further experiments have to take into account the amount of dirt falling on the ground. The ground becomes very dirty when the wool still holds seeds and other products in the fleece after washing. Palynological and other botanical analyses could be done in places where textile activities are found, provided the soil is of the right condition and an archaeological dig takes place. Perhaps specific pieces of dirt could not be washed out of the fleece and were removed by teasing and pulling the fibres through teeth. This could help to get a better understanding whether there were different places on the sites specifically for the production of fabrics and textiles or that it was done in all places, if the botanical samples correspond throughout the site. It would also help to reconstruct the natural environment of the site and to understand all the placed the (domesticated) sheep were held.

The unusable remnants were thrown away. These would influence the outcome of the experiment. Especially the remnants of the combing formed quite a pile (figure 15). It would be noteworthy that the BA/IA cultures would use this. Not all could be used to produce fabrics, but could still function differently. Perhaps the remnants of the raw wool were used as insulation material as we still do to this day. The people could have understood that if they wore wool in order to keep warm, the same effect would be reached if the same type of fibres would be put in the houses. Or vice versa.

SAMENVATTING

Het onderzoek naar archeologische textilia is belangrijk. Om dit statement kracht bij te zetten is het nodig om deze voorwerpen te begrijpen. Waarom maakten en gebruikten men vroeger deze objecten? Voordat deze vraag beantwoord kan worden is het nodig om het productieproces te begrijpen. Elke keuze gemaakt tijdens het proces heeft invloed op het eindproduct. Dit is wat de productie van textilia zo complex maakt. In deze scriptie wordt er gefocust op een sorteringspreparatietechniek van wollen vezels, waarna de experimenteel geprepareerde en gesponnen draden vergeleken worden met archeologische monsters van wollen draden uit Roswinkel Smilde-Ravensmeer en Oss.

Er is speciaal voor dit onderzoek een nieuwe methodologie ontwikkeld, doordat er tot op heden geen literatuur beschikbaar is over het onderwerp. Er wordt gekeken naar de reactie van wollen vezels op het kammen en kaarden. Het teesen, als schoonmaaktechniek, is bijgevoegd als 'controlegroep'.

De reactie is zichtbaar onder een microscoop. De verschillen zitten in de handgesponnen draad, zoals het gebruik van verschillende vezeltypes, het gebruik van verschillende vezel lengtes, de uitlijning van de vezels, de hoeveelheid krimp en de luchtigheid van de draad op basis van de dichtheid van de draden. Daarnaast komt de aanraking van de draad overeen met welke techniek is gebruikt, ondanks dat dit vaak op het blote oog niet zo lijkt. De geteesde draden kunnen zowel gekamd of gekaard aanvoelen, maar onder de microscoop wordt zichtbaar dat de vezels weinig uitlijning vertonen.

Uit de vergelijking van de archeologische monsters met de experimentele draden, komt dat de archeologische vezels uitlijning vertonen en weinig krimp bevatten. Wellicht is dit een factor voor het verkrijgen van de zeer fijne diameter van de draad. Door een VP-SEM te gebruiken, in plaats van een stereolichtmicroscoop, zoals voor het experimentele materiaal, zijn er veel details zichtbaar. Toch waren de monsters uit Oss minder nuttig door de sterke mineralisatie. Hieruit kan geconcludeerd worden dat de schijnbaar zelfde soort vezelreactie ook kan komen door post-depositionele oorzaken. Hier tegenin brengend is het erg onwaarschijnlijk dat de vezels in de natuur sterk uitlijnen. Een preparatietechniek voor het sorteren van wollen vezels moet zijn gebruikt.

ABSTRACT

The research of archaeological textilia is important. The empower this statement, the textilia of the past have to be understood. Why did people make and use these products? To get a grasp of the answer, the production process has to be understood. Due to its complexity, every part of the chain functions as a choice, influencing the final product. This thesis focusses on the sorting preparation of woollen fibres, comparing experimentally processed and spun threads with archaeological samples of woollen yarn from Roswinkel, Smilde-Ravensmeer and Oss.

The research starts with setting up a new methodology for the experiment, because little to none has been written on the subject. Focussing on the preparation of woollen fibres, the different reactions to carding, combing and teasing techniques are captured in a handspun thread. The visible reaction of the fibres are noticeable under a microscope. Differences are use of different fibre types, different fibre lengths, the alignment, the amount of crimp and the airiness between the fibres. The feel often corresponds with the used technique. The threads spun of the teased fibres feel either carded or combed, but are much less aligned.

Comparing the analysis of the experimental yarn to the archaeological samples, the fibres show much alignment and almost no crimp. The threads are also of a very fine diameter. By using a VP-SEM instead of a stereo light microscope, as had been used for the experimental samples, many details are noticeable. Much can be seen in the material excavated from the peat, but the Oss material was often too mineralized. Therefore, the seemingly fibre reaction to the preparation technique could have been due to post-depositional causes. Contradictory, it seems unlikely that the fibres align (almost) perfectly in nature, concluding some sorting technique must have been used.

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TABLE OF FIGURES

TABLE OF APPENDICES

APPENDIX 1

Oss-Horzak 2004	put	vlak	spoor	vul	segm
V06374ker	186	1	193	-	-
 Used as top			 Used as bottom	Diameter width	52
				Length	23
				Diameter hole	7
				Weight	55
Type: big, round, one half curved, one half flat					

Oss-Horzak 2004	put	vlak	vak	spoor	vul	segm
VO1694ker	9	3	-	177	3	2
					Diameter width	49
					Length	30
					Diameter hole	11
					Weight	53
Type: big biconial						

APPENDIX 2

Leiden University, Faculty of Archaeology BA THESIS 2016 JBCM Nobelen	NAME		
DATE	FORM NR.		
PHOTO NR.	MICRO NR.		
1) FIBRE			
□ *Ovis aries "Icelandic"* (long)	□ *Ovis aries "Shetland"* (short)		
2) FIBRE PREPARATION TECHNIQUE			
□ CARDING			
□ COMBING			
□ NO PREPARATION			
2) SPINDLE WHORLS (*spinning of 1 thread*)			
□ WHORL VO6374ker (z)	□ TOP	□ MIDDLE	□ BOTTOM
□ WHORL VO6374ker (s)	□ TOP	□ MIDDLE	□ BOTTOM
□ WHORL VO1694ker (z)	□ TOP	□ MIDDLE	□ BOTTOM
□ WHORL VO1694ker (s)	□ TOP	□ MIDDLE	□ BOTTOM

Name: initials of the spinner

Date: date of spun thread

Form nr.: same as the bag, for example 'ice kaard 1'. The fibre type is either 'ice' (=Icelandic) or 'shet' (=Shetland).

Photo nr./micro nr. have not been used.

Fibre: corresponds with the ice/shet at the form nr.

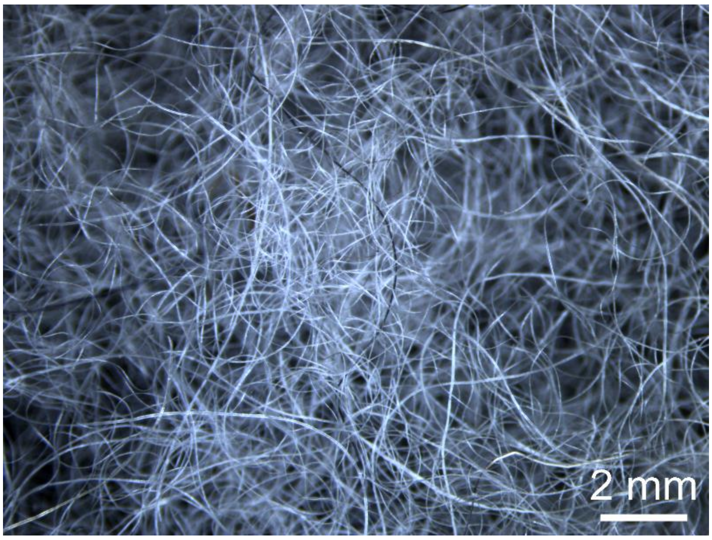
Fibre preparation technique: stands for the sorting techniques 'kaard' (=carding), 'kam' (=combing) and 'onb' (=hand teased). In the form, 'no preparation' stands for the teasing.

Spindle whorls (spinning of 1 thread): the boxes in front of the type of whole, the spinning direction and the location of the whorl on the spindle stick is checked depending on what is used. As a right hand spinner from Europe, the series began spinning from bottom z to top s. The height of the whorls was leading, thus spinning bottom z and s, than middle z and s and then top z and s. The uneven numbers are therefore always spun z and the even numbers s. Bags 1-6 were spun by whorl VO6374ker and 7-12 by VO1694ker.

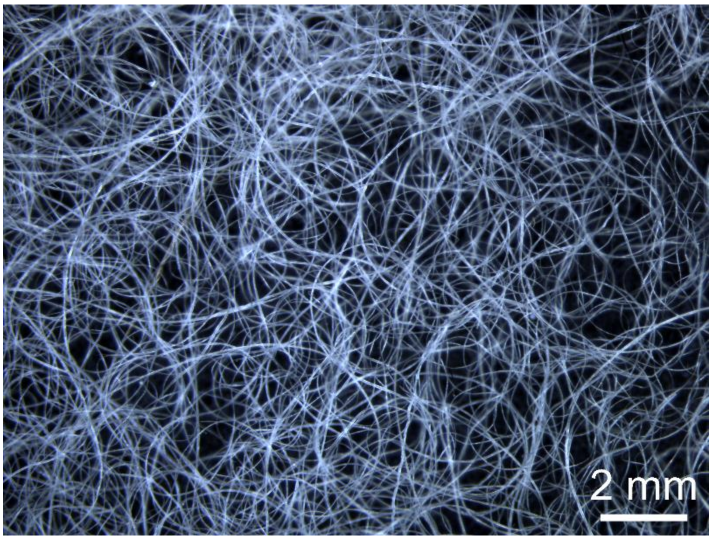
APPENDIX 3

3.1 Sample Fibres Before Spinning

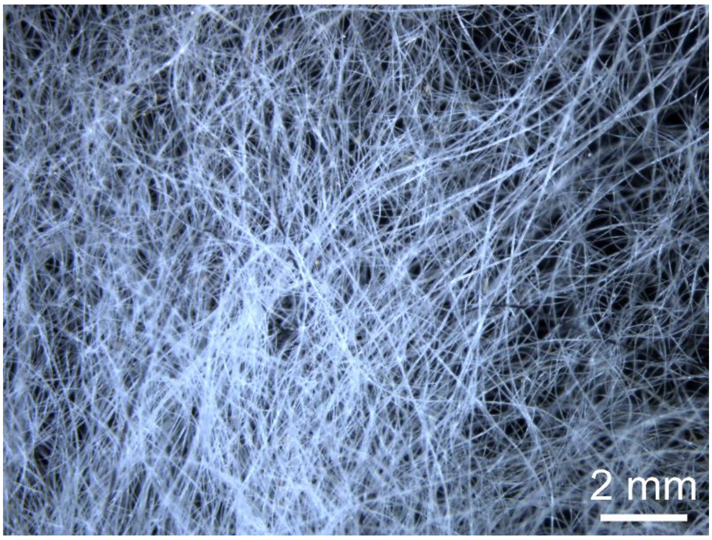
All samples have been taken from bag number 8, before the content was spun.



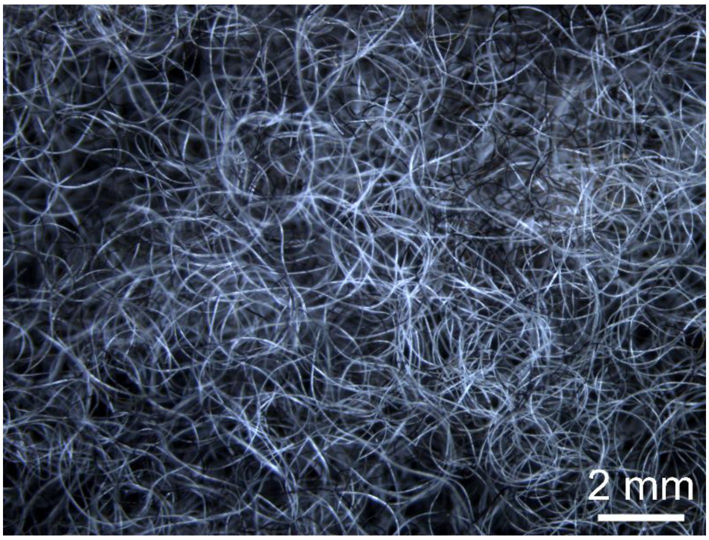
3.1.1 Microscopic Samples 1: sample of carded Icelandic fibres



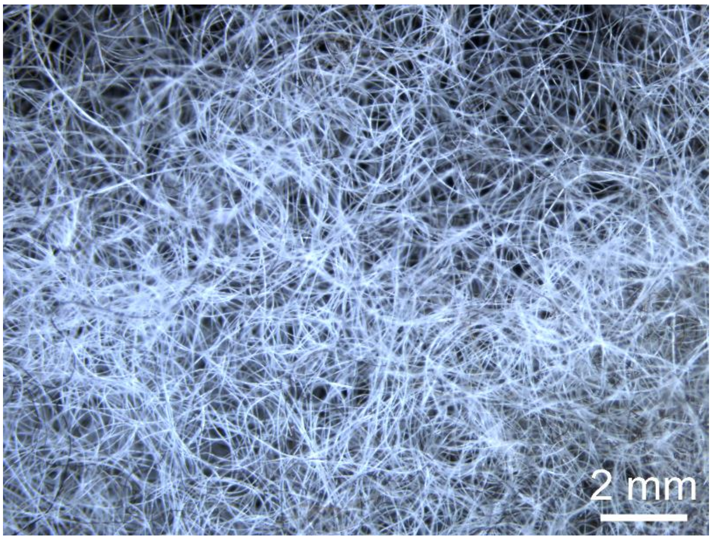
3.1.2 Microscopic Samples 3: sample of combed Icelandic fibres



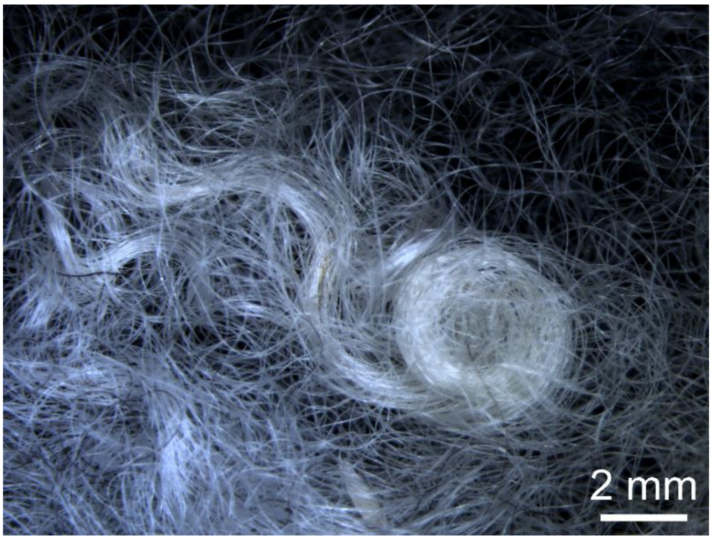
3.1.3 Microscopic Samples 2: sample of teased Icelandic fibres



3.1.4 Microscopic Samples 5: sample of carded Shetland fibres

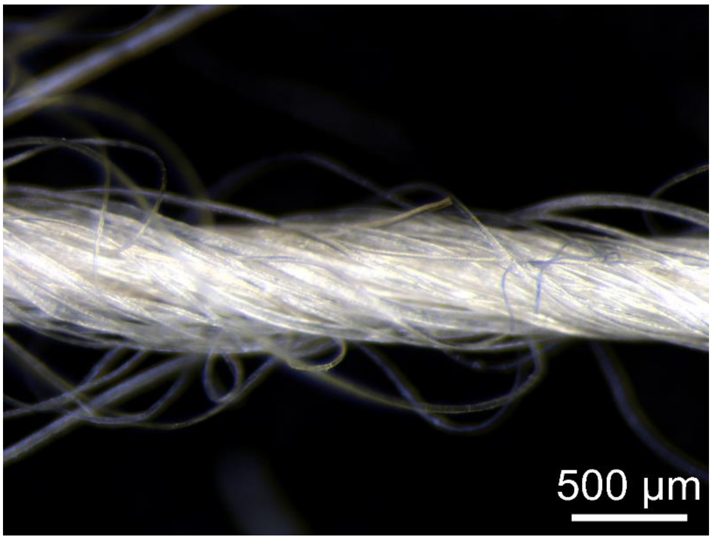


3.1.5 Microscopic Samples 4: sample of combed Shetland fibres

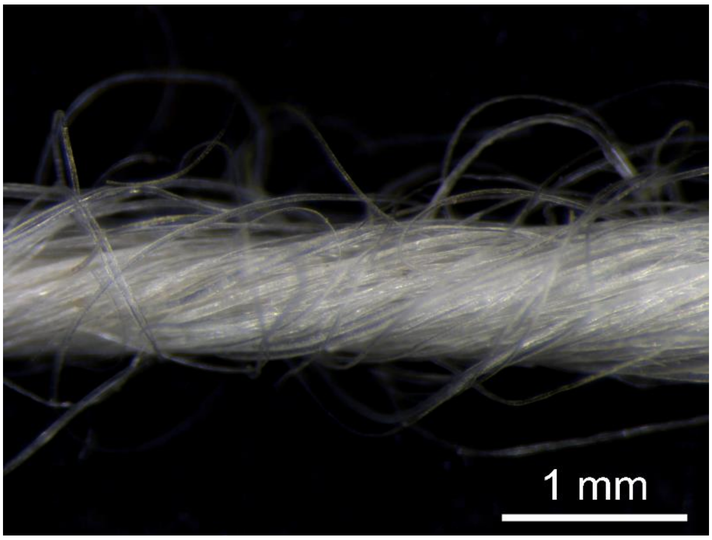


3.1.6 Microscopic Samples 6: sample of teased Shetland fibres

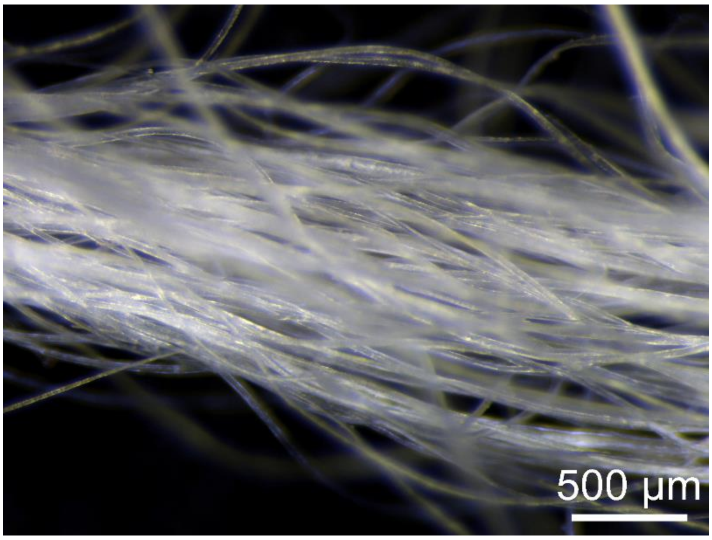
3.2 Carded Icelandic Samples



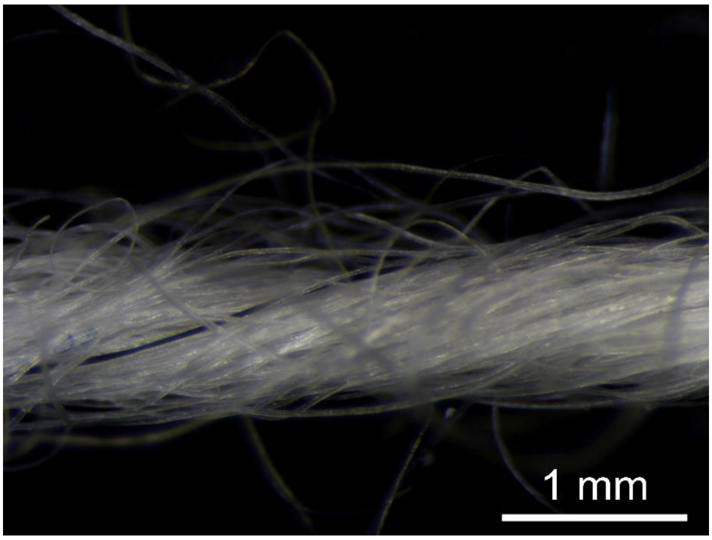
3.2.1 Carded sample 1:
carded Icelandic fibres, sample bag 1.
spun z by Jasmijn Nobelen with spindle whorl VO6374ker in bottom position



