FROM FLAX TO LINEN

Experiments with flax at Ribe Viking Centre

Bo Ejstrud
Stina Andresen
Amanda Appel
Sara Gjerlevsen
Birgit Thomsen

Edited by Bo Ejstrud

FROM FLAX TO LINEN

Experiments with flax at Ribe Viking Centre

Bo Ejstrud
Stina Andresen
Amanda Appel
Sara Gjerlevsen
Birgit Thomsen

Edited by Bo Ejstrud

Ribe Viking Centre & University of Southern Denmark
Esbjerg - 2011

Bo Ejstrud, Stina Andresen, Amanda Appel, Sara Gjerlevsen, Birgit Thomsen:
From Flax to Linen
- experiments with flax at Ribe Viking Centre

Maritime Archaeology Programme
University of Southern Denmark
www.sdu.dk/maritimearchaeology

Edited by Bo Ejstrud
Print: Print & Sign, University of Southern Denmark

ISBN: 978-87-992214-6-2

Published by:
Maritime Archaeology Programme
University of Southern Denmark
Niels Bohrs Vej 9-10
DK-6700 Esbjerg
Denmark

Printed in Denmark 2011

FOREWORD

After more than 15 years of working experience with Viking Age crafts, the staff at Ribe Viking Centre has built up a vast knowledge on the tools and processes that was part of daily life a thousand years ago. In order to consolidate and document this knowledge the Centre approached me proposing a joint project between the Centre and the University of Southern Denmark. We decided to focus on flax and linen in 2010.

The group of authors consists of Birgit Thomsen from Ribe Viking Centre, and from the University I participated together with students Amanda Appel and Sara Gjerlevsen. In fact the students did much of the practical work together with Birgit Thomsen, and were responsible for describing the results in this report. Later we were fortunate to have Stina Andresen, archaeologist and curator at Varde Museum, joining the project. The subject of her master thesis was exactly flax during the Iron and Viking Ages (Andresen 2005), and Stina contributed much valuable knowledge to the project, not least on the archaeology of flax processing.

It was a very inspiring collaboration for all parties involved. In following the entire process from seed to shirt, the project ended up being the most comprehensive that we have been able to find in the literature, although this was never a goal in itself.

The archaeology programme, which is taught at the University of Southern Denmark, is in maritime archaeology. One may wonder why we engage in an experimental project on flax. To this we can say that although our students are well-read in maritime aspects of past societies, they are trained foremost as archaeologists. This means that their future jobs are not limited to wreck diving, but that they can take on broader aspects of the profession. We teach a master programme, and the students enter with a range of undergraduate degrees from around the world. Therefore it was natural for us to go into this project. On the maritime aspect of archaeology we have at least gained valuable insight, and a new found respect, on sail making through this work.

One main lesson from the project is perhaps that the historical visitor centres, such as Ribe Viking Centre, have a vast practical experience and knowledge, which is important to archaeology, but that it is rarely utilized in a more controlled setting. Flax has been grown annually at the Centre for more than 15 years. With this report we have been able to document some of the experience gained at the Centre, and also to put that experience into the context and perspective of professional archaeology.

Not least in that respect it has been an edifying project to participate in. With the enthusiasm of the participants and the inspiring setting the work was conducted it, it was even fun.

Esbjerg, 24 January 2011

Bo Ejstrud

Associate professor, PhD
University of Southern Denmark

CONTENT

1. INTRODUCTION

The archaeological record shows that linen was an important part of Viking Age clothing. Linen cloth developed gradually from being virtually nonexistent in Scandinavia at the start of the first millennium AD, to being an important part of fashion during the Viking Age a thousand years later (Bender Jørgensen 1986).

The importance of linen is also very visible among the many re-enactors of the period, and every self-respecting ”leisure Viking” will own at least a shirt or a skirt of linen. Re-enactment is also done professionally, as part of the tourist related activities in Visitor centres and museums across the country. Ribe Viking Centre is such an open-air visitor centre, recreating authentic milieus from Ribe and its nearest surrounds during the Viking Age. The centre also works as a teaching institution, where young people, for which the normal school system is not currently a viable option, can get a different kind of schooling experience, and therefore be helped further on in the educational system. Both staff and pupils on Ribe Viking Centre are therefore dressed as “Vikings” during the tourist season, where they work with different crafts across the site, recreating a living experience of the Viking age, at least in aspects. In this they make a valuable regional contribution to the tourism industry as well as playing an important role in social and educational aspects of contemporary society. From the University side, we have gained much respect for the professionalism and success with which both tasks are handled on an everyday basis at the Viking Centre.