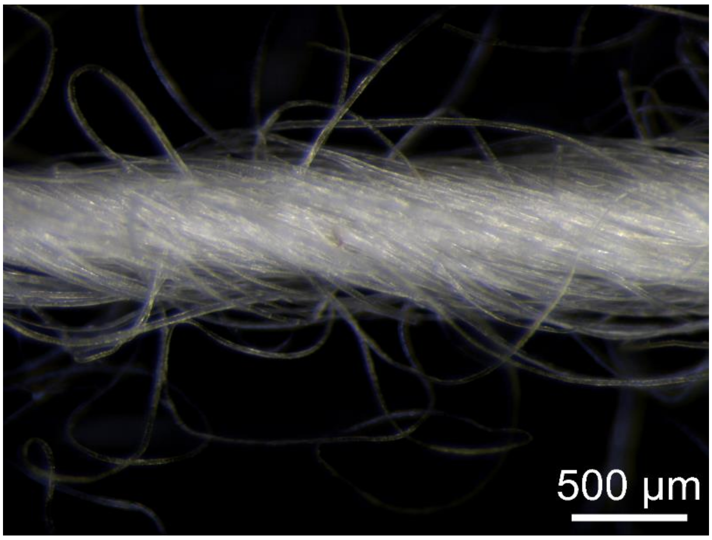
3.2.2 Carded sample 3:
carded Icelandic fibres, sample bag 2.
spun s by Jasmijn Nobelen with spindle whorl VO6374ker in bottom position



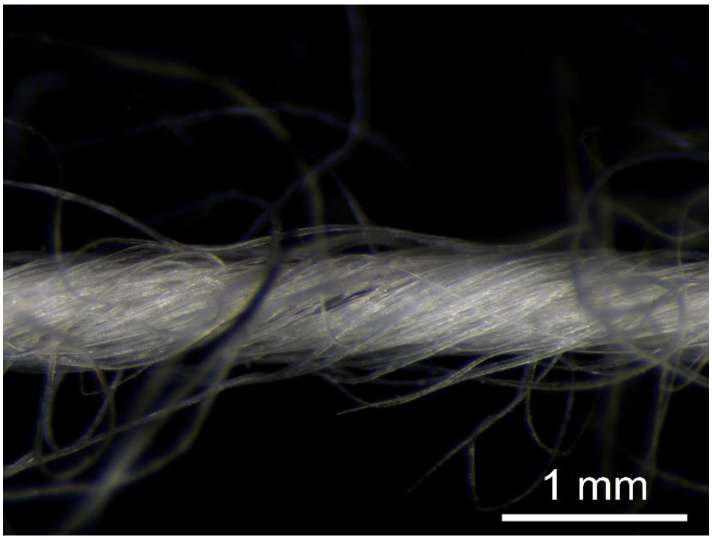
3.2.3 Carded sample 2:
carded Icelandic fibres, sample bag 3.
spun z by Jasmijn Nobelen with spindle whorl VO6374ker in middle position



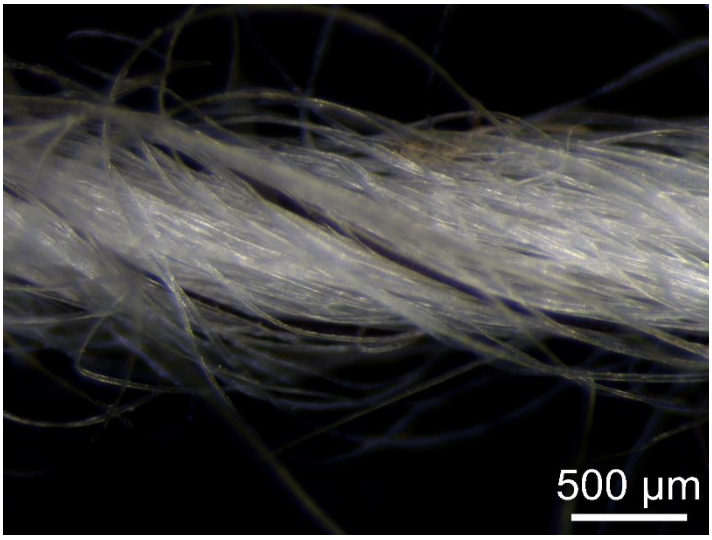
3.2.4 Carded sample 5:
carded Icelandic fibres, sample bag 4
spun s by Jasmijn Nobelen with spindle whorl VO6374ker in middle position



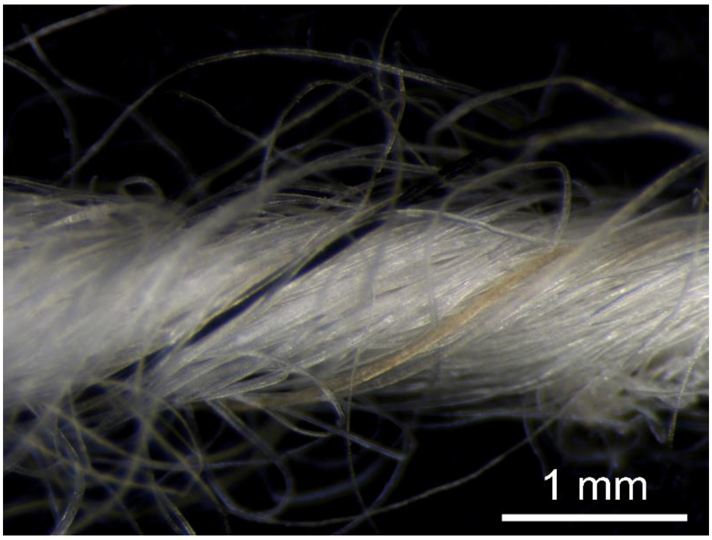
3.2.5 Carded sample 4:
carded Icelandic fibres, sample bag 5.
spun z by Jasmijn Nobelen with spindle whorl VO6374ker in top position



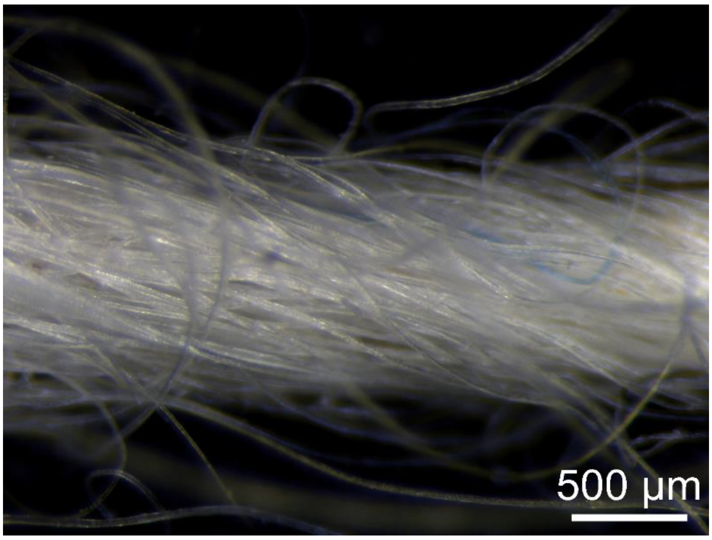
3.2.6 Carded sample 6:
carded Icelandic fibres, sample bag 6.
spun s by Jasmijn Nobelen with spindle whorl VO6374ker in top position



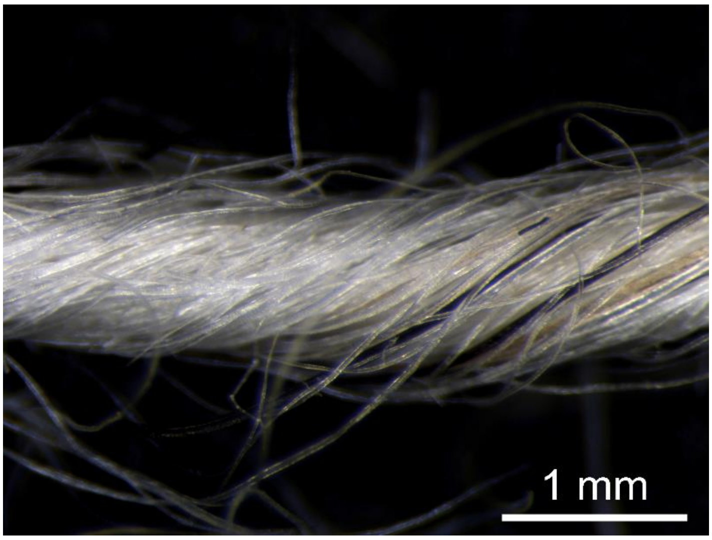
3.2.7 Carded sample 8:
carded Icelandic fibres, sample bag 7.
spun z by Jasmijn Nobelen with spindle whorl VO1694ker in bottom position



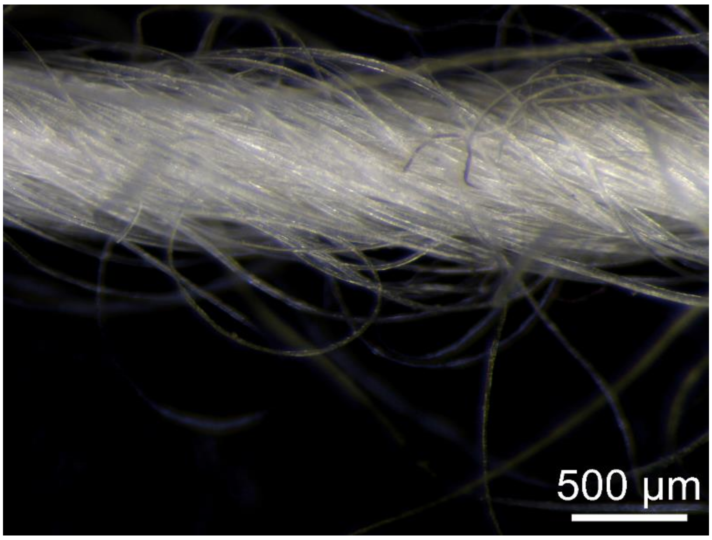
3.2.8 Carded sample 7:
carded Icelandic fibres, sample bag 8.
spun s by Jasmijn Nobelen with spindle whorl VO1694ker in bottom position



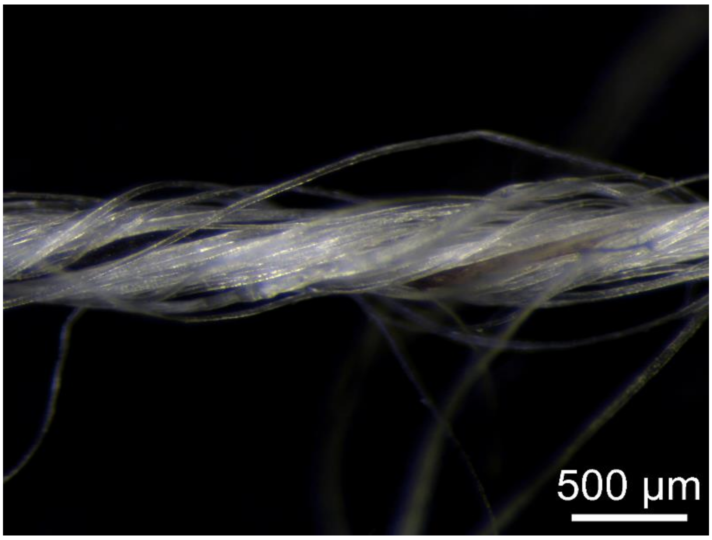
3.2.9 Carded sample 9:
carded Icelandic fibres, sample bag 9.
spun z by Jasmijn Nobelen with spindle whorl VO1694ker in middle position



3.2.10 Carded sample 11:
carded Icelandic fibres, sample bag 10.
spun s by Jasmijn Nobelen with spindle whorl VO1694ker in middle position

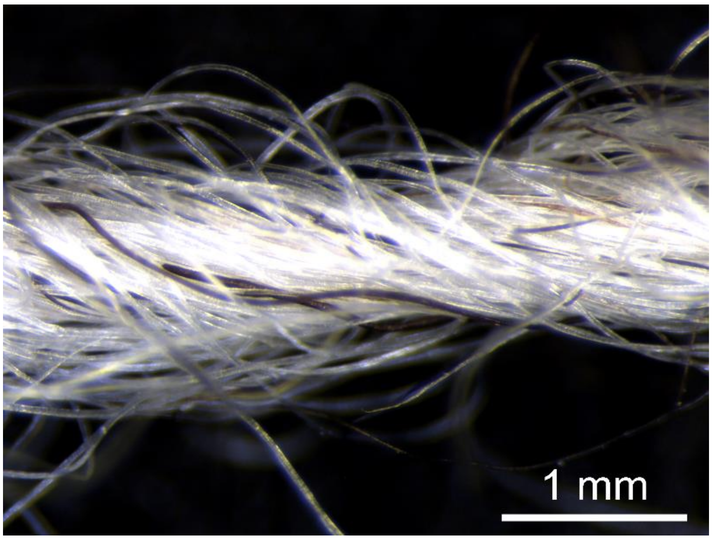


3.2.11 Carded sample 10:
carded Icelandic fibres, sample bag 11.
spun z by Jasmijn Nobelen with spindle whorl VO1694ker in top position

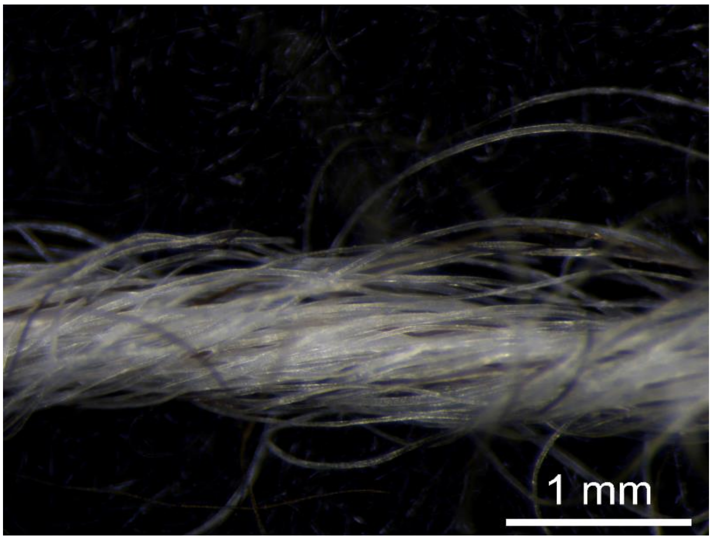


3.2.12 Carded sample 12:
carded Icelandic fibres, sample bag 12.
spun s by Jasmijn Nobelen with spindle whorl VO1694ker in top position

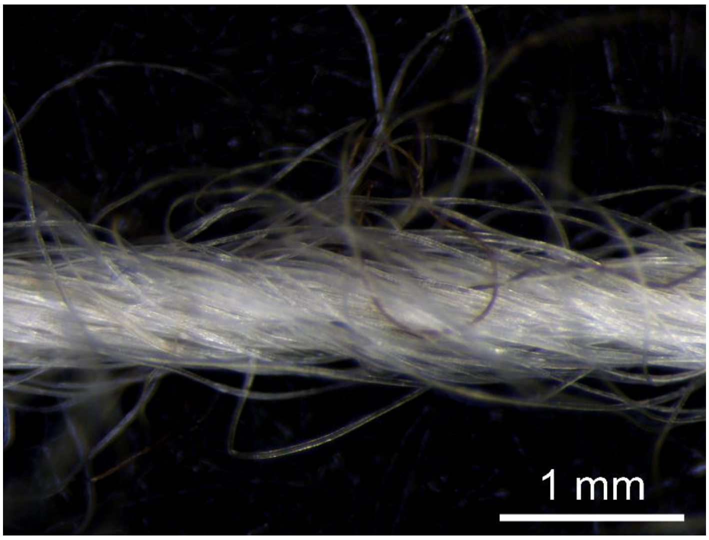
3.3 Carded Shetland Samples



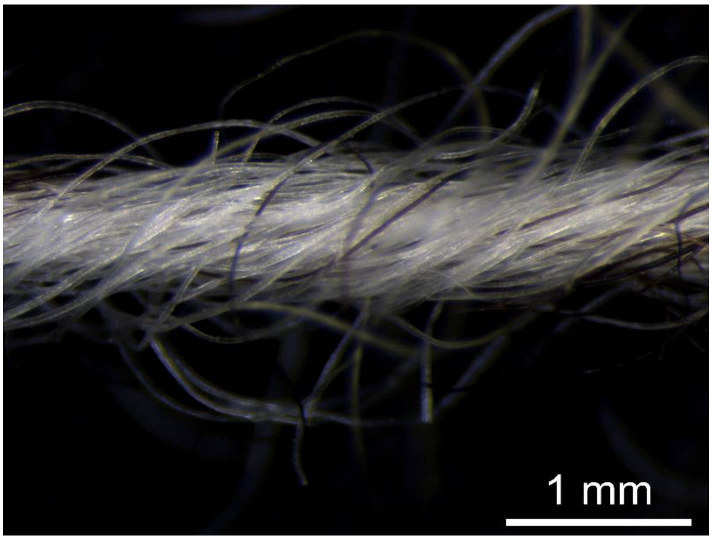
3.3.1 Carded sample 13:
carded Shetland fibres, sample bag 1.
spun z by Jasmijn Nobelen with spindle whorl VO6374ker in bottom position



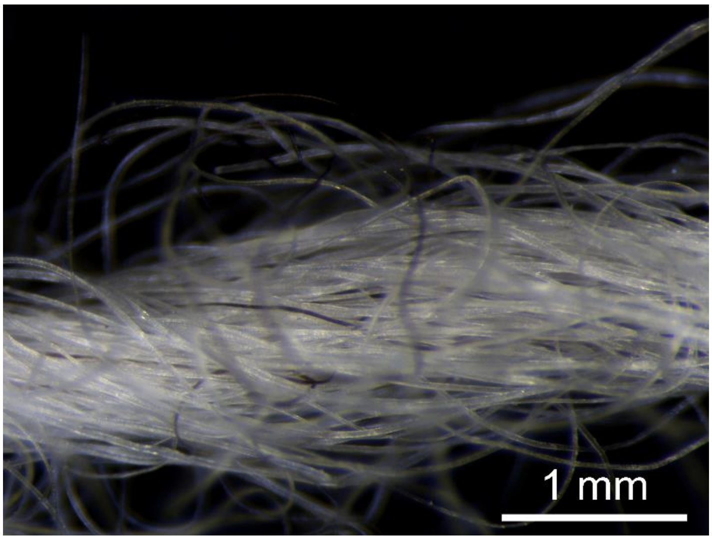
3.3.2 Carded sample 14:
carded Shetland fibres, sample bag 2.
spun s by Jasmijn Nobelen with spindle whorl VO6374ker in bottom position



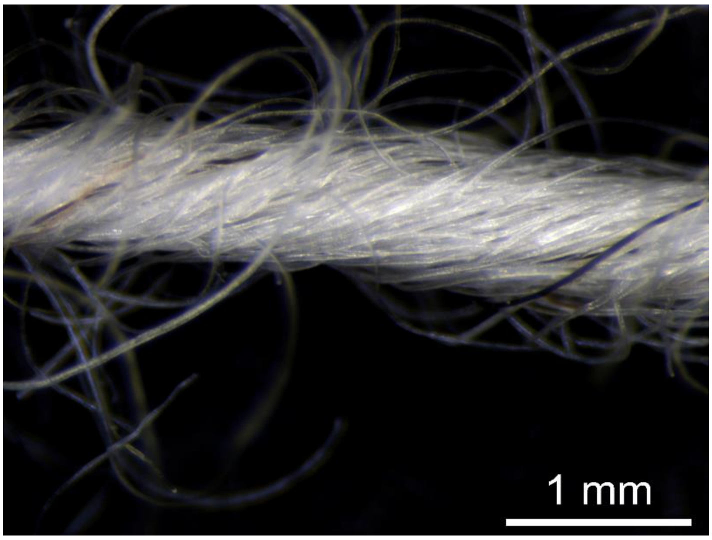
3.3.3 Carded sample 15:
carded Shetland fibres, sample bag 3.
spun z by Jasmijn Nobelen with spindle whorl VO6374ker in middle position



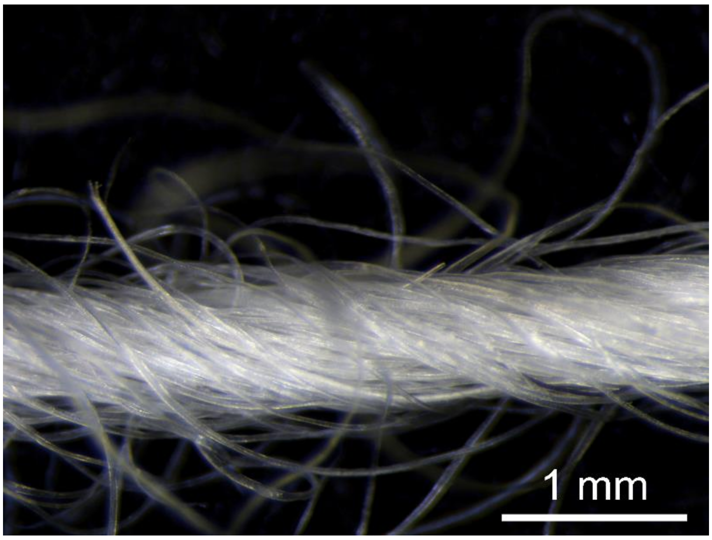
3.3.4 Carded sample 16:
carded Shetland fibres, sample bag 4.
spun s by Jasmijn Nobelen with spindle whorl VO6374ker in middle position