The main parts of the garments worn at Ribe Viking Centre are made from linen (Figure 1). Visitors to the Centre will therefore be met with a vision of the Viking Age, where linen is a very dominant part of the fashion during the period. But it this true? Or possibly one should better ask: What kind of effort would such an extensive use of linen represent? One thing that we did notice during our work at the Centre was that while visitors could readily appreciate the effort behind the buildings and the crafts shown at the centre, the clothing was a more invisible factor, even though the making of clothes must have been an important part of life in the Viking Age. The work presented in the following helped illustrate just how important it must have been.

Figure 1. Linen garments are used daily by the staff and pupils at Ribe Viking Centre.

The project

During 2010 experiments on the production of flax and linen were conducted at Ribe Viking Centre, in cooperation between the Centre and the University of Southern Denmark. The experiments included the entire production sequence from growing the flax to working it into fibres and finally spinning, weaving and sewing. The background for making this study was that the Centre wanted to document and consolidate the knowledge on flax that had accumulated among its staff, not least to prepare for changes in staff that will occur in a foreseeable future.

To anchor this work in something more concrete, we decided to centre the experiments on a single and in fact quite simple question. The only linen garment that we actually know from the Viking Age is the Viborg shirt, which we will present in more detail below. The experiments presented in this report are therefore organized around one main question:

- **How long would it take to make a Viborg shirt?**

In the process of answering this question, we could also realize the other aims of this project, which was to investigate and document in detail the many stages of the process from flax to linen. We also wanted to couple the practical knowledge and workmanship of the Centre's staff with the archaeological knowledge and scientific method of the University's staff and students. And we wanted to make this knowledge available to a wider audience. The last aim is achieved through this report, but also through the many sessions at the Viking Centre, where the project was met with much interest, both from the general visitors to the centre, but especially perhaps from the community of Viking reentactors, of which the Viking Centre houses several hundred every year. These reentactors come from all of Northern Europe, and to accommodate this audience, and because of the potential interest of this work to the wider scientific community we decided to write this report in English. The processes are also documented in photos and video.

In practice the work was organized as weekly sessions, which could be fitted into the work schedules of all parties involved, with some irregularity. The experiments ran from May 2010, where the flax fields were sown, and through to December 2010, where the last experiments were made. This report was finished during the first weeks of 2011.

The Viborg shirt

The experiments were thus centred on the linen shirt from Viborg (Fentz 1988; 1989; 1992; 1998). The shirt was found on the 11th century settlement at Viborg Søndersø during excavations in 1984/85. This settlement was submerged in connection with the building of dams during the 14th century, and conditions were therefore very wet with generally good preservation. The shirt was found as a lump of textile material tucked into what was presumably a posthole. Several lucky circumstances helped preserved the cloth. This included the presence of bark and charcoal near the shirt which may have helped in creating favourable pH levels, the wet conditions in general and possibly the presence of clay in the posthole. Linen is rarely preserved in the ground, and therefore this find is unique in the European archaeological record.

During conservation and subsequent analysis it was found that the lump of textiles was from the remains of a male shirt in Z/Z spun tabby linen. The weave had a density of 22/12 threads per cm^2 (warp/weft). The preserved selfedges are straight, and the cloth generally woven with great evenness. The warp is slightly thicker than the weft and harder spun, so the cloth has warp facing, with the warp dominating the structure, although the weft is still visible. The thickness of the thread is equivalent to a 20/1 thread in modern terms.

The shirt can be reconstructed using the preserved seams and selfegdes to align the remaining fragments. It is assumed that it had long sleeves, although they were not preserved, but the rest of the shirt is sufficiently preserved for a fairly accurate reconstruction (Figure 2). It is a complicated design, with eight different types of seams identified. The stitching is very regular, and the seams are completely flat.

The shirt is basically a poncho-type, with no shoulder seams. It is a slim-fit, cut so that the shoulders are slightly wider than the waist. The side seams are not continued below the waist line, but the back side overlaps the front and is fastened to it down about 5 cm from the waist. Otherwise the lower end of the shirt forms loose flaps on front and back. The body of the shirt is lined down to the waist. The lining is fastened to the outer fabric at the shoulders and waist, and in a distinct pattern at the front and back.