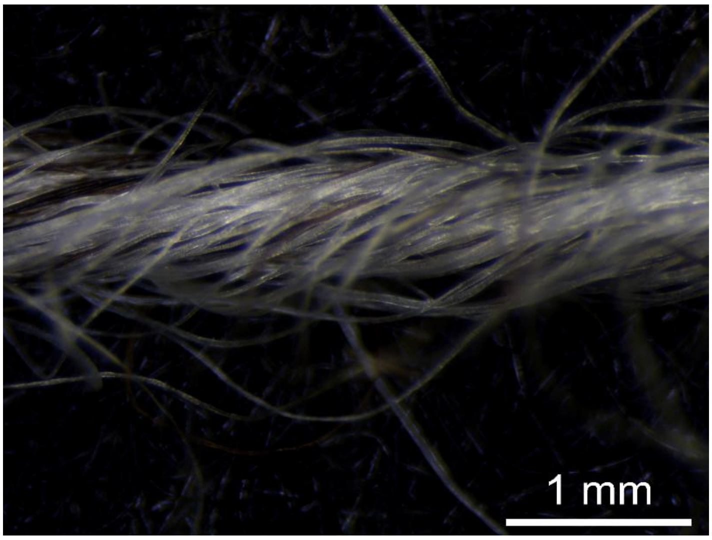
3.3.5 Carded sample 17:
carded Shetland fibres, sample bag 5.
spun z by Jasmijn Nobelen with spindle whorl VO6374ker in top position



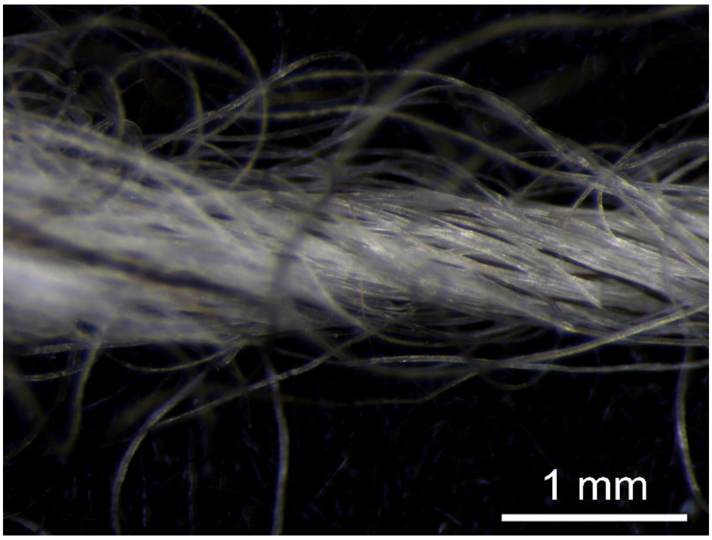
3.3.6 Carded sample 18:
carded Shetland fibres, sample bag 6.
spun s by Jasmijn Nobelen with spindle whorl VO6374ker in top position



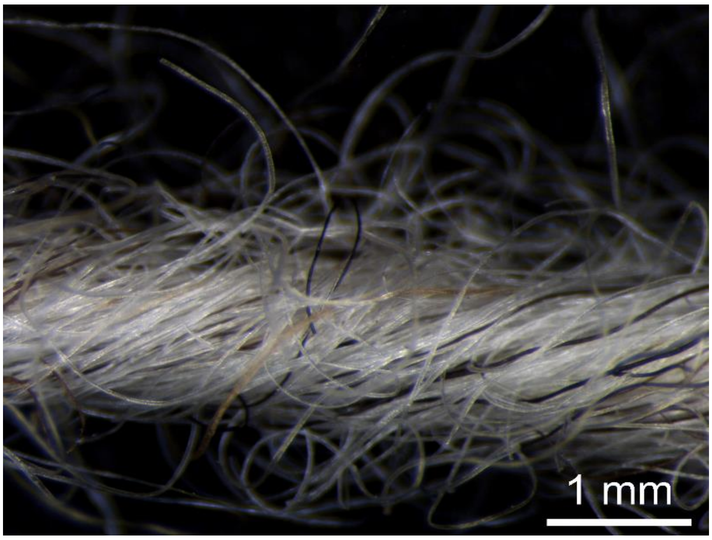
3.3.7 Carded sample 19:
carded Shetland fibres, sample bag 7.
spun z by Jasmijn Nobelen with spindle whorl VO1694ker in bottom position



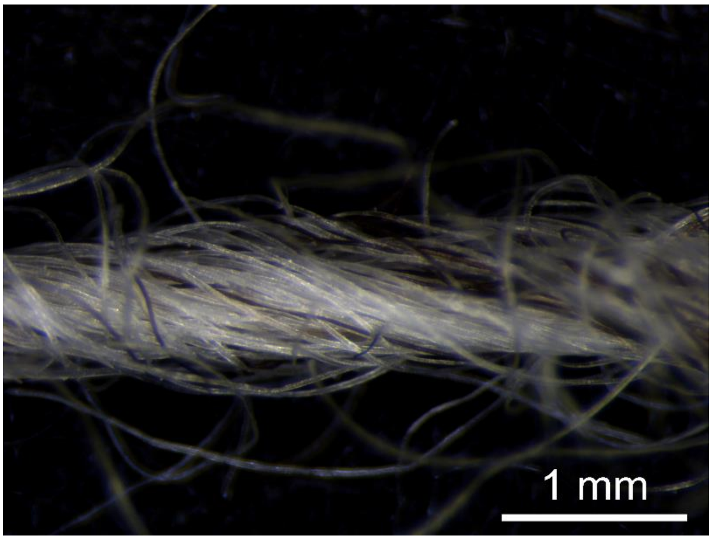
3.3.8 Carded sample 20:
carded Shetland fibres, sample bag 8.
spun s by Jasmijn Nobelen with spindle whorl VO1694ker in bottom position



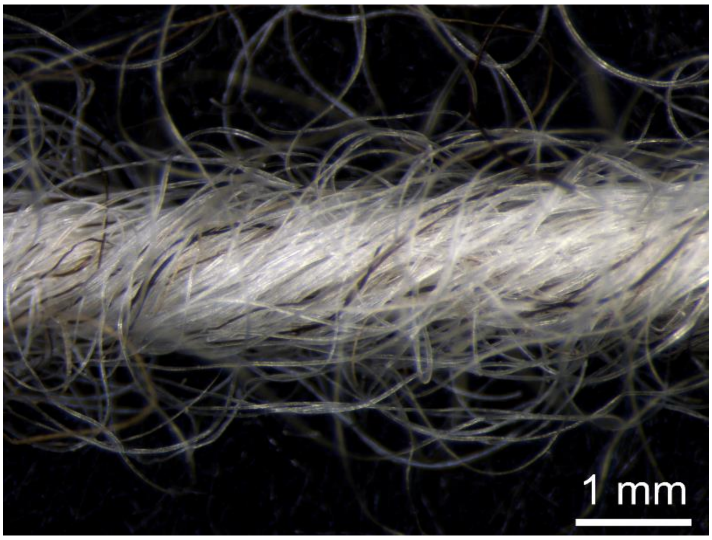
3.3.9 Carded sample 21:
carded Shetland fibres, sample bag 9.
spun z by Jasmijn Nobelen with spindle whorl VO1694ker in middle position



3.3.10 Carded sample 22:
carded Shetland fibres, sample bag 10.
spun s by Jasmijn Nobelen with spindle whorl VO1694ker in middle position

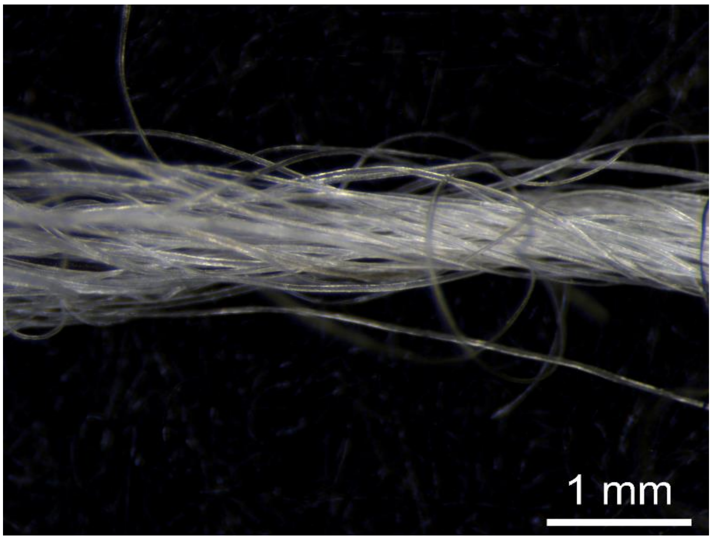


3.3.11 Carded sample 23:
carded Shetland fibres, sample bag 11.
spun z by Jasmijn Nobelen with spindle whorl VO1694ker in top position

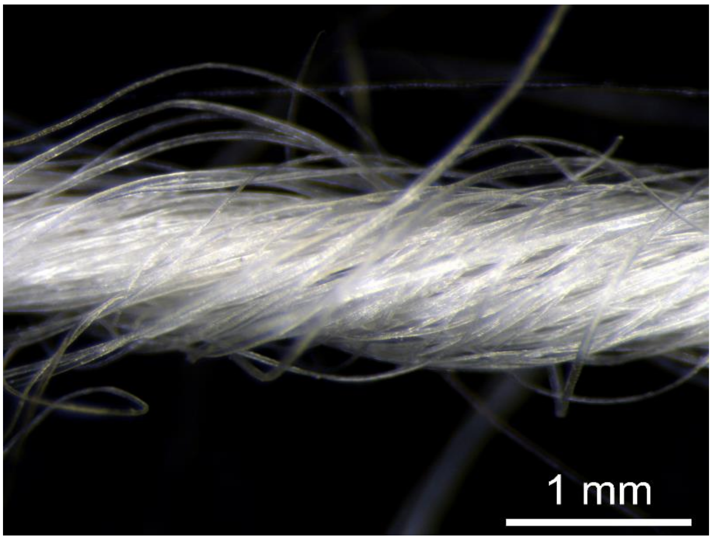


3.3.12 Carded sample 24:
carded Shetland fibres, sample bag 12.
spun s by Jasmijn Nobelen with spindle whorl VO1694ker in top position

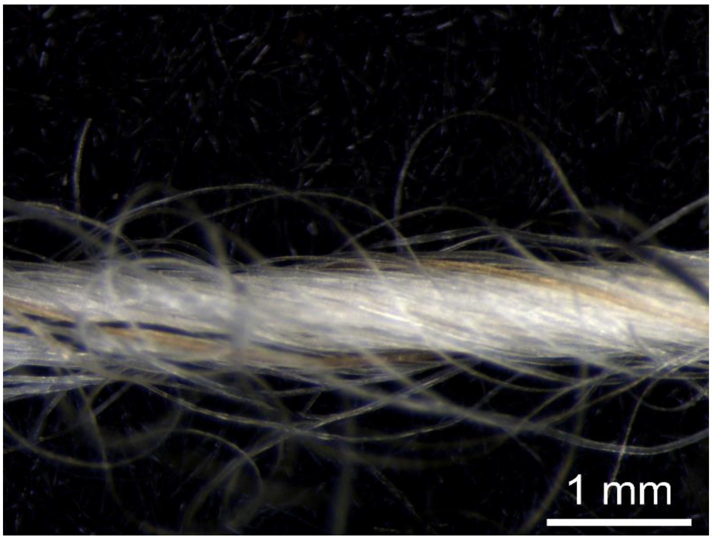
3.4 Carded and Combed Icelandic Samples



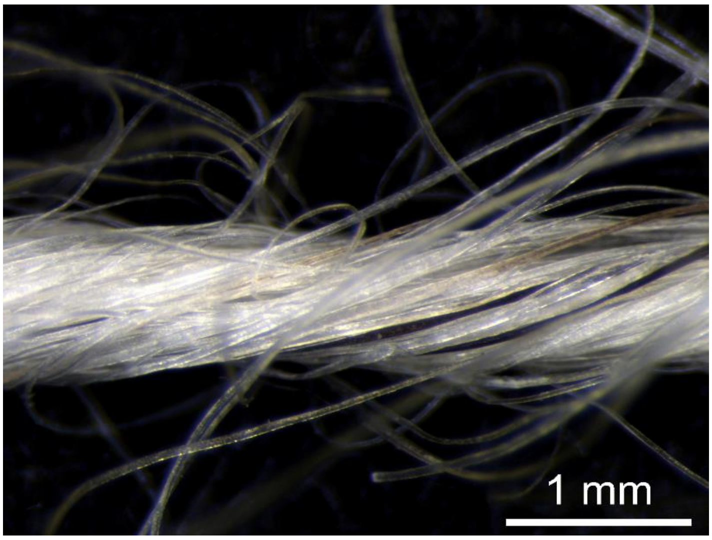
3.4.1 Combed sample 1:
combed Icelandic fibres, sample bag 1.
spun z by Jasmijn Nobelen with spindle whorl VO6374ker in bottom position



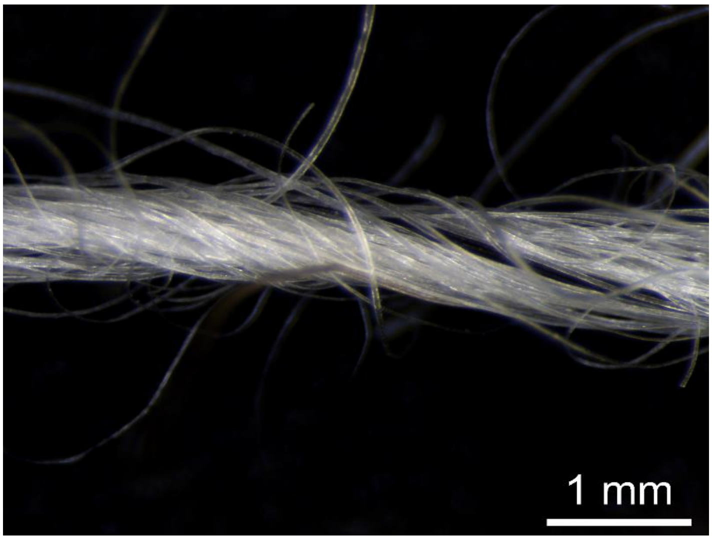
3.4.2 Combed sample 2:
combed Icelandic fibres, sample bag 2.
spun s by Jasmijn Nobelen with spindle whorl VO6374ker in bottom position



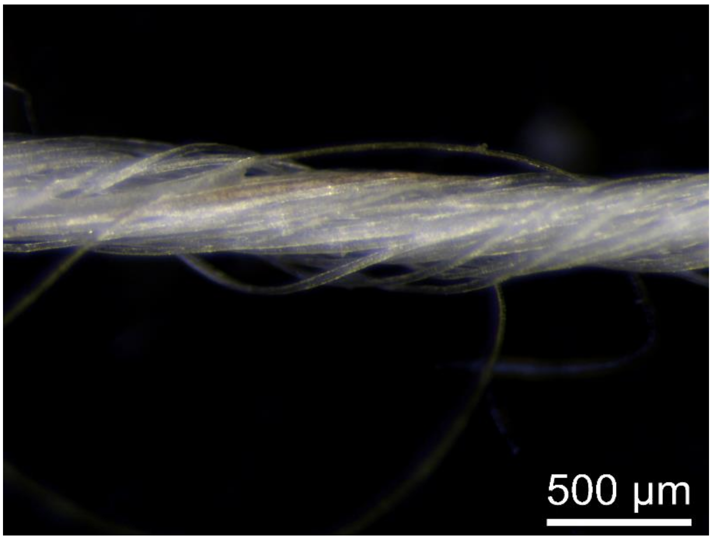
3.4.3 Combed sample 3
combed Icelandic fibres, sample bag 3.
spun z by Jasmijn Nobelen with spindle whorl VO6374ker in middle position



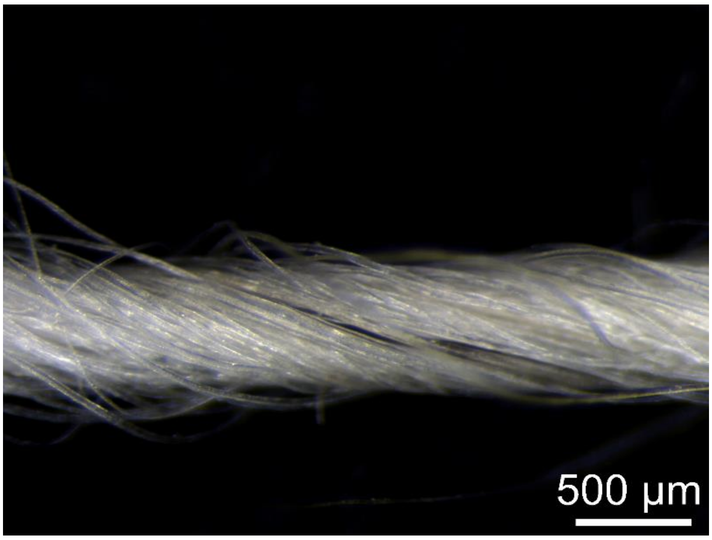
3.4.4 Combed sample 5:
combed Icelandic fibres, sample bag 4.
spun s by Jasmijn Nobelen with spindle whorl VO6374ker in middle position



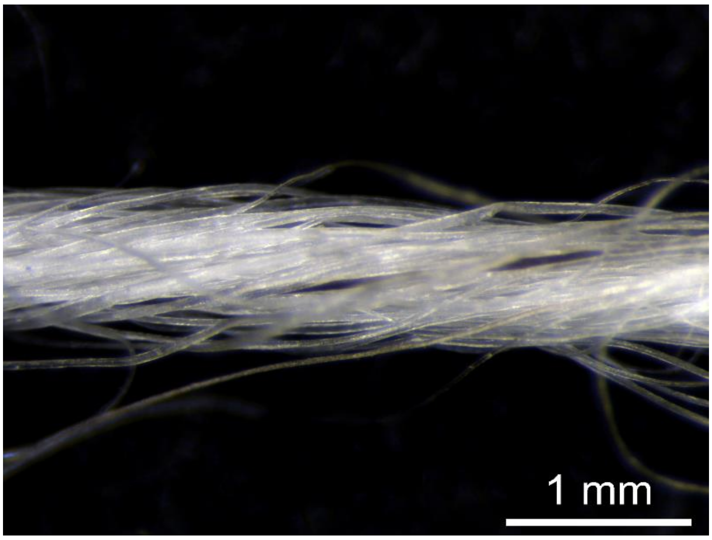
3.4.5 Combed sample 4:
combed Icelandic fibres, sample bag 5.
spun z by Jasmijn Nobelen with spindle whorl VO6374ker in top position



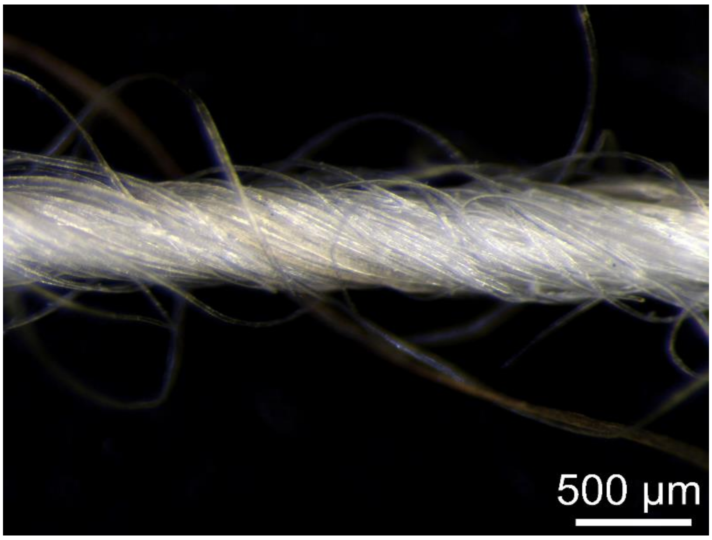
3.4.6 Combed sample 6:
combed Icelandic fibres, sample bag 6.
spun s by Jasmijn Nobelen with spindle whorl VO6374ker in top position



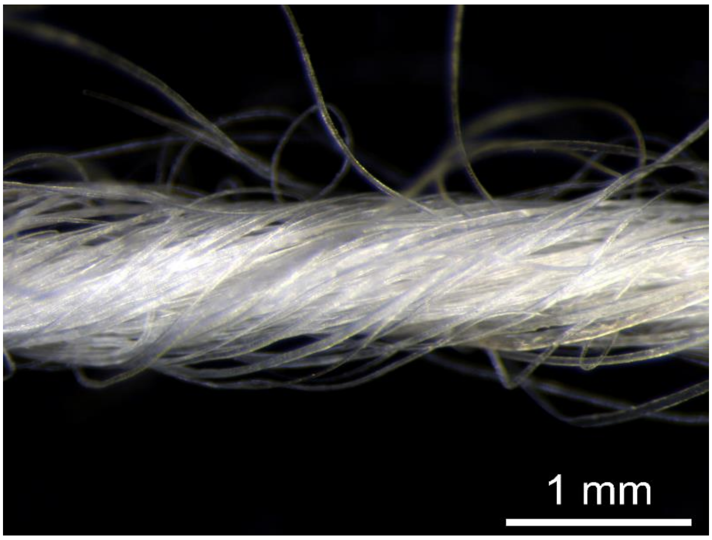
3.4.7 Combed sample 7:
combed Icelandic fibres, sample bag 7.
spun z by Jasmijn Nobelen with spindle whorl VO1694ker in bottom position