The neck opening is almost square and slits asymmetrically in the right hand side. The opening is closed with a band, which extends into two free ends, each passing through a gliding knot to close the front of the neck opening.

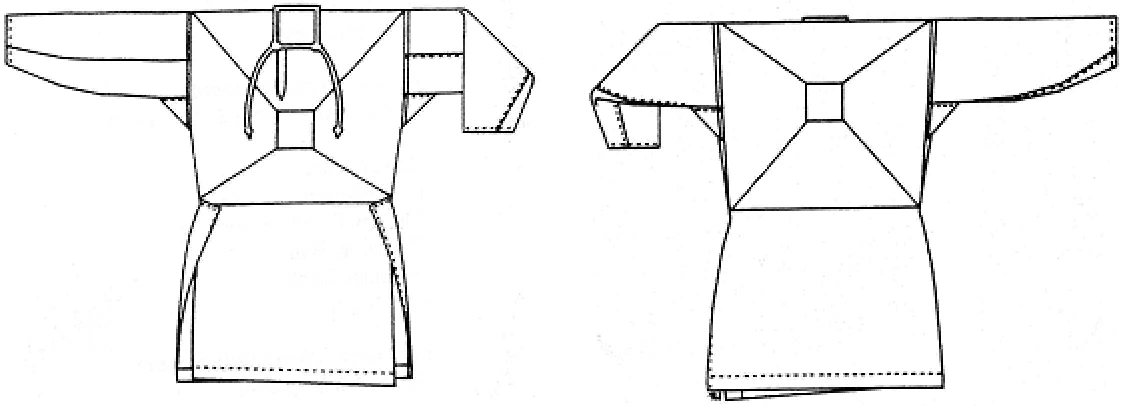

Figure 2. The Viborg shirt as reconstructed. After Fentz 1988.

Based especially on the selfedges and the warp direction of each piece of cloth, a cutting pattern for the shirt has been suggested (Figure 3). The pieces would fit on a piece of linen, which was 2.36m long and 0.95m wide, in all 2.242 m^2.

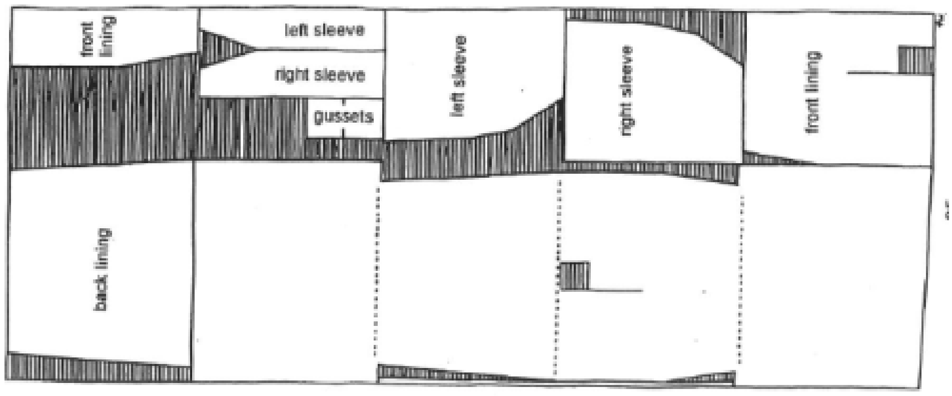

Figure 3. Cutting pattern with the pieces laid out on the warp. Redrawn from Fentz 1988.

The shirt represents one of the very few pieces of secular clothing found from this period, and thus is interesting in showing the clothes of secular citizens and the trends they acquired from around Europe by this period (Fentz 1987: 45). The shirt generally gives an impression of good quality, both in weaving and sewing. But whether it is above average quality is impossible to say, with this shirt being the only known example in Northern Europe.

Flax

Common flax (Linum usitatissimum L.) is a member of the family *Linaceae*, of which the genus *Linum* is the most common with more than 200 species (Høst 1982). The plant can grow to a good metre and has one or more slender stalks with relatively short lanceolate leaves. A short taproot has fibrous branches that may extend up to a metre in the ground, depending on soil conditions. Its Latin name means “very useful”, which it is, producing both edible seeds and spinnable fibres. The plant is a cultured form, which does not grow in nature, and is most likely developed from *Linum Bienne* (Mill.) (Helbæk 1959).

Flax can be grown both for its seeds and for its fibres. Today the plant exists in two variants: *Linum usitatissimum Humile* (or *L.u. crepitans*) and *Linum usitatissimum vulgare*. The *Humile* variant is grown for its seeds. It is generally shorter, with larger leaves, and has a higher tendency to tiller. More stalks means more seeds per plant, which is beneficial in this production. With the *vulgare* variant, which is used for fibre production, tillering is less prevalent. It is also less desirable, as a single straight stalk from each plant produces the best quality fibre. It is not known when these two variants have separated, but it is generally assumed that this has happened in relatively recent times (Brøndegaard 1979).

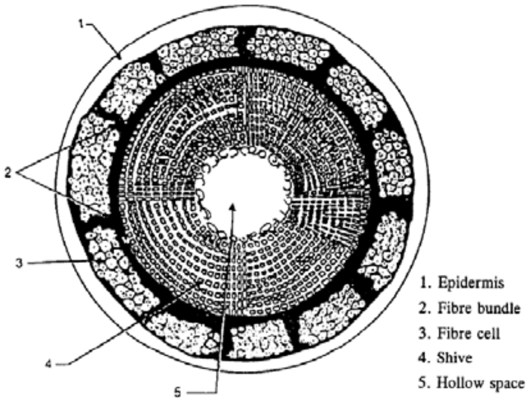

Figure 4. Cross section of flax stem (Zienkiewitz & Fröier 1979, here from Pallesen 1996).

The flax stem is a few millimetres thick and consists of several layers. The outside of the stalk is protected by an epidermis. Inside this outer layer, the fibres lie in bundles, each with 10-40 single fibres. It is these fibres that are used in textile production. The number of fibre bundles varies with climate, soil and other growing conditions. The fibres and bundles are held together with pectin and lignin. The fibre is a cellulose polymer, but its structure is crystalline, making the fabric strong and crisp, and more prone to wrinkle (Kers *et al.* 2010).

Inside the fibre bundles the shives make the woody core of the plant. They must be removed before the plant can be used. Finally there is an inner hollow space in the centre of the stalks, making the plant relatively light.

The fibres of flax are very strong, while also being long and smooth, and this gives a fine thread which is highly absorbent and a good heat conductor, so the fabric feels both cool and pleasant against the skin (Hodges 1989: 123). These properties make the flax textiles very well suited for warm weather or as undergarments. When flax fibres get wet, their strength increases by 20% (Kers *et al*. 2010), which also makes them well suited for maritime uses, such as lines and sails. For such uses the coarser fibres (tow), that are less valuable in making clothes, are very suitable.

From flax to linen

The process from flax plant to linen cloth is complicated and involves several stages. We shall return to these processes in more detail throughout this report, but it is practical to present an initial overview here.

Cultivation

Flax will grow on most any soil that is suitable for crops, but –as most crops- grows best on sandy to clayey loams. As the plant grows fast it is susceptible to water stress during the growth season, and does not grow optimally on gravel or coarse sand. On the other hand should the soil be well drained, and heavy clays or wetlands are not suited either. Areas with a coastal climate are especially well suited for cultivation of flax (Renfrew 1973: 124). Being a cultured plant, flax competes poorly against weeds, and during germination and the early growth stages must be weeded thoroughly. In a Danish climate flax is sown during April-May.

Normally flax will right itself after heavy rains. However, high levels of N in the soil can cause lodging, a phenomenon we did also observe during the experiments. The level of fertilizing is a balance, because the plants grows fast and therefore needs a good soil to grow in. On the other hand high levels of nutrients will cause not only lodging but also thick stems and fibres that are less suited for textile production. Especially older treatises on agriculture are therefore very varied in their recommendations for how much a flax field should be fertilized, if at all. Often the flax fields were part of a rotations system, which reduces diseases.

The plants blossoms in July and August after which the seed capsules develop, and the plant is ready for harvesting, which is called pulling. Flax is mostly pulled green, not fully matured, to get a finer fibre. After pulling the flax, the plants must be dried before further processing can take place.

Rippling

Once dry, the flax is *rippled* (or *threshed*) to separate the seed capsules from the stalks. This can be done by hand, but most likely a *ripple comb* was used. This is simply a large comb through which the stalks are pulled to loosen the seed capsules. This tool is known both on Egyptian wall paintings, as well as from recent historical examples (Højrup 1974).