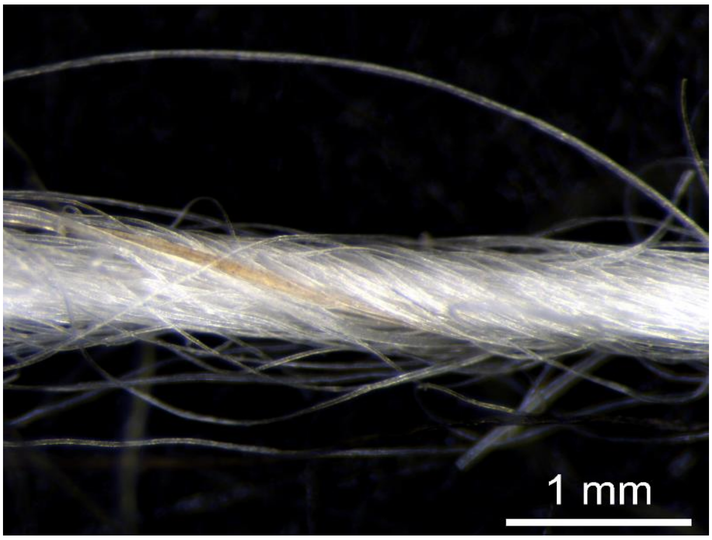
3.4.8 Combed sample 8:
combed Icelandic fibres, sample bag 8.
spun s by Jasmijn Nobelen with spindle whorl VO1694ker in bottom position



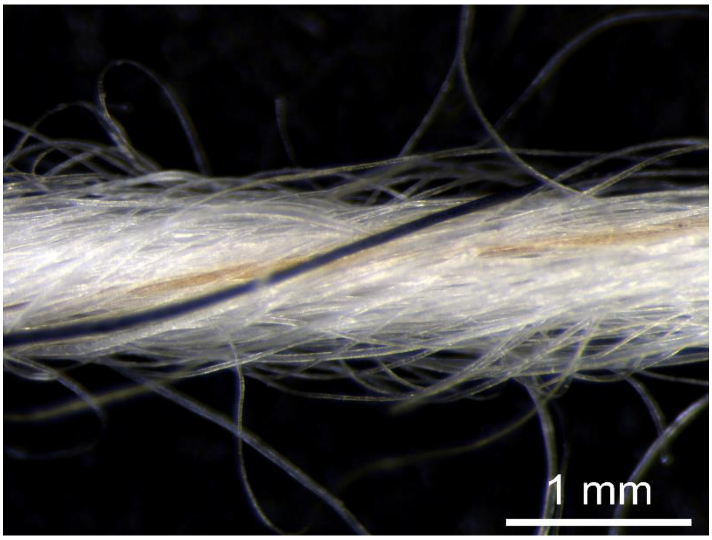
3.4.9 Combed sample 9:
combed Icelandic fibres, sample bag 9.
spun z by Jasmijn Nobelen with spindle whorl VO1694ker in middle position



3.4.10 Combed sample 10:
combed Icelandic fibres, sample bag 10.
spun s by Jasmijn Nobelen with spindle whorl VO1694ker in middle position

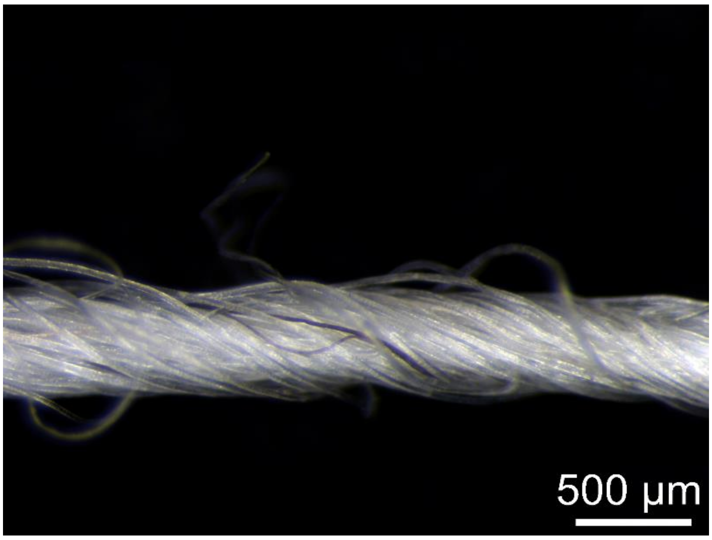


3.4.11 Combed sample 11:
combed Icelandic fibres, sample bag 11.
spun z by Jasmijn Nobelen with spindle whorl VO1694ker in top position

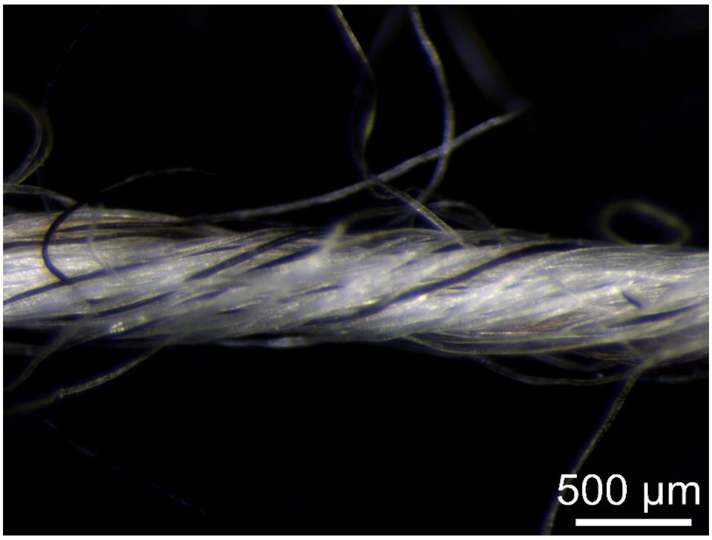


3.4.12 Combed sample 12:
combed Icelandic fibres, sample bag 12.
spun s by Jasmijn Nobelen with spindle whorl VO1694ker in top position

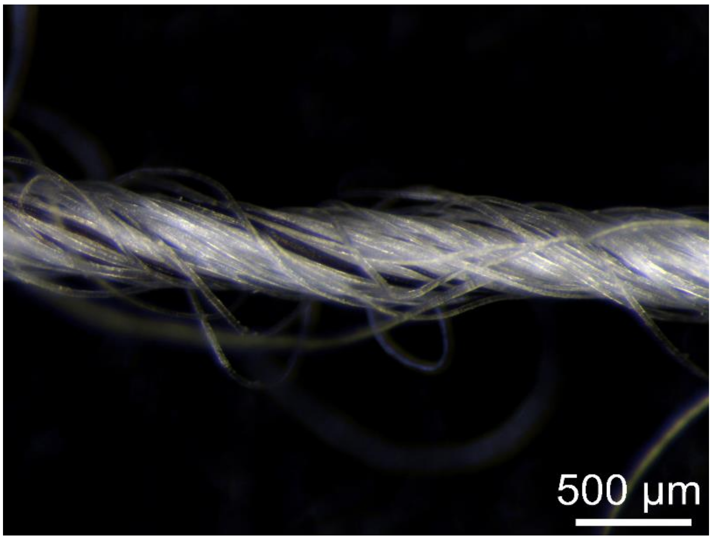
3.5 Combed Shetland Samples



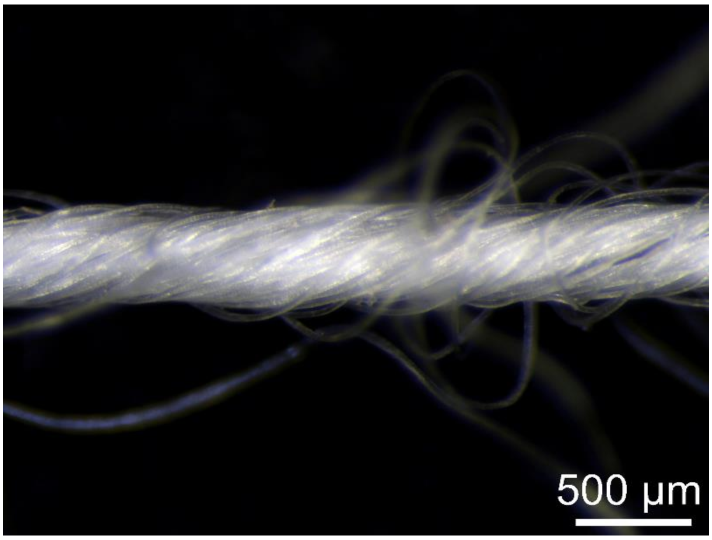
3.5.1 Combed sample 13:
combed Shetland fibres, sample bag 1.
spun z by Jasmijn Nobelen with spindle whorl VO6374ker in bottom position



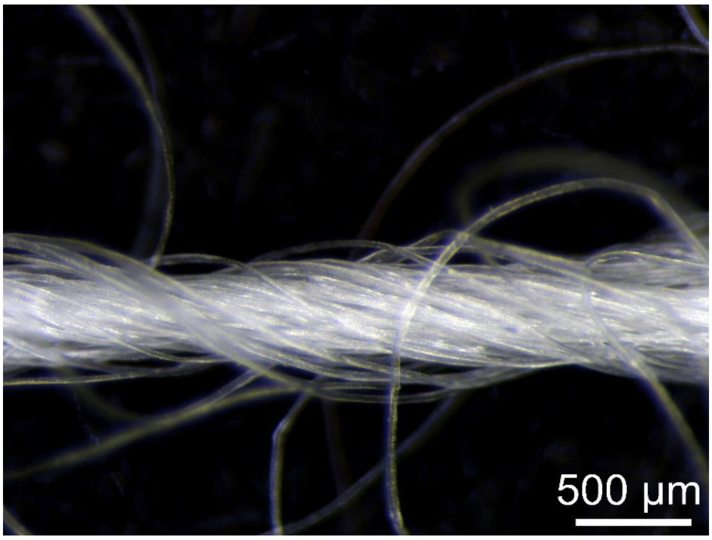
3.5.2 Combed sample 14:
combed Shetland fibres, sample bag 2.
spun s by Jasmijn Nobelen with spindle whorl VO6374ker in bottom position



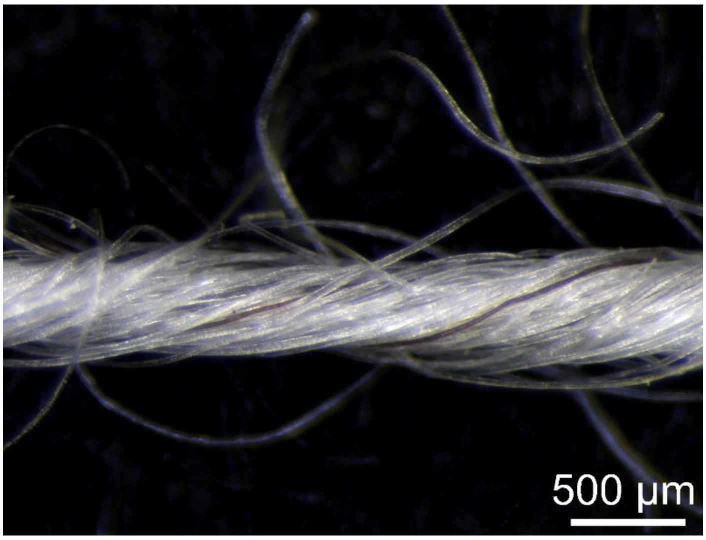
3.5.3 Combed sample 15:
combed Shetland fibres, sample bag 3.
spun z by Jasmijn Nobelen with spindle whorl VO6374ker in middle position



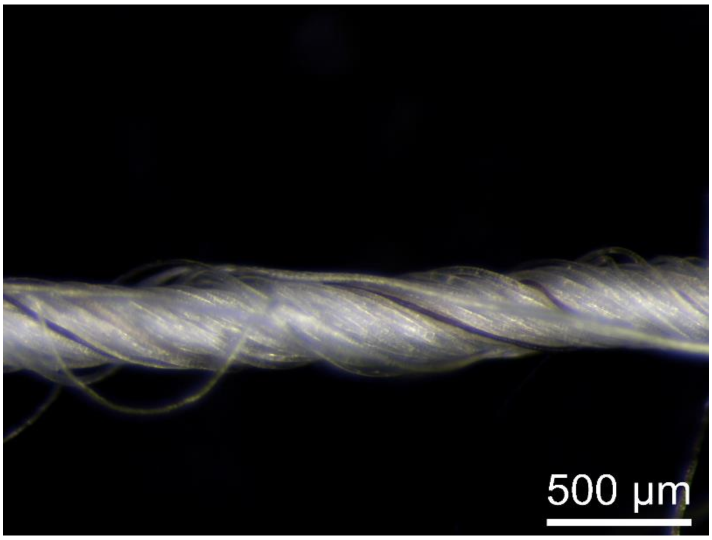
3.5.4 Combed sample 17:
combed Shetland fibres, sample bag 4.
spun s by Jasmijn Nobelen with spindle whorl VO6374ker in middle position



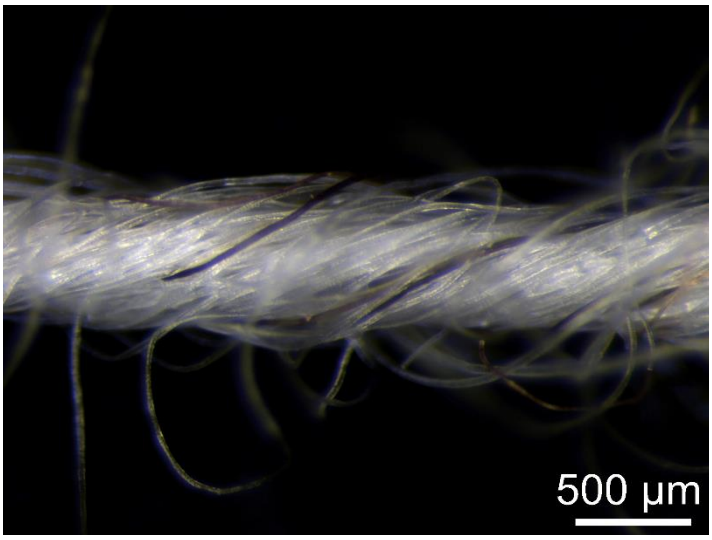
3.5.5 Combed sample 16:
combed Shetland fibres, sample bag 5.
spun z by Jasmijn Nobelen with spindle whorl VO6374ker in top position



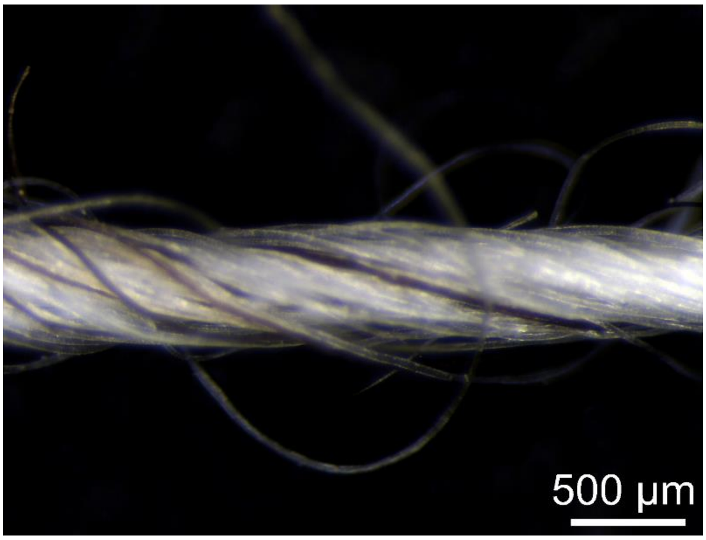
3.5.6 Combed sample 18:
combed Shetland fibres, sample bag 6.
spun s by Jasmijn Nobelen with spindle whorl VO6374ker in top position



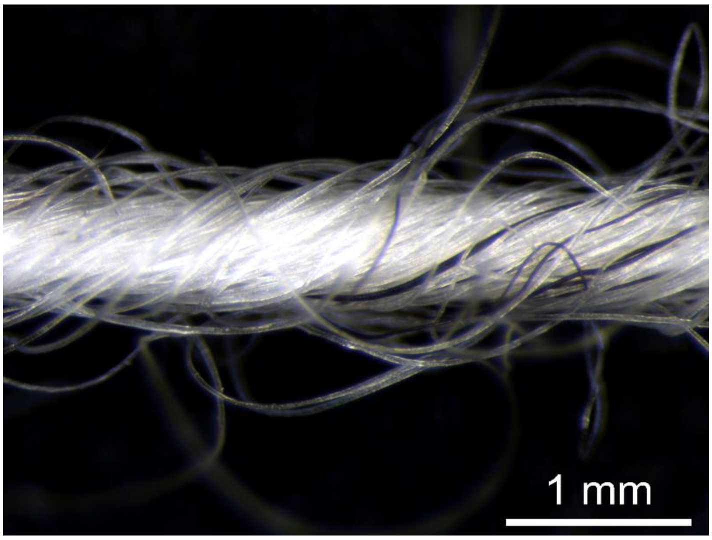
3.5.7 Combed sample 20:
combed Shetland fibres, sample bag 7.
spun z by Jasmijn Nobelen with spindle whorl VO1694ker in bottom position



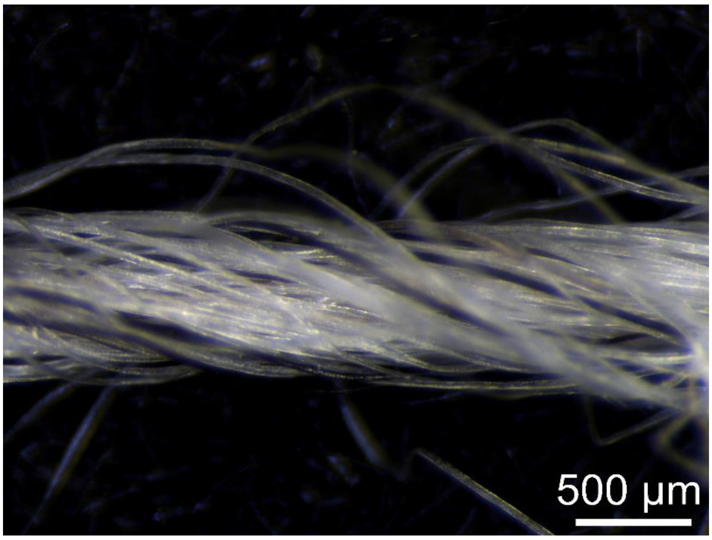
3.5.8 Combed sample 19:
combed Shetland fibres, sample bag 8.
spun s by Jasmijn Nobelen with spindle whorl VO1694ker in bottom position



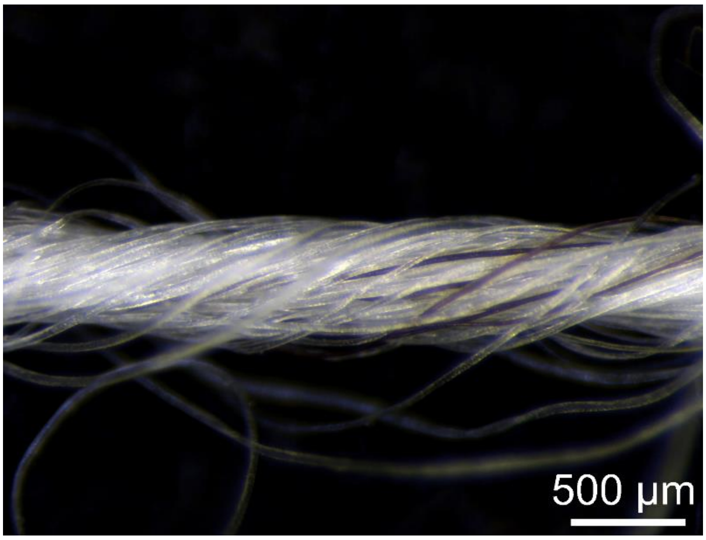
3.5.9 Combed sample 21:
combed Shetland fibres, sample bag 9
spun z by Jasmijn Nobelen with spindle whorl VO1694ker in middle position



3.5.10 Combed sample 23:
combed Shetland fibres, sample bag 10
spun s by Jasmijn Nobelen with spindle whorl
VO1694ker in middle position

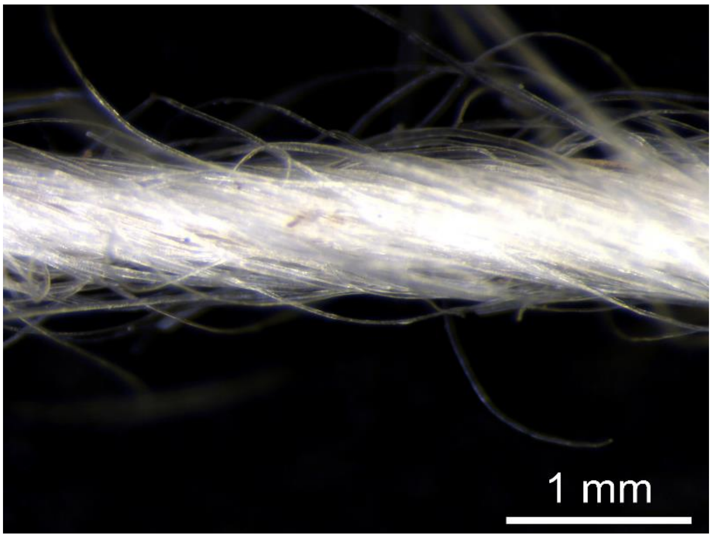


3.5.11 Combed sample 22
combed Shetland fibres, sample bag 11
spun z by Jasmijn Nobelen with spindle whorl
VO1694ker in top position:

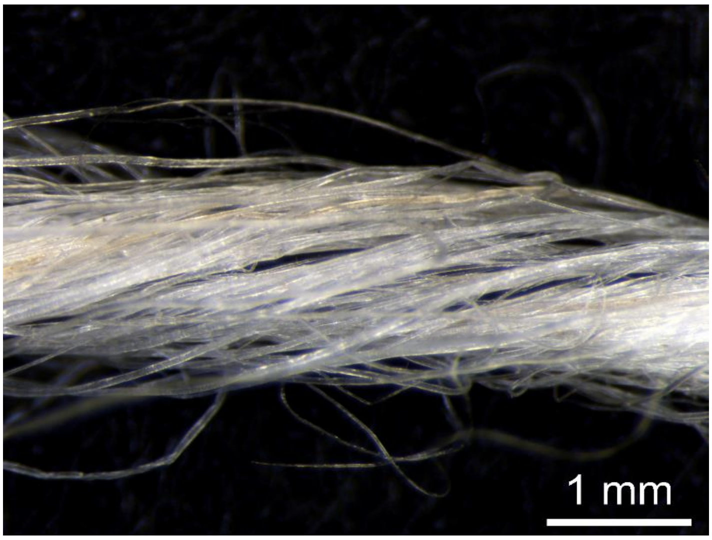


3.5.12 Combed sample 24:
combed Shetland fibres, sample bag 12
spun s by Jasmijn Nobelen with spindle whorl
VO1694ker in top position

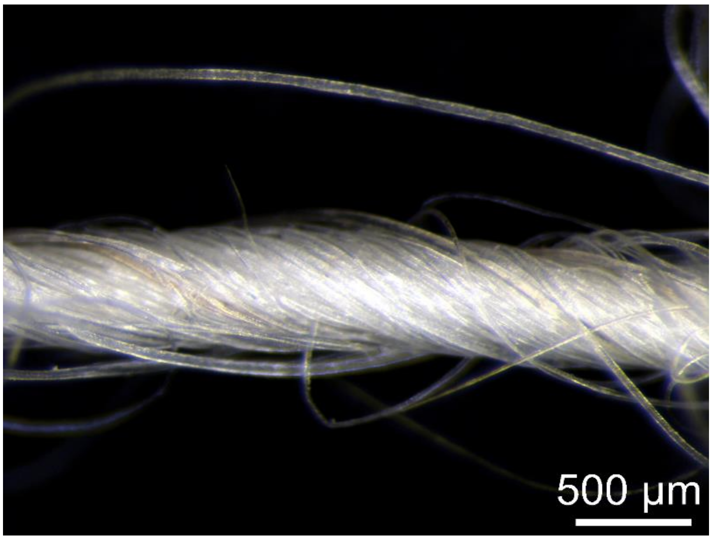
3.6 Teased Icelandic Samples



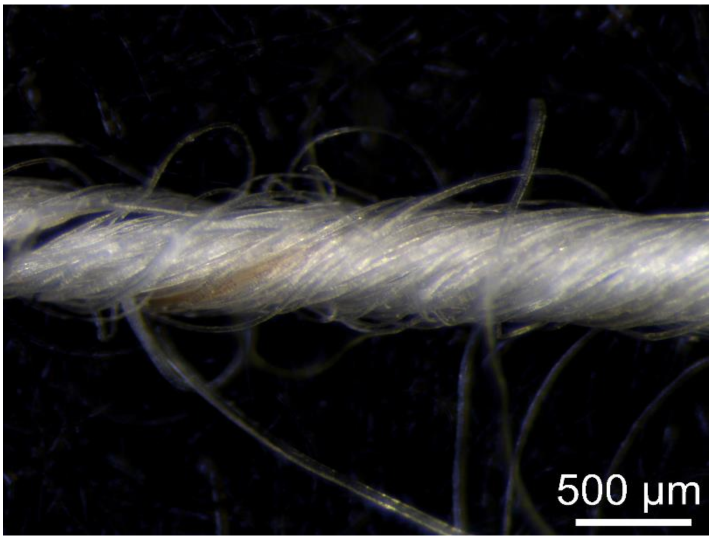
3.6.1 Teased sample 1:
teased Icelandic fibres, sample bag 1.
spun z by Jasmijn Nobelen with spindle whorl VO6734ker in bottom position



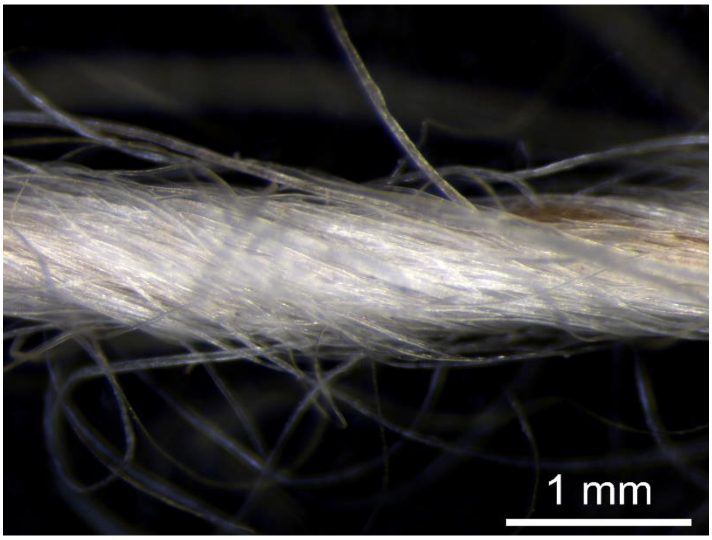
3.6.2 Teased sample 3:
teased Icelandic fibres, sample bag 2.
spun s by Jasmijn Nobelen with spindle whorl VO6734ker in bottom position



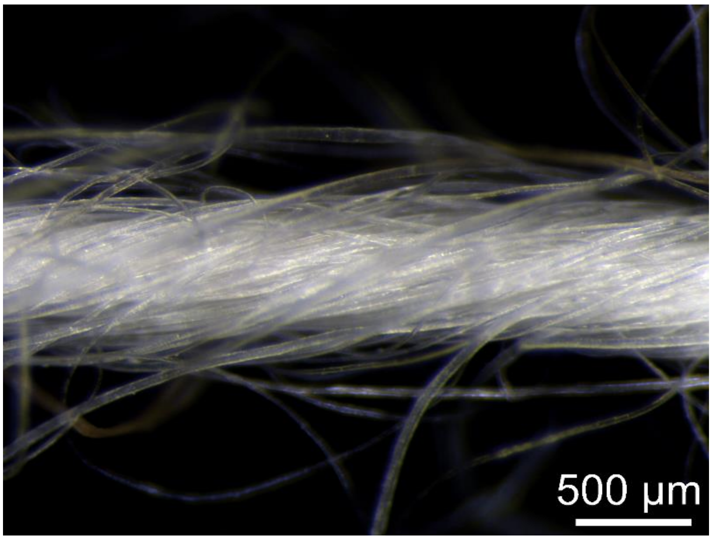
3.6.3 Teased sample 2:
teased Icelandic fibres, sample bag 3.
spun z by Jasmijn Nobelen with spindle whorl VO6734ker in middle position



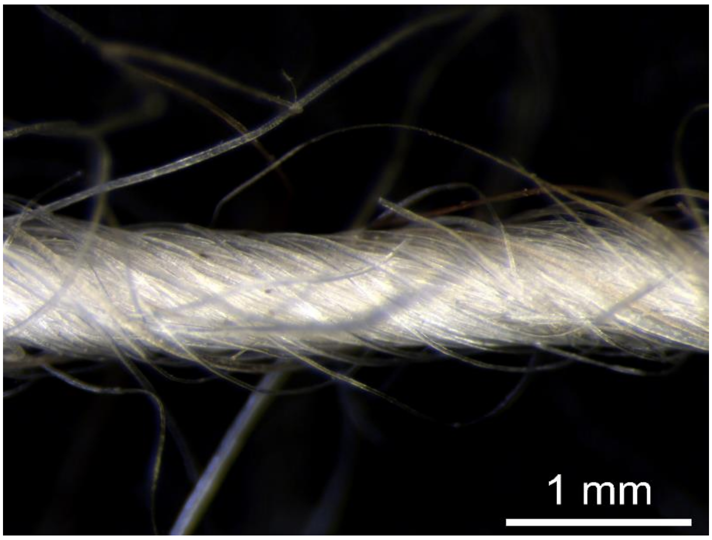
3.6.4 Teased sample 4:
teased Icelandic fibres, sample bag 4.
spun s by Jasmijn Nobelen with spindle whorl VO6734ker in middle position



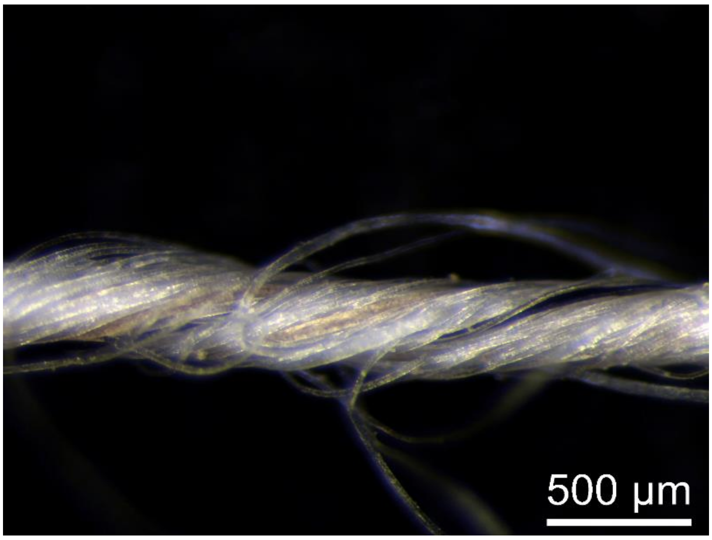
3.6.5 Teased sample 5:
teased Icelandic fibres, sample bag 5.
spun z by Jasmijn Nobelen with spindle whorl VO6734ker in top position



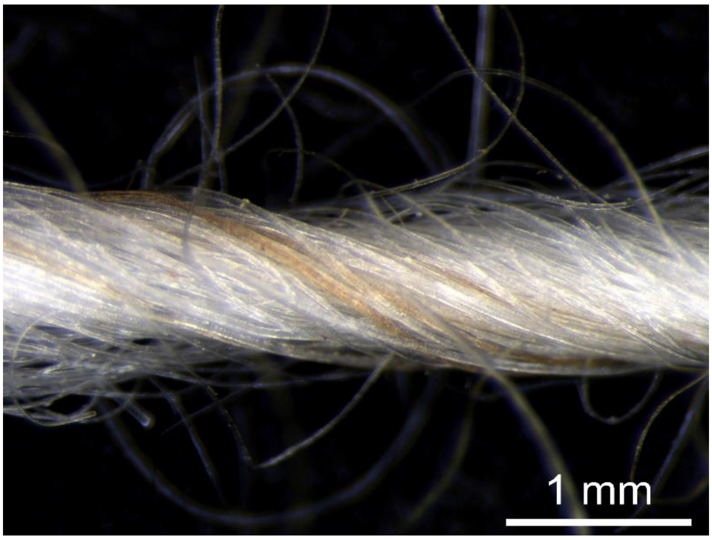
3.6.6 Teased sample 6:
teased Icelandic fibres, sample bag 6.
spun s by Jasmijn Nobelen with spindle whorl VO6734ker in top position



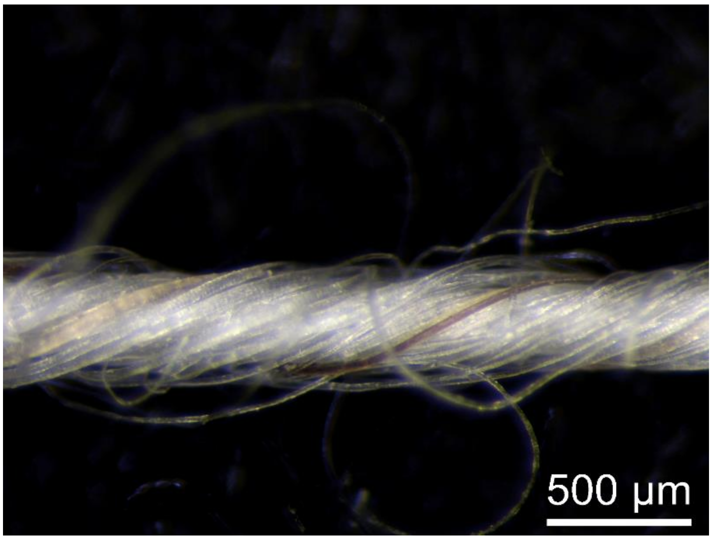
3.6.7 Teased sample 8:
teased Icelandic fibres, sample bag 7.
spun z by Jasmijn Nobelen with spindle whorl VO1694ker in botom position



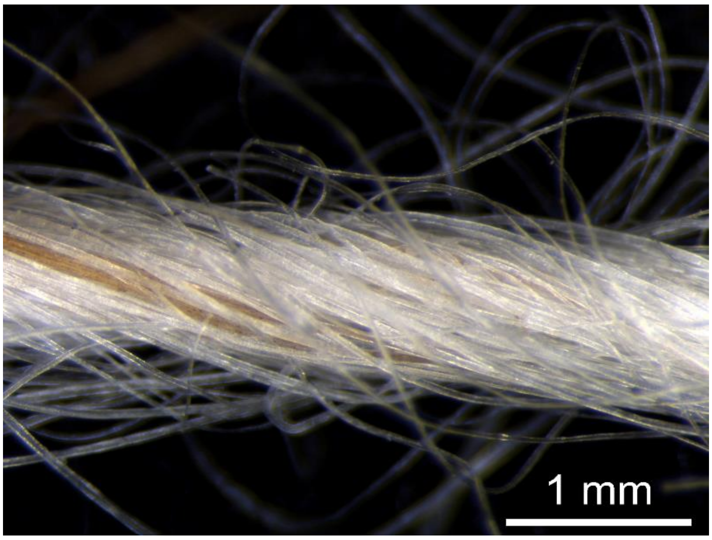
3.6.8 Teased sample 7:
teased Icelandic fibres, sample bag 8.
spun s by Jasmijn Nobelen with spindle whorl VO1694ker in bottom position



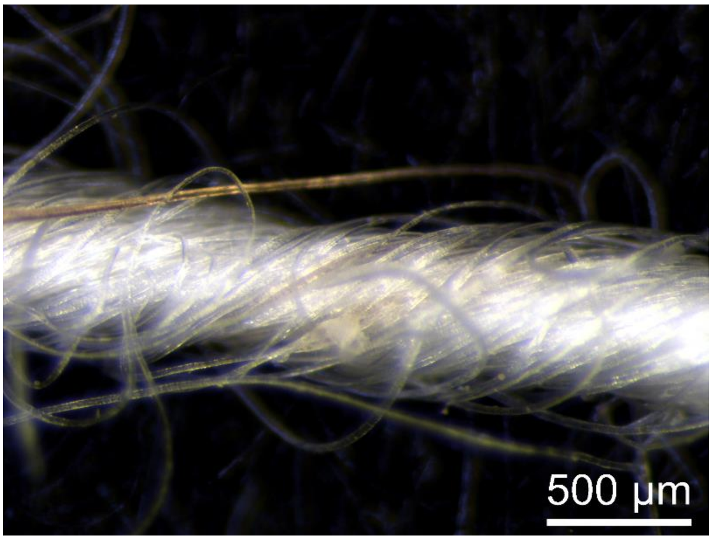
3.6.9 Teased sample 9:
teased Icelandic fibres, sample bag 9.
spun z by Jasmijn Nobelen with spindle whorl VO1694ker in middle position



3.6.10 Teased sample 11:
teased Icelandic fibres, sample bag 10.
spun s by Jasmijn Nobelen with spindle whorl VO1694ker in middle position

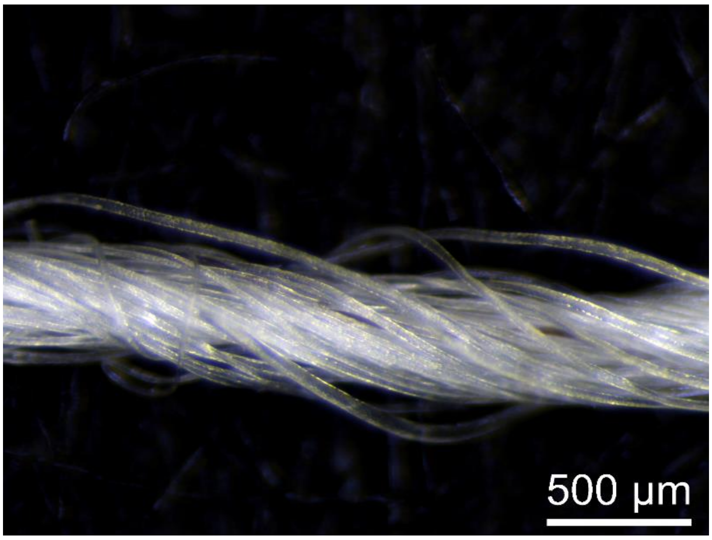


3.6.11 Teased sample 10:
teased Icelandic fibres, sample bag 11.
spun z by Jasmijn Nobelen with spindle whorl VO1694ker in top position

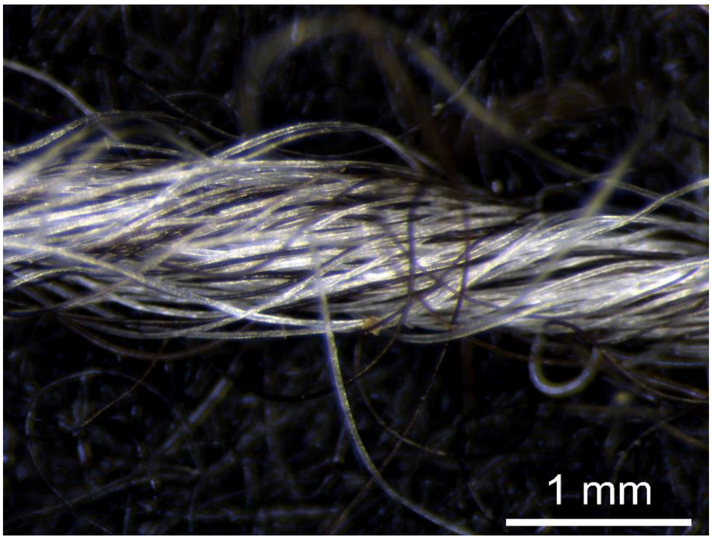


3.6.12 Teased sample 12:
teased Icelandic fibres, sample bag 12.
spun s by Jasmijn Nobelen with spindle whorl VO1694ker in top position

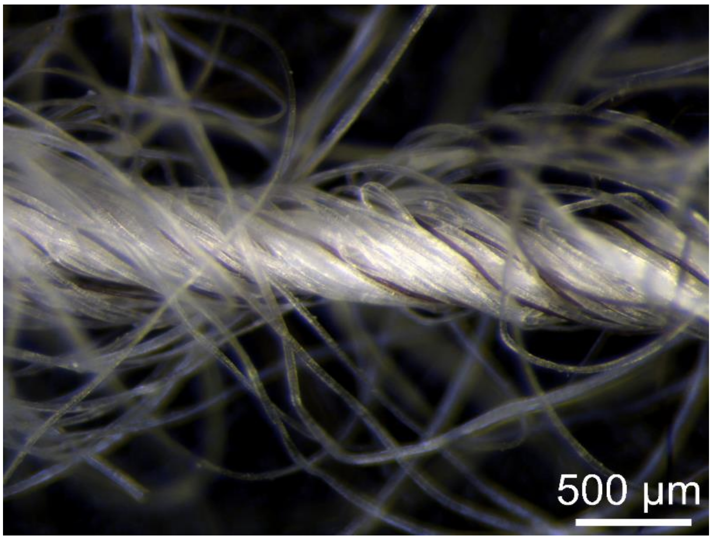
3.7 Teased Shetland Samples



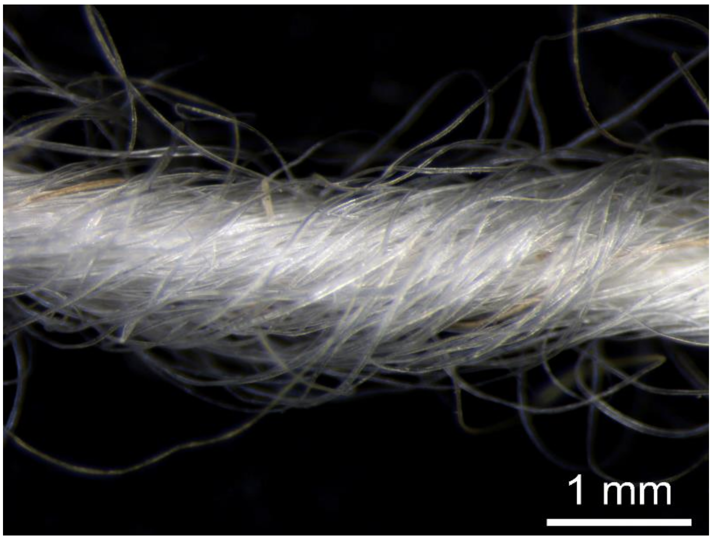
3.7.1 Teased sample 14:
teased Shetland fibres, sample bag 1.
spun z by Jasmijn Nobelen with spindle whorl VO6374ker in bottom position