The seeds must then be separated from the capsules. Some of them are kept as seeds for next year's crop, while the rest can be used for extracting linseed oil, which has many uses. The seeds can also be used directly in food, as is known in the stomach content from some of the Early Iron Age bog bodies (Helbæk 1951; 1959).

Retting

Retting is the process of loosening the fibres from the rest of the plant. This is achieved through a bacterial process, where the pectin A and lignin which holds the plant together is dissolved. The best quality is generally achieved through *water retting*, where bundles of stalks are submerged in water. The plants float readily, and must be weighed down. Depending on temperature, the process may take only a few days but the normal range under Danish weather conditions is one to two weeks. Water retting can be done in a pond or in slowly running water. If using a pond the water must be changed after being used a couple of times. If overdone the fibres themselves start to decay. The process must therefore be monitored closely (Mannering 1995). When finished, the plants have a distinct rotten smell, and must be rinsed in clean water to stop the process.

An alternative to water retting is *dew retting* (or *field retting*). Here the stalks are spread out in a thin layer on a grass field. Fungi are more active in the retting process, which does not have any health related effects on people or animals. The plants are laid out in long rows, and have to be turned regularly for the microbes to work evenly on both sides.

Dew retting generally gives a lower yield and quality of the fibre than water retting. Apparently *snow retting*, where the flax is left outside for several months during winter, is considered to produce the worst result (Anonymous 1888), although Sändh (1977) mentions that it gives an even retting. Immediately one would expect that snow retting would produce a bad quality, as retting is a bacterial process, and the cold temperatures of winter would not further such a process. This method was probably mainly used in regions at high latitudes or high altitudes, where snow cover is normal during the winter months, and snow retting therefore a necessity (Daud 1996).

Breaking

After retting, the stalks must be dried again before it is possible to break them. Breaking the stalks is a simple mechanical process to separate the shives from the fibres. The stalks are beaten systematically until the woody parts breaks and start to loosen from the fibres. This can obviously be done with a number of different instruments including some very simple ones. The historically known breaker was presumably also used in the Viking Age. At least some wooden pieces found at Feddersen Wierde from the first half of the first millennium AD has a striking resemblance with later breakers (Haarnagel 1979). They are 35-70 cm long pieces of wood and 3-10 cm wide pieces of wood. Like some, but not all, historically known breakers, there are angular indentations along the edges of these pieces. Other breakers have straight edges.

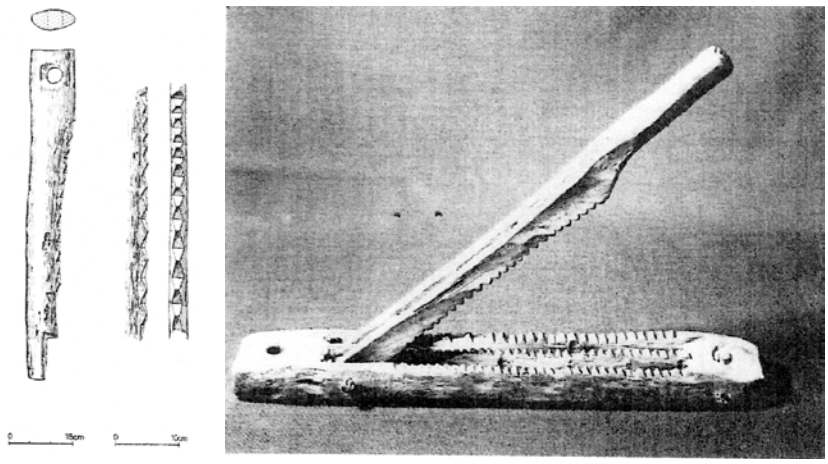

Figure 5. Left: Possible fragment of breaker from Feddersen Wierde. (Haarnagel 1979, Table 28.4). Right: Breaker from Norway. The legs are missing (Hoffmann 1991: 62).

Together with the breakers, so called “linen clubs” are also known both in the archaeological and historical material. These are one-hand clubs, which are also used to beat the flax. As they are found in Viking Age context, we shall return to these clubs, and their possible use.

Scutching

To remove the shives the broken stalks are scutched. Egyptian wall paintings show this done by pulling the fibres between two sticks. Historically scutching was done by using a scutching knife and a scutching board. The shives are removed, as well as possible, by a applying the scutching knife in a firm scraping movement down along the fibres, which are held over the scutching board (Figure 6).

Figure 6. Scutching of flax. Picture from www.fynhistorie.dk. The lack of shives at the foot of the scutching board shows that this is a staged picture.