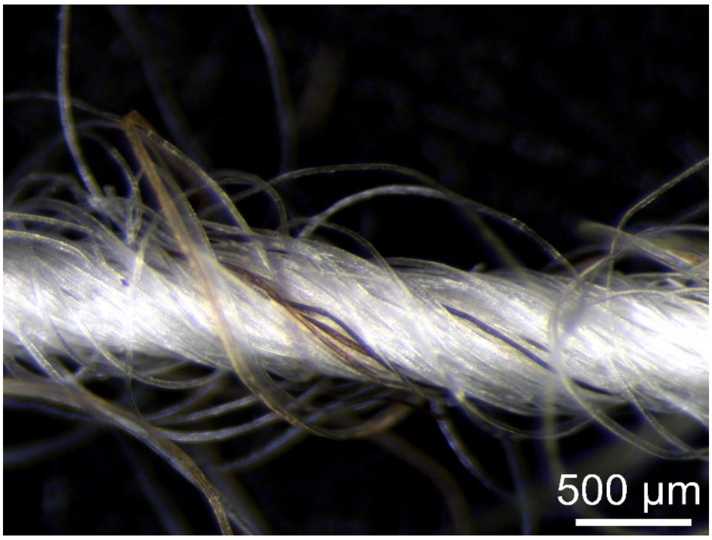
3.7.2 Teased sample 13:
teased Shetland fibres, sample bag 2.
spun s by Jasmijn Nobelen with spindle whorl VO6374ker in bottom position



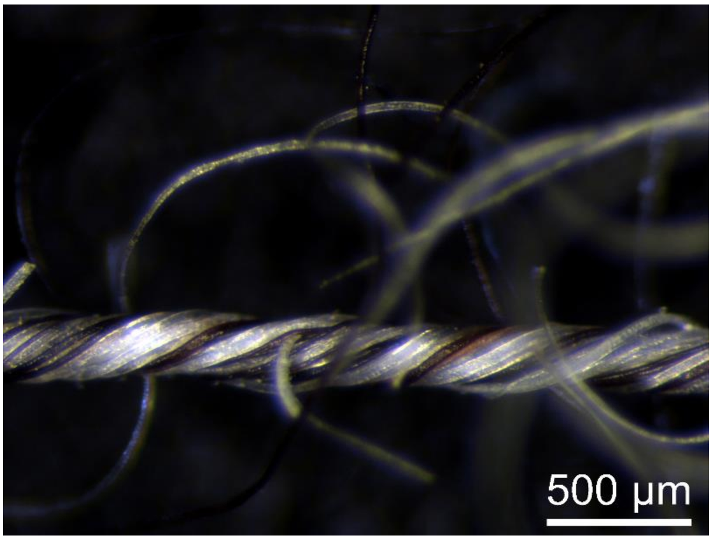
3.7.3 Teased sample 15:
teased Shetland fibres, sample bag 3.
spun z by Jasmijn Nobelen with spindle whorl VO6374ker in middle position



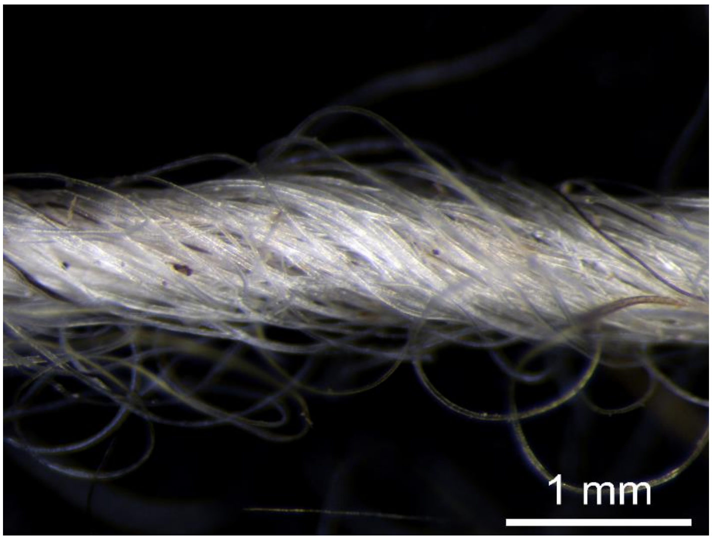
3.7.4 Teased sample 17:
teased Shetland fibres, sample bag 4.
spun s by Jasmijn Nobelen with spindle whorl VO6374ker in middle position



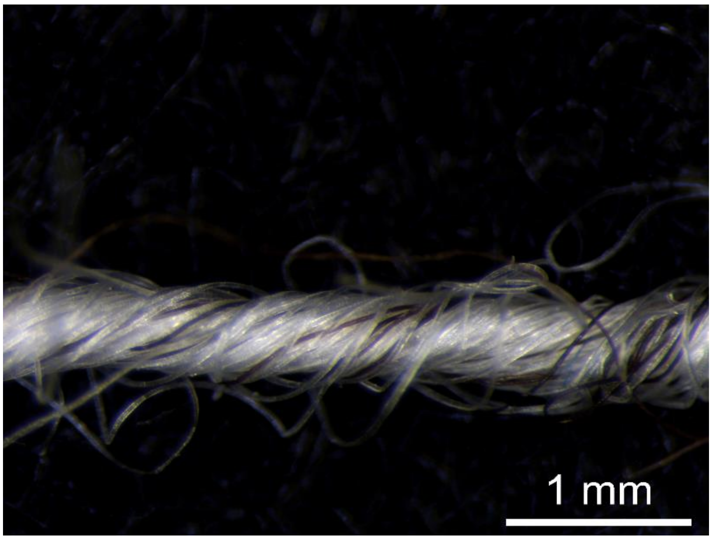
3.7.5 Teased sample 16:
teased Shetland fibres, sample bag 5.
spun z by Jasmijn Nobelen with spindle whorl VO6374ker in top position



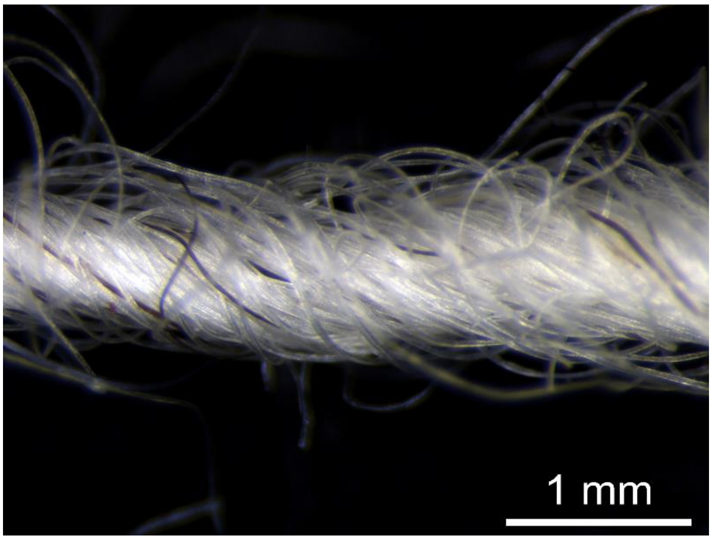
3.7.6 Teased sample 18:
teased Shetland fibres, sample bag 6.
spun s by Jasmijn Nobelen with spindle whorl VO6374ker in top position



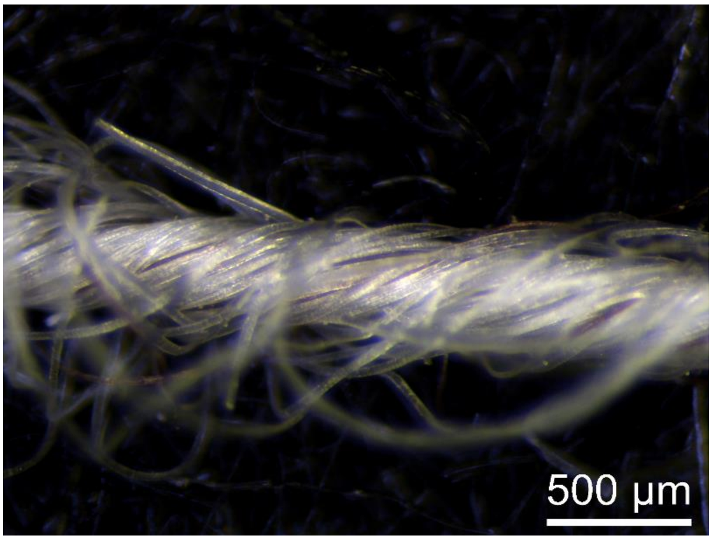
3.7.7 Teased sample 20:
teased Shetland fibres, sample bag 7.
spun z by Jasmijn Nobelen with spindle whorl
VO1694ker in bottom position



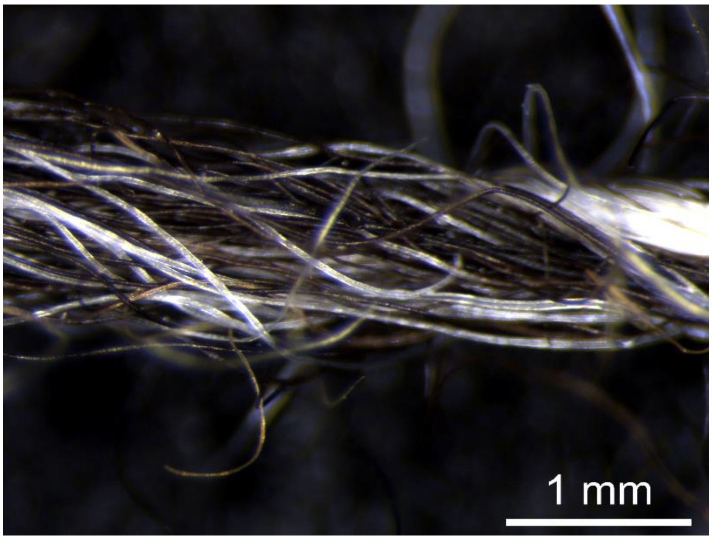
3.7.8 Teased sample 19:
teased Shetland fibres, sample bag 8.
spun s by Jasmijn Nobelen with spindle whorl
VO1694ker in bottom position



3.7.9 Teased sample 21:
teased Shetland fibres, sample bag 9.
spun z by Jasmijn Nobelen with spindle whorl
VO1694ker in middle position



3.7.10 Teased sample 22:
teased Shetland fibres, sample bag 10.
spun s by Jasmijn Nobelen with spindle whorl VO1694ker in middle position

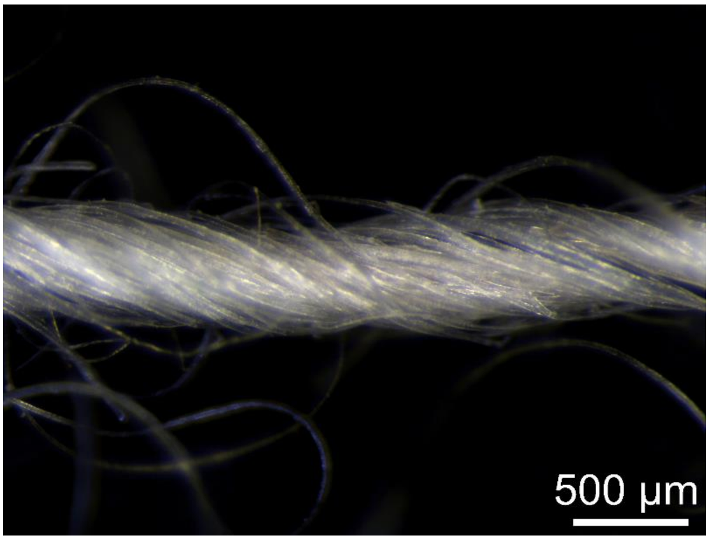


3.7.11 Teased sample 23:
teased Shetland fibres, sample bag 11.
spun z by Jasmijn Nobelen with spindle whorl VO1694ker in top position

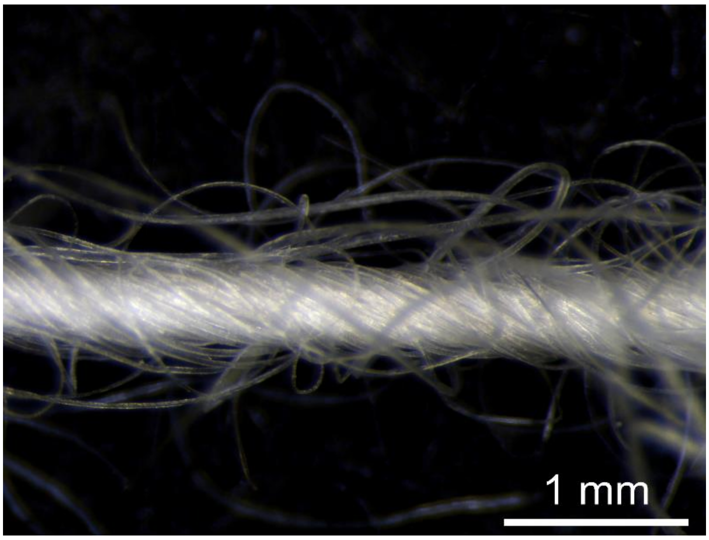
3.7.12 Teased sample 24:
teased Shetland fibres, sample bag 12.
spun s by Jasmijn Nobelen with spindle whorl VO1694ker in top position

3.8 Additional Expert Samples

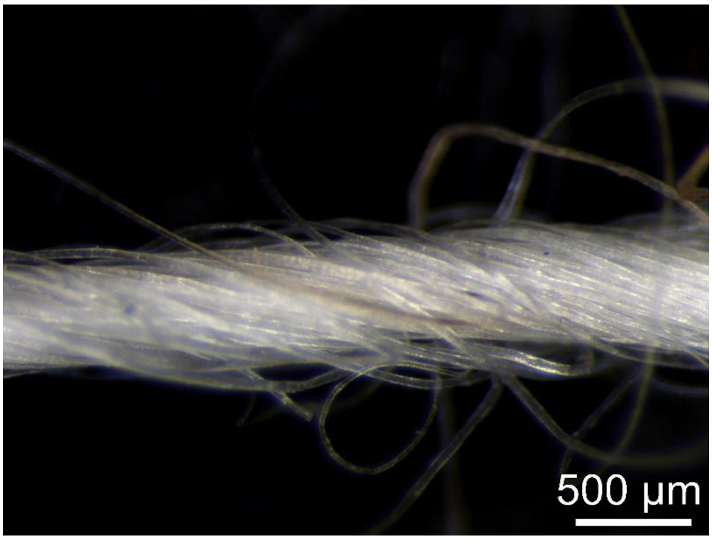
A. Reurink



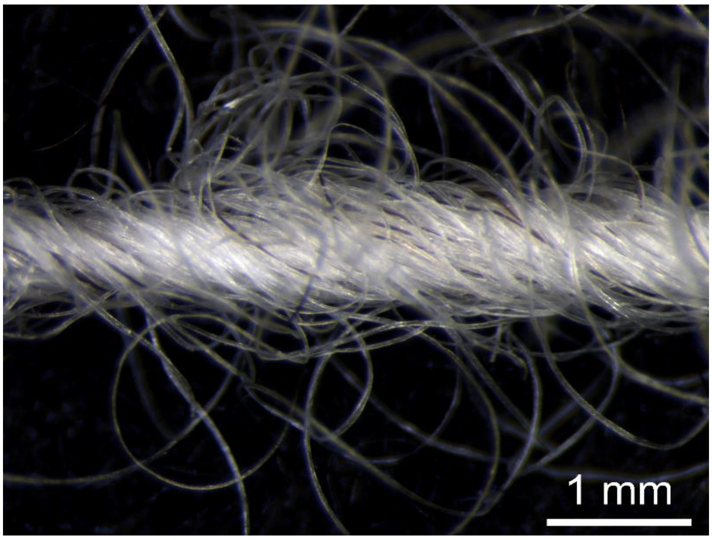
3.8.1 Reurink sample 1:
carded Icelandic 5, spun by A. Reurink with spindle VO6374ker (z) in bottom position.



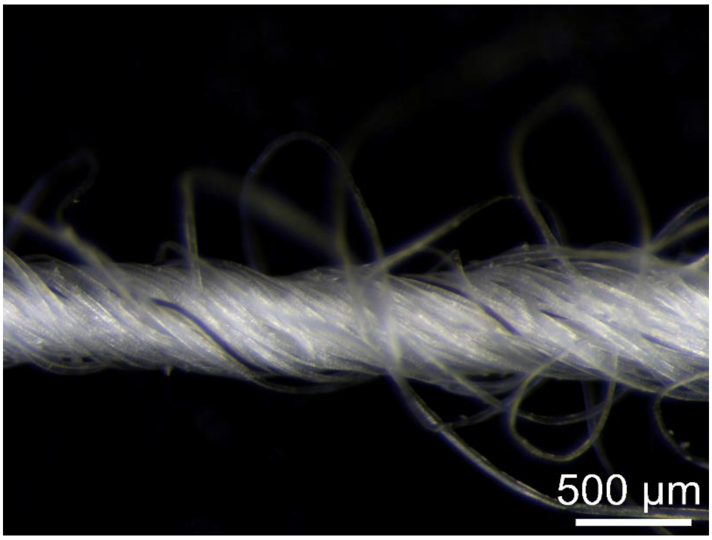
3.8.2 Reurink sample 2:
combed Icelandic 5, spun by A. Reurink with spindle VO6374ker (z) in bottom position.



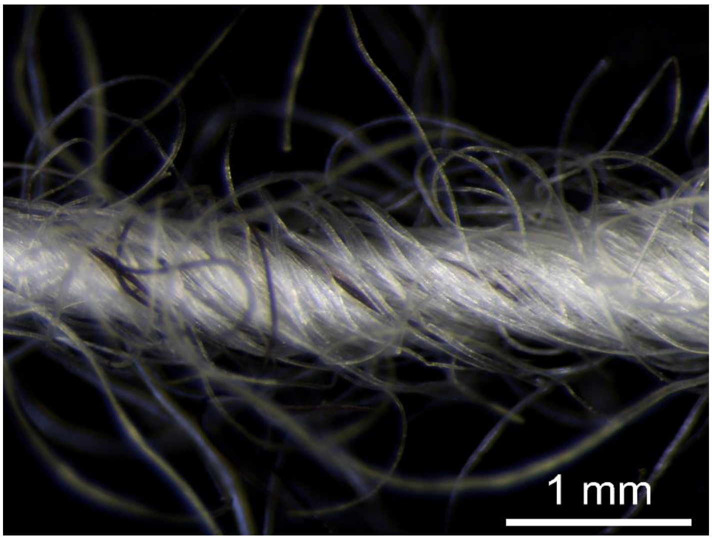
3.8.3 Reurink sample 3:
teased Icelandic 5, spun by A. Reurink with spindle VO6374ker (z) in bottom position.



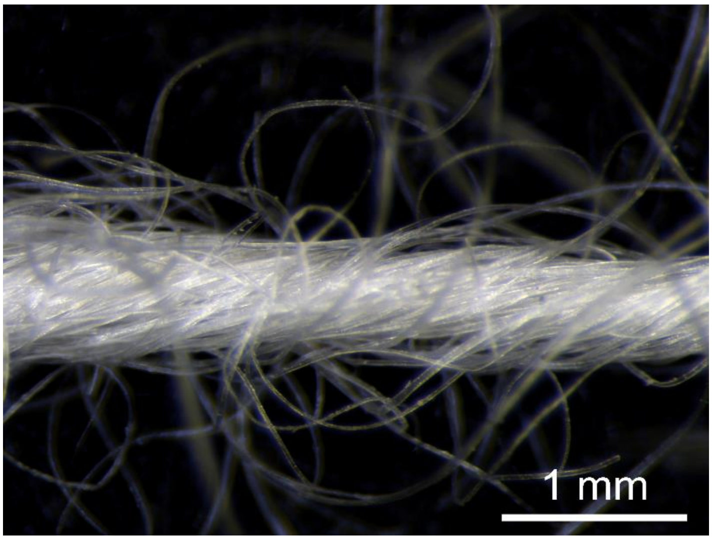
3.8.4 Reurink sample 4:
carded Shetland 5, spun by A. Reurink with spindle VO6374ker (z) in bottom position.



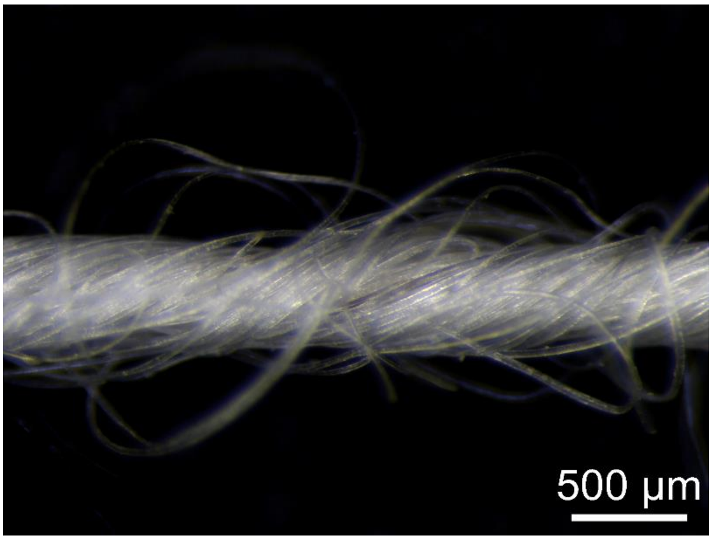
3.8.5 Reurink sample 5:
combed Shetland 5, spun by A. Reurink with spindle VO6374ker (z) in bottom position.