Heckling

Heckling is the last process before spinning. The fibres are drawn through a heckle (or hackle); a comb with a number of long teeth. The purpose of heckling is to remove the last impurities, and to straighten the fibres to make them into spinnable bundles. The short fibres that are stuck in the heckle are called tow. These fibres can be spun as well, but can only be used for coarser products, and will mostly contain some shives. Tow can also be used for lines and ropes as well as filling material. Finally being ready to spin, it is after this stage that the product changes name from flax to linen.

The fragment of what has been interpreted as a Neolithic heckle is known from Lüscherz, Switzerland (Vogt 1937; Hald 1950: 127). The heckle is a shield shaped board with one straight and thickened edge in one end, and a handle extending from the other. A number of holes across the board are assumed to have held a large number of thorns. In our experience the fastening of such thorns would have to have been very strong, as heckling requires the application of quite some force.

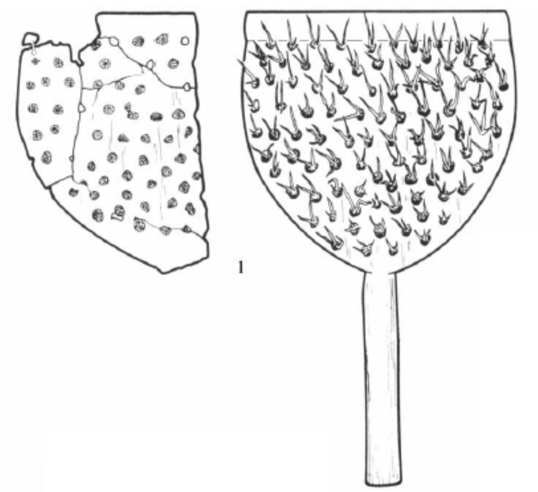

Figure 7. Neolithic heckle from Lüscherz, Switzerland. Left: original. Right: reconstruction. From Barber (1991).

From later periods heckles are known in the form of comb like implements with long iron teeth, placed in several rows. Such heckles are known from the Viking Age (*cf*. chapters 2 and 4), but are also known from earlier periods, e.g. from a Migration Period grave at Storholmen in Norway (Hjørundal 1991), as well as later.

Spinning, weaving, cutting and sewing

The flax must thus go through several processes before it is even ready to undergo the processes that are more immediately associated with textile production, in the form of spinning, weaving, and finally tailoring the garment. Linen may also be bleached, or possibly dyed, although the white, clean appearance of the fabric is a recurrent theme in historical sources across the ages. Bleaching is done in the sun.

Project design

With the many processes involved in the production of linen, the project could well be divided into a number of separate phases. Each process is therefore considered individually from the others, making its own set of experiments. This had practical advantages to the project. Not least that the individual processes could be done in a more random order. The further processing of flax stems could run simultaneously with the growing experiments and did not have to wait for the flax in the fields to mature. Also, the experiments at one stage were not dependent on the quality of the work and materials in a previous stage of the experiment. The Viborg shirt was most likely spun from a high quality fibre, and we could not expect to produce a high quality from the relatively meagre soils that Ribe Viking Centre is placed on. But the shortcomings of the soils, and possibly our working of the crop, had no effect on the spinning experiments, as we could acquire flax of high quality to work with. In fact the spinning experiments were some of the first work we did. This principle thus helped secure more reliable results from the experiments.

From the onset it was clear that although experiments would be made on all stages of the production of a Viborg shirt, we would not make a full shirt from start to finish. Instead each process had to be investigated individually, and the results added up from more limited experiments. To get a target value to work from, we started by calculating how much thread was needed to weave the Viborg shirt. In her original publication of the shirt, Mytte Fentz (1989) gave a cutting pattern for the Viborg shirt, making it fit onto a piece of fabric that was 0.95×2.36 metres. The density of the fabric was given as 22/12 per cm^2, and the thickness of the thread as 20/1. From these numbers it can be calculated that more than 10 km of hand spun thread had to be made to make one Viborg shirt and that the fabric would weigh slightly over 750 grams (Figure 8). As described above this particular shirt is not even very large, and would probably only fit a young man. These numbers should illustrate why it was not feasible to make the full shirt from start to end during these experiments. It was certainly also a good illustration of the importance of cloth making in daily life during the Viking Age, when we presented this project to visitors to the centre.