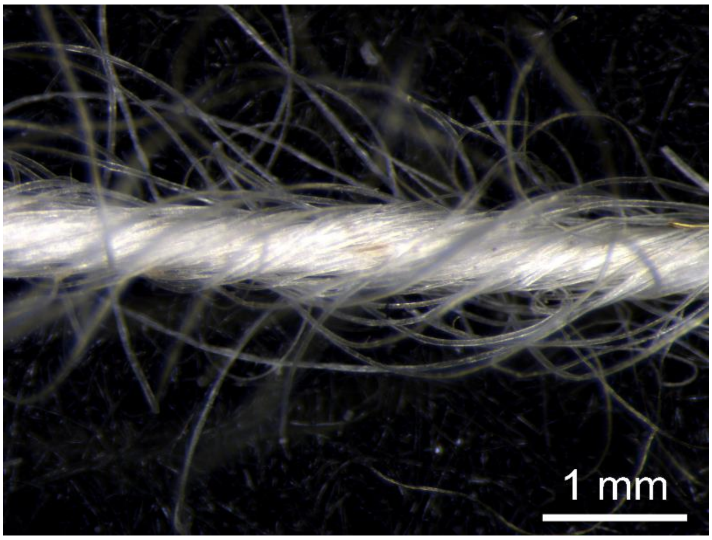
3.8.6 Reurink sample 6:
teased Shetland 5, spun by A. Reurink with spindle VO6374ker (z) in bottom position.



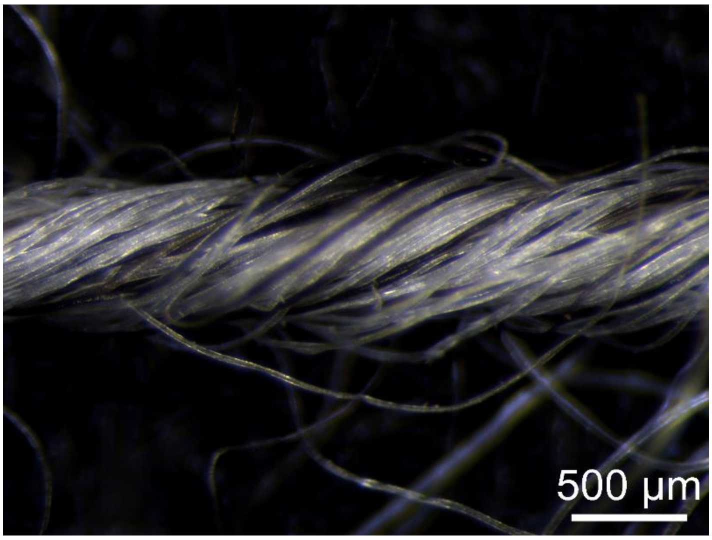
3.8.7 VE sample 2:
carded Icelandic 6, spun by G. Vogelsang-Eastwood with spindle VO6374ker (s) in bottom position.



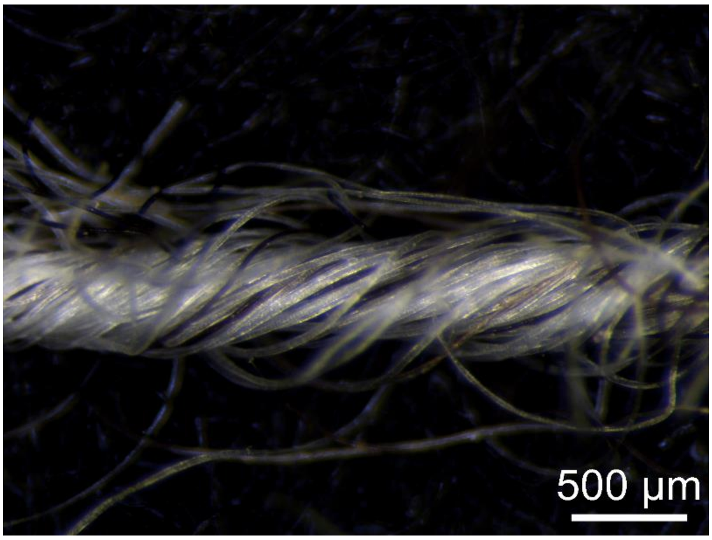
3.8.8 VE sample 1:
combed Icelandi 6, spun by G. Vogelsang-Eastwood with spindle VO6374ker (s) in bottom position.



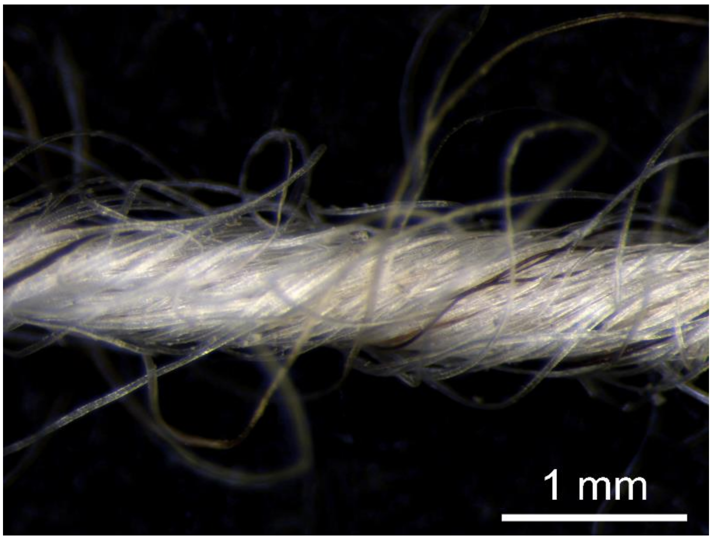
3.8.9 VE sample 3:
teased Icelandic 6, spun by G. Vogelsang-Eastwood with spindle VO6374ker (s) in bottom position.



3.8.10 VE sample 5:
carded Shetland 6, spun by G. Vogelsang-Eastwood with spindle VO6374ker (s) in bottom position.

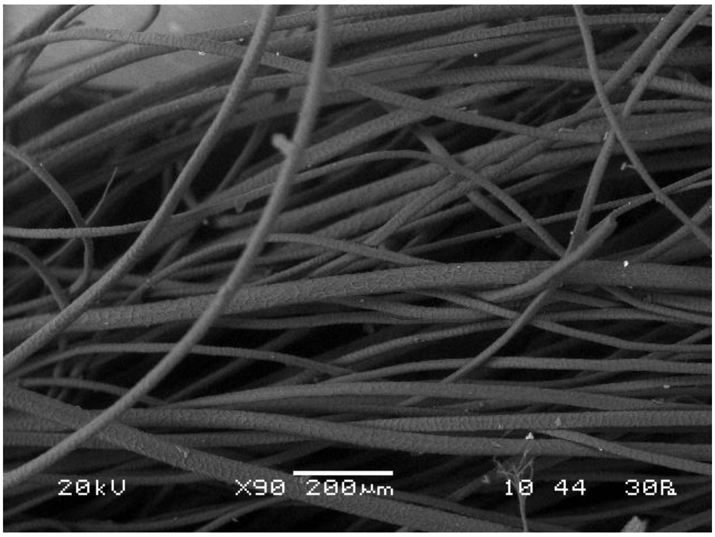


3.8.11 VE sample 4:
combed Shetland 6, spun by G. Vogelsang-Eastwood with spindle VO6374ker (s) in bottom position.

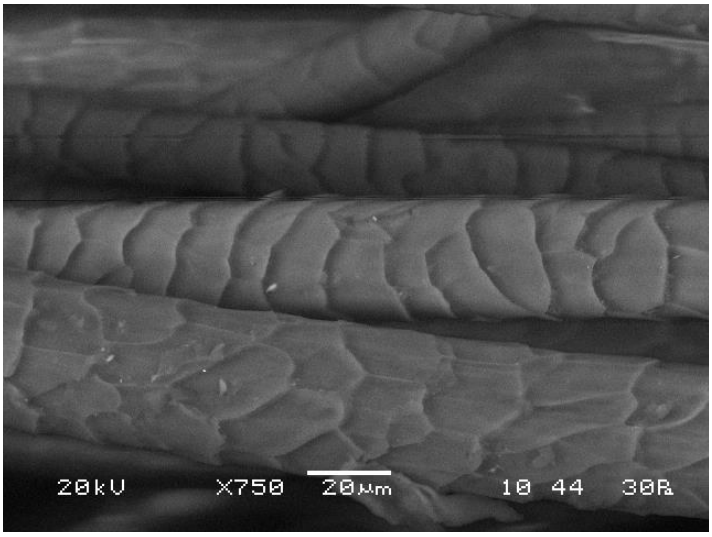


3.8.12 VE sample 6:
teased Shetland 6, spun by G. Vogelsang-Eastwood with spindle VO6374ker (s) in bottom position.

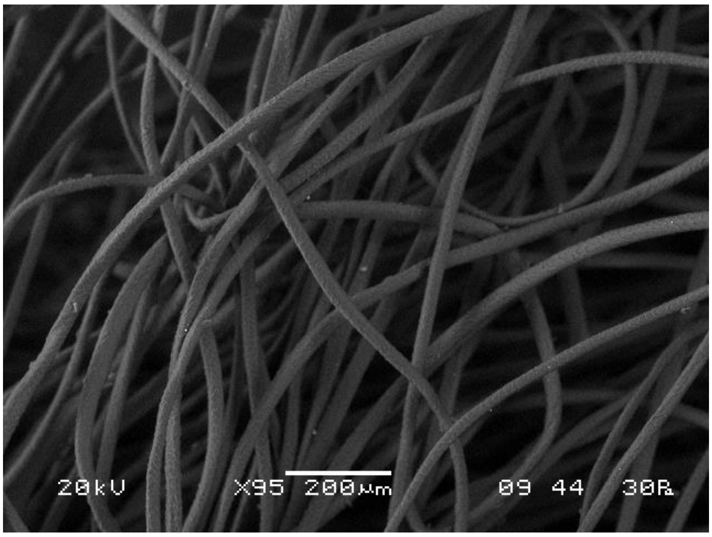
3.9 Experimental Samples VP-SEM



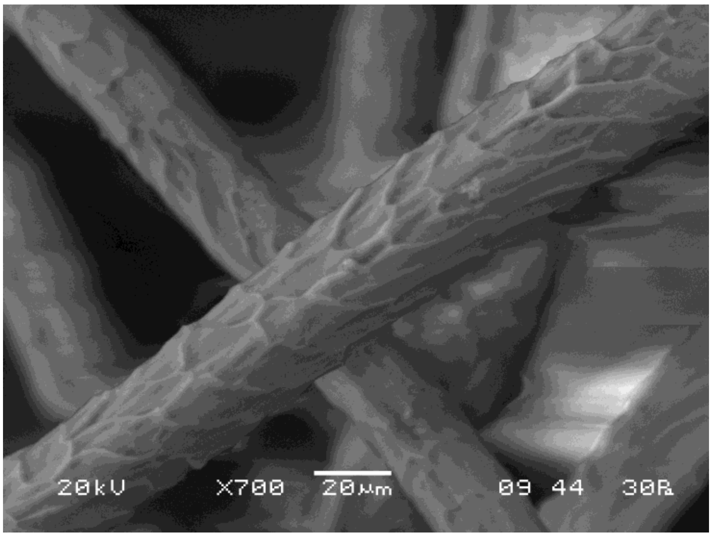
3.9.1 Experimental SEM sample 1:
teased Icelandic fibres, sample bag 3.
the fibres a slighlty aligned, due to the unrecognizable z-spun. The fibres show crimp.
I. Joosten and J. Nobelen.



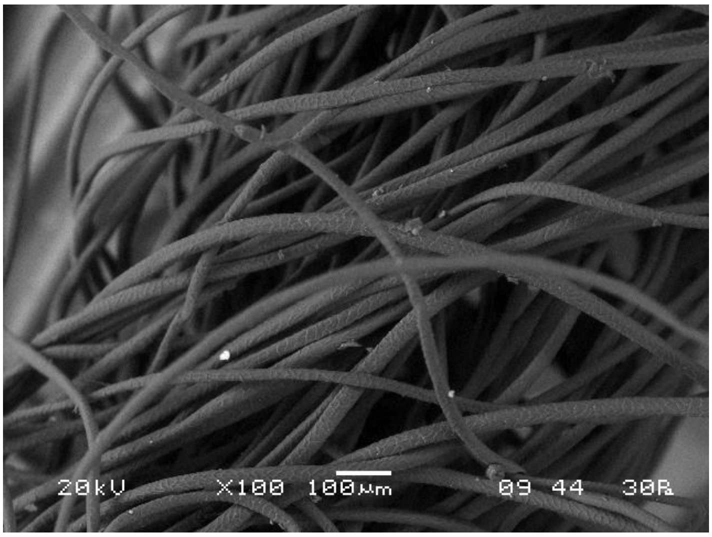
3.9.2 Experimental SEM sample 2:
teased Icelandic fibres, sample bag 3.
The thinner fibre (top) has a regular scale pattern, compared to the thicker fibre (bottom).



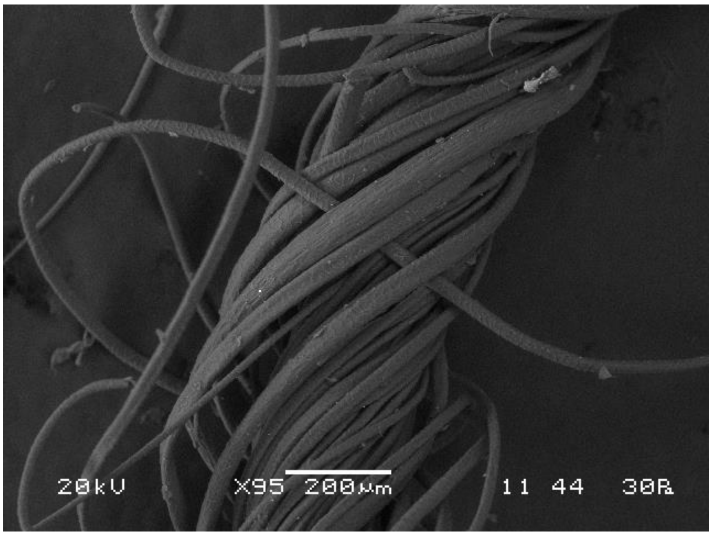
3.9.3 Experimental SEM sample 3:
carded Shetland fibres, sample bag 4.
The fibres are aligned, but jumpy. The s-spun is unrecognizable, but the crimp is.
I. Joosten and J. Nobelen



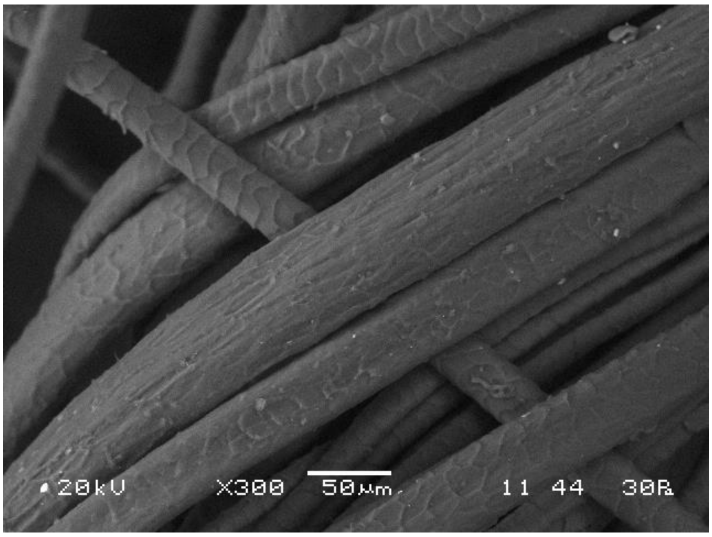
3.9.4 Experimental SEM sample 4:
carded Shetland fibres, sample bag 4.
The scales on the thicker fibres are pointy.



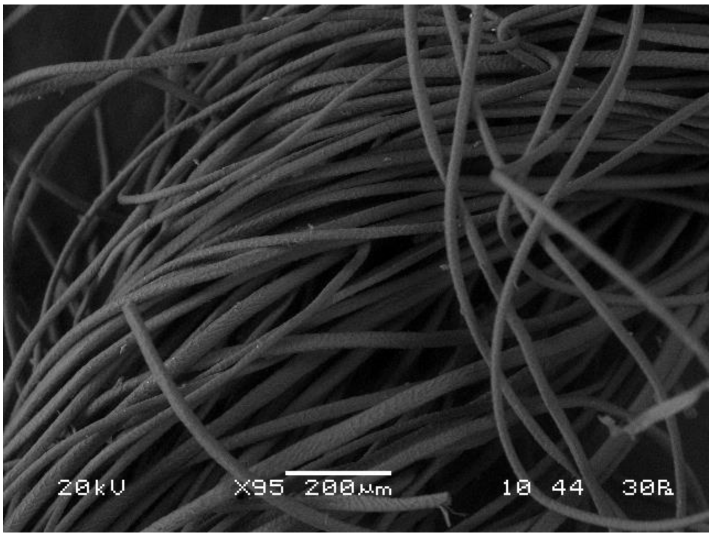
3.9.5 Experimental SEM sample 5:
teased Shetland fibres, sample bag 5.
The fibre thickness in the z-spun thread is regular. There is an alignment noticeable, but differs throught the layers of the thread. the core is fairly straight, whereas the fibres surrounding it show more of the twist; the outer layer of the fibres is almost horizontal. The fibres show crimp and have air between them.
I. Joosten and J. Nobelen



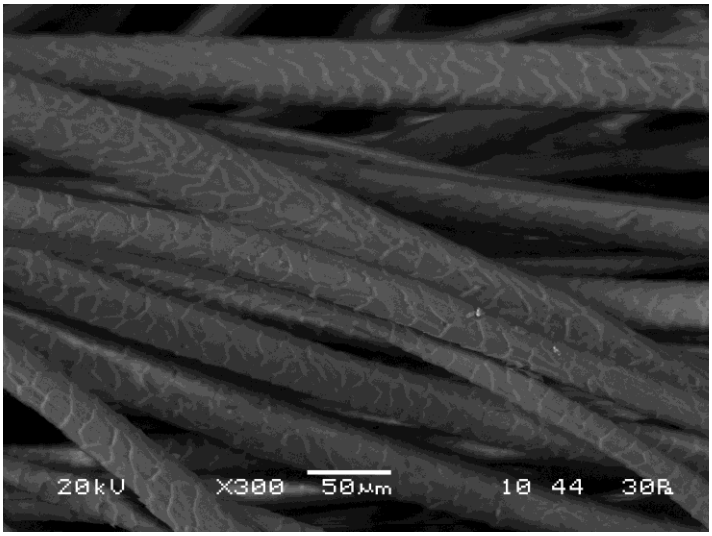
3.9.6 Experimental SEM sample 6;
combed Icelandic fibres, sample bag 7.
Almost all fibres are aligned and there is no difference in twist in the layers of the thread (contrast to Experimental SEM sample 5). The thread has not many hollow spaces between the fibres.
I. Joosten and J. Nobelen



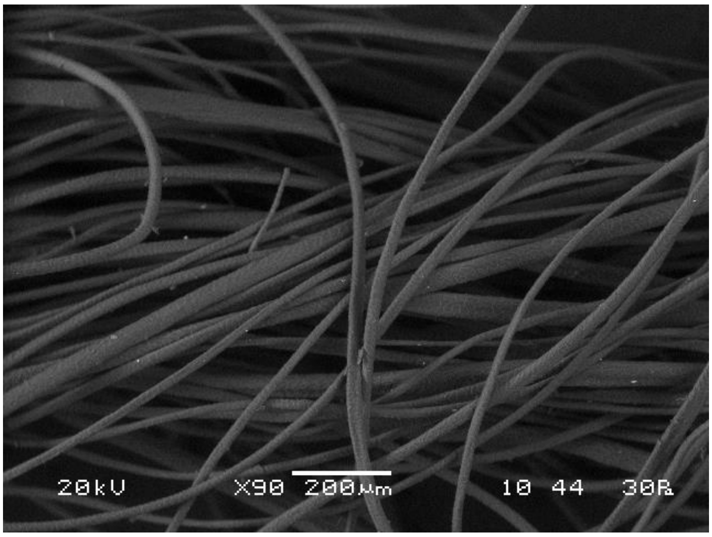
3.9.7 Experimental SEM sample 7: combed Icelandic fibres, sample bag 7. The thicker fibre shows wear marks of possibly either carding or combing. However, a different scale pattern is recognizable, compared to the thinner fibre crossing under. I. Joosten and J. Nobelen



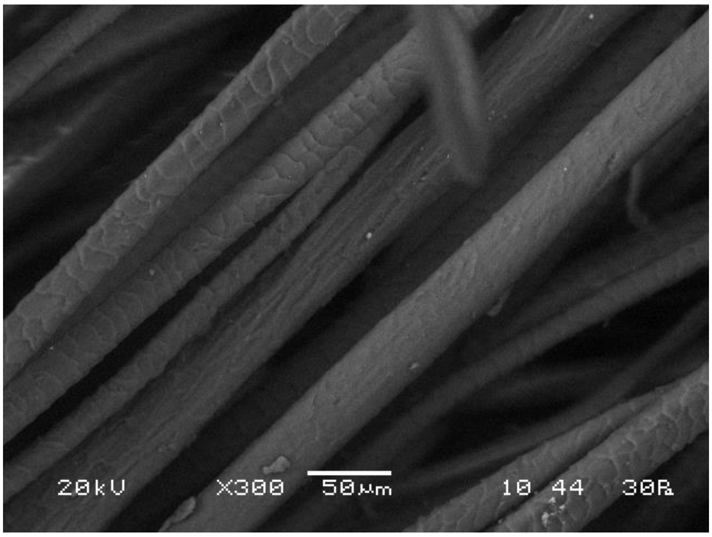
3.9.8 Experimental SEM sample 8: combed Shetland fibres, sample bag 7. The fibres are aligned and horizontally very near to each other. However, possibly the crimp makes some fibres jumpy (right) and creates some hollow spaces. I. Joosten and J. Nobelen



3.9.9 Experimental SEM sample 9: combed Shetland fibres, sample bag 7. The fibres show similar scale patterns, thus possible the same type of woollen fibres of the breed. This would be the effect of the sorting by combs. I. Joosten and J. Nobelen



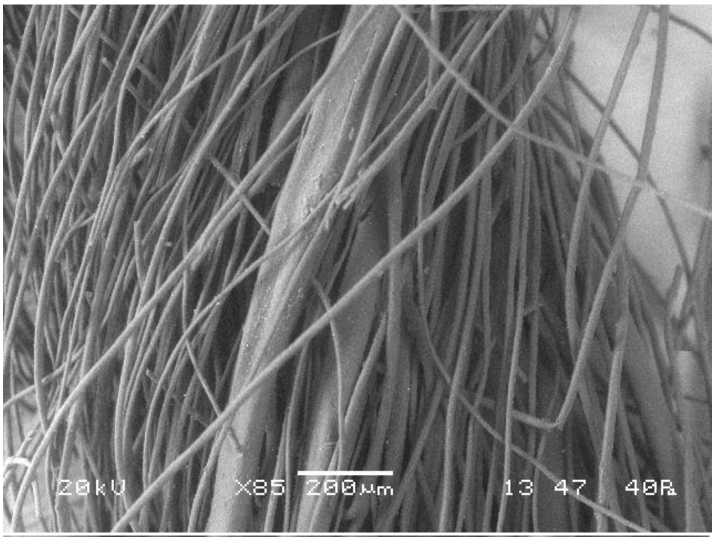
3.9.10 Experimental SEM sample 10: combed Icelandic fibres, sample bag 8.
The fibres are aligned in a s-twist, but are not as aligned as would be expected of combed fibres. There are also hollow spaces between the fibres, possibly the effect of noticeable crimp.
I. Joosten and J. Nobelen



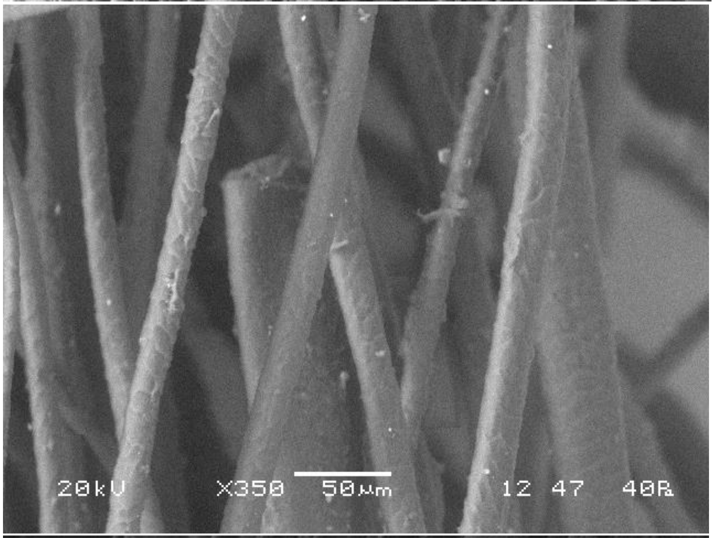
3.9.11 Experimental SEM sample 11: combed Icelandic fibres, sample bag 8.
Different scale pattern noticeable, thus possible different woollen fibres of the breed. That would be the effect of the carding before combing, mixing the different type of fibres. In the middle of the picture, the thicker fibre is damaged (see also Experimental SEM sample 7).

APPENDIX 4

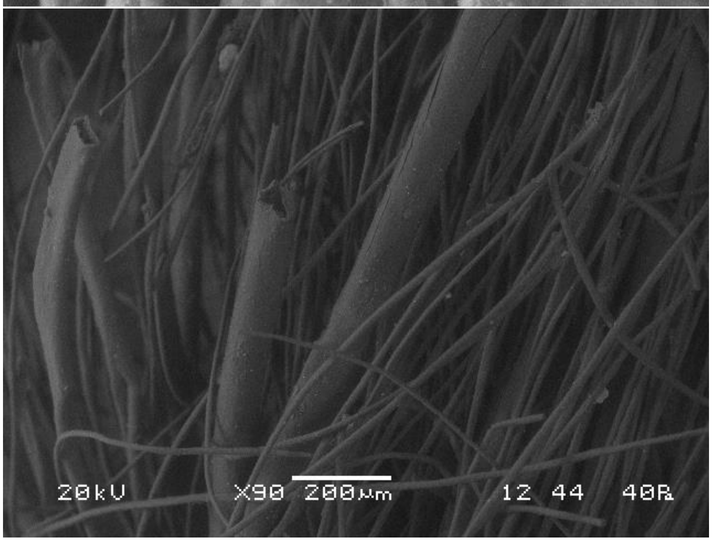
4.1 Woollen Balls of Yarn: Sample BW1, BW2 and BWV



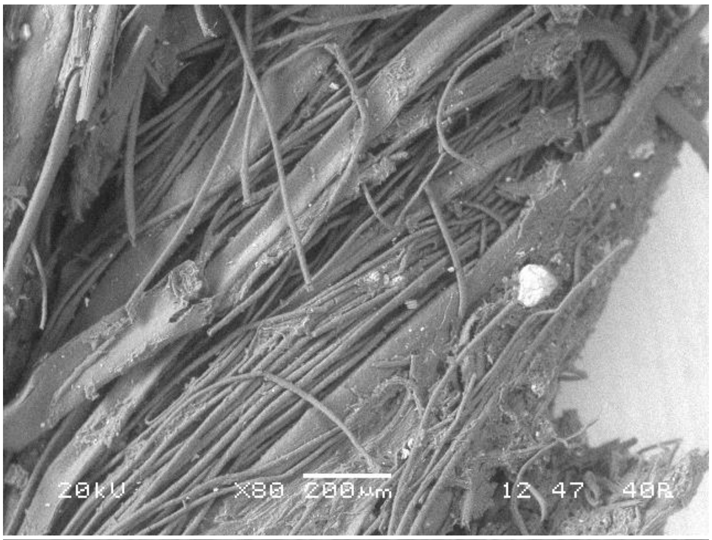
4.1.1 Ball sample 3:
'BW1' sample z-sun of very fine woollen fibres and a few thicker plant fibres, all very aligned and compact. The plant fibres might not have been intentionally part of the thread.
I. Joosten and J. Nobelen



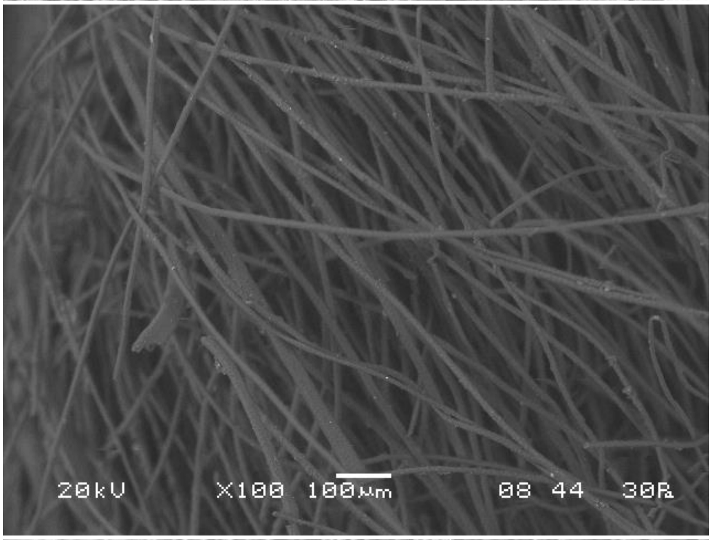
4.1.2 Ball sample 2:
'BW1': sample of z-spun different woollen fibres. The very fine fibres show similar scales, whereas the thicker fibre in the background has a more regular scale pattern.
I. Joosten and J. Nobelen



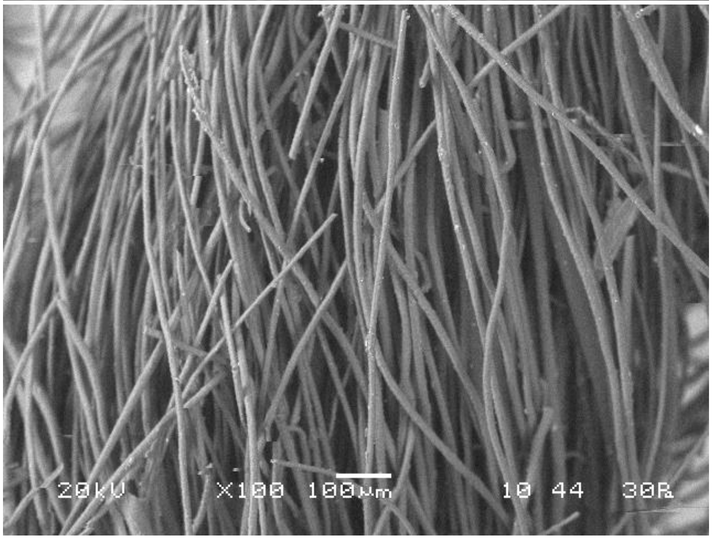
4.1.3 Ball sample 1:
'BW1': sample of z-spun very fine woollen fibres with broken and fractured plant fibres.
I. Joosten and J. Nobelen



4.1.4 Ball sample 5:
'BW2': z-spun woollen thread, but too dirty for analysis. Here, the plant fibres are most likely part of the thread by post-depositional causes.
I. Joosten and J. Nobelen

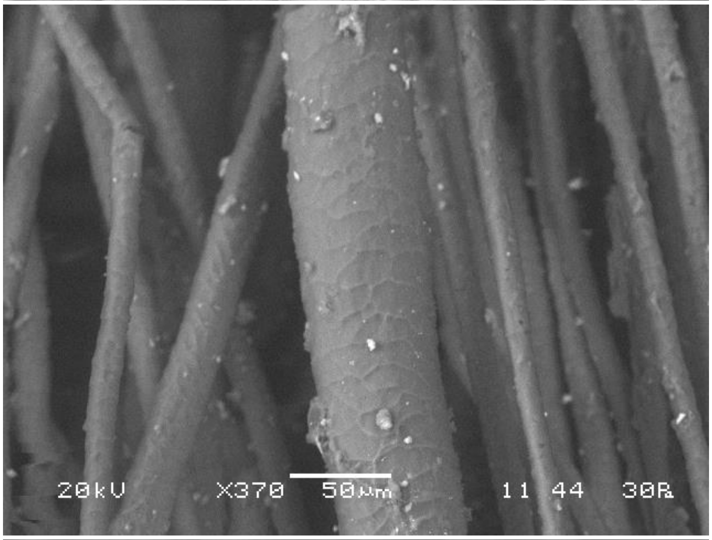


4.1.5 Ball sample 4:
'BWV': very fine, aligned woollen fibres in a s-spun thread with a few fibres in a more horizontal position than the other fibres.
I. Joosten and J. Nobelen

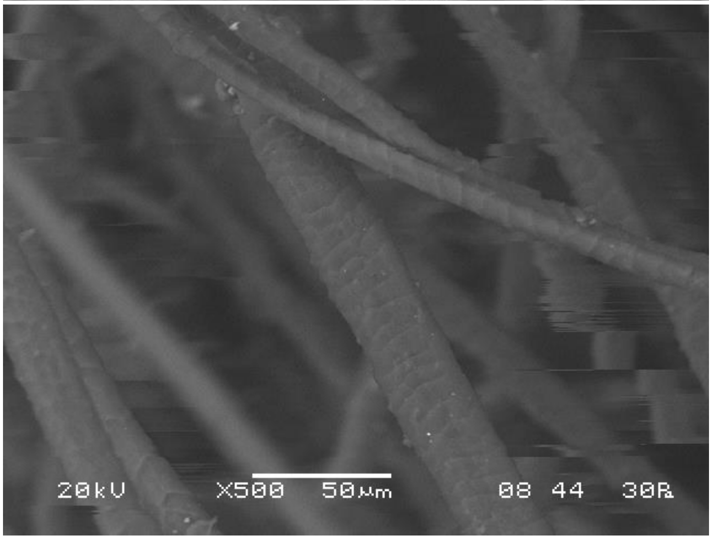


4.1.6 Ball sample 6:
'BWV': very fine, very aligned woollen fibres in a s-spun thread.

4.1.7 Ball sample 7:
'BWV': different woollen fibre thicknesses and plant fibres. The thinnest fibres have a regular scale pattern compared to the more irregular ones of the thicker threads.
I. Joosten and J. Nobelen

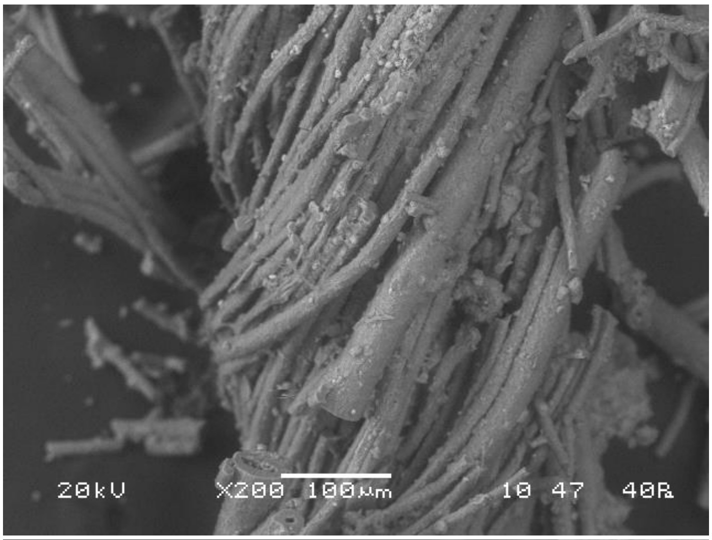


4.1.8 Ball sample 8:
'BWV': an irregular scale pattern on a thicker woollen fibre.
I. Joosten and J. Nobelen

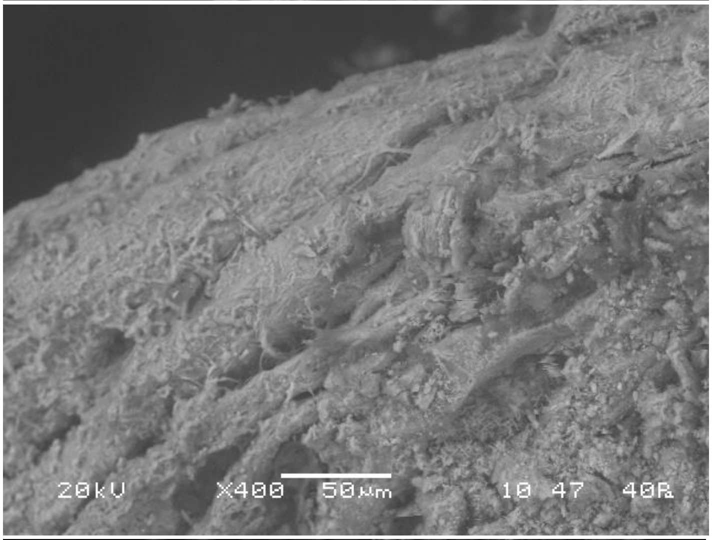


4.1.9 Ball sample 9:
'BWV': a regular scale pattern on the thinner woollen fibre, compared to the irregular scale pattern on the thicker fibre behind.
I. Joosten and J. Nobelen

4.2 'Vorstengraf van Oss': Samples A22, B2, C1A2, C2A2 and E2

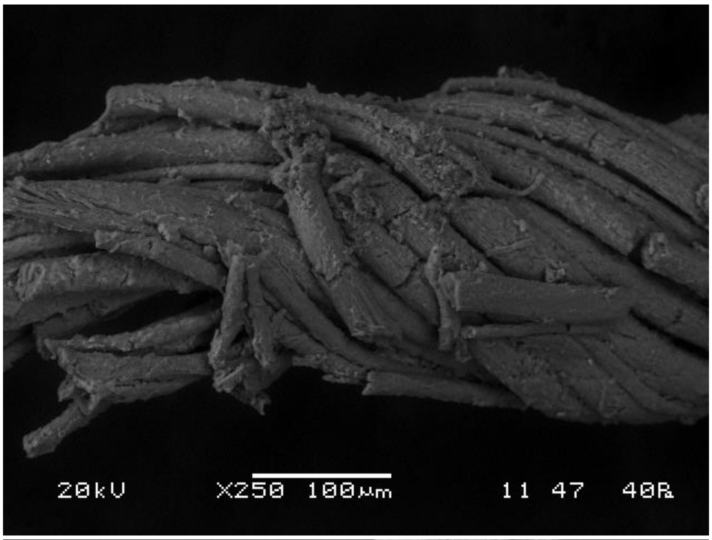


4.2.1 Oss sample 1:
A22: mineralized and broken woollen fibres of a z-spun thread. Different fibre thicknesses and the fibres are very aligned, seemingly without hollow space between them.
I. Joosten and J. Nobelen

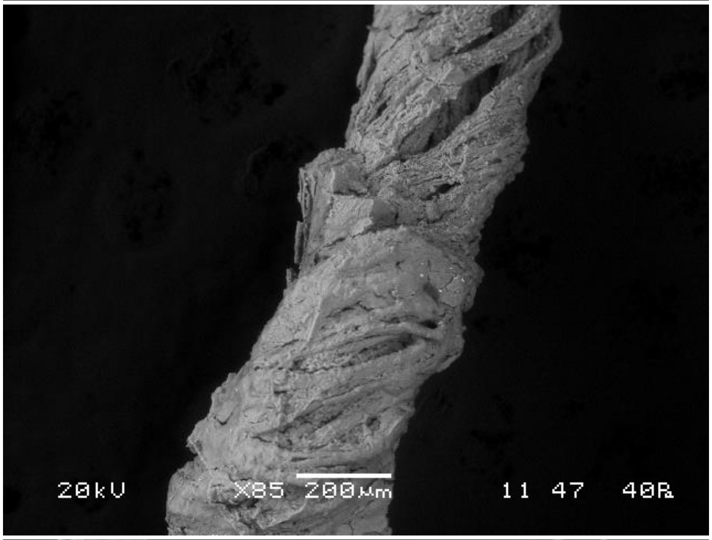


4.2.2 Oss sample 2:
B2: too mineralized for analysis
I. Joosten and J. Nobelen

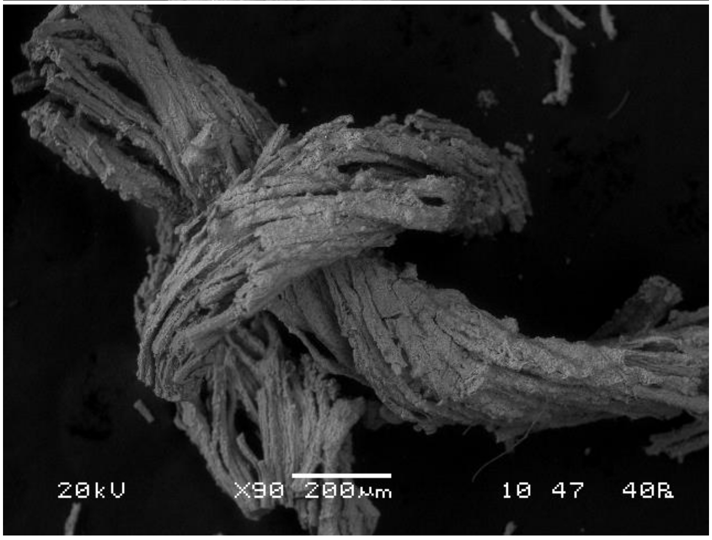
4.2.3 Oss sample 3:
C1A2: two s-spun threads overlapping in a cross. Bundles of fibres seem to make the thread, possible the effect of post-depositional causes. The fibres are very aligned and without hollow spaces between the fibres.
I. Joosten and J. Nobelen



4.2.4 Oss sample 4:
C1A2: z-spun thread of very fine, very aligned woollen fibres without hollow spaces. All mineralized.
I. Joosten and J. Nobelen



4.2.5 Oss sample 5:
C2A2: z-spun woollen thread, too mineralized for analysis.
I. Joosten and J. Nobelen



4.2.6 Oss sample 6:
E2: two s-spun threads of very fine and aligned woollen fibres crossing over eachother. Too mineralized for analysis.