The experiments were to fulfil two somewhat opposite goals. Firstly we wanted to investigate the making of a Viborg shirt. This required sets of controlled experiments, done by skilled artisans. But it was also a main goal of the Viking Centre to document the process of linen production. To achieve this we used an apprentice system, where the archaeologists were taught how to use the different tools and techniques in linen production. This approach has ensured a much deeper understanding of the processes, which can hopefully also be read from the following chapters. Some of the processes were so simple that only limited training was necessary. For instance it did not take long to find a rhythm and technique for pulling the flax or heckling it. In these cases the work of both Centre and University staff and students has been timed. But in more complicated work, like spinning and weaving, the two goals were separated in different sets of work.

LINEN THREAD FOR THE VIBORG SHIRT					
1.	**Number of threads for warp:**		**2.**	**Length of warp:**	
	Completed width of fabric:	0.95m		Completed fabric length	2.36m
	+ weave shrinkage and washing	0.10m		+ weave shrinkage and washing	0.22m
	Reed width	*1.05m*		*Weave length*	*2.58m*
	Warp density, threads / cm	22 threads		Spare warp	0.50m
	Warp threads total	***2310 threads***		***Warp length total***	***3.08m***
	Length of warp thread	**2310 threads X 3.08 m**			**7.11km**
3.	**Number of threads for weft:**		**4.**	**Width of weft:**	
	Weave length	2.60m		Reed width	1.05m
	Weft density, threads / cm	12 threads		+ weave shrinkage and washing	0.05m
	Weft threads total	***3120 threads***		***Weft width total***	***1.10m***
	Length of weft thread:	**3120 threads X 1.10m**			**3.43km**
	LENGTH OF LINEN THREAD FOR THE VIBORG SHIRT: (7.11 + 3.43 km)				**10.54km**

Running length per kg for ½ bleached linen thread corresponding to 20/1 is		14000m
Warp weight	$\frac{2310 threads \times 3.08 m}{14000 m / kg}$	508 g
Weft weight	$\frac{3120 threads \times 1.10 m}{14000 m / kg}$	245g
WEIGHT OF LINEN THREAD FOR THE VIBORG SHIRT (508 + 245 g)		**753g**

Figure 8. The length and weight of the thread needed to weave the Viborg shirt.

A third goal was more implicit. Ribe Viking Centre is a visitor centre, with tourists visiting the centre all during the summer season. It is the purpose of the centre to present the Viking Age to these visitors, and therefore our experiments naturally did become part of this work. This however did work somewhat against the timed experiments. While talking to interested tourists fulfilled an important *raison d'être* of doing this kind of work, it was also a distraction, and we had to make some judgement calls on site as to whether to pursue the experiment or the presentation of it. We have tried to balance the two, but in some cases this balance was difficult. As natural in an extensive project like this, running over more than half a year and with several participants, plain mistakes were also made. Although surprisingly seldom seen in scientific reporting, we have presented such mistakes quite openly throughout this report. Science does in fact not get better by pretending.

Structure of this report

In chapter 2 we will present and discuss the evidence we have for linen production and use during the Viking Age. Ribe Viking Centre already had available all the tools needed for processing the flax during the experiments. Great care is taken in making the tools as authentic as possible, and the Centre has a close cooperation with archaeologists and other specialists to ensure this. However when it comes to the details of such tools, evidence is obviously missing, and some tools has to be made by analogy from later periods. As part of a large survey of Norwegian textile tools, Marta Hoffmann discussed this problem (1991). She found that although primarily known from 18th and 19th century contexts, many tools must have had a long use period behind them. This does seem a valid point, as many of these tools used in flax processing can be found relatively unaltered in even relatively old archaeological context. One example is the wooden fragments from Feddersen Wierde mentioned above, which can reasonably be interpreted as breakers for flax or other plant fibres, as they are virtually indistinguishable from more recent examples. On the other hand one should be careful in classifying objects based on their similarity with later tools. Hoffmann mentions several examples of this. Among others she mentions tools with several rows of iron spikes. They are mostly classified as heckles for flax, but may in fact have been cards for wool. One could add the Neolithic heckle from Lüscherz which is shown above (Figure 7). It certainly looks more like a hand card than a heckle, at least when assessed in light of the way we have heckled flax.

The experiments are presented in chapters 3 to 5. To answer our primary question on how long it would take to make a Viborg shirt, it was clear that we had to measure a) the time spend on each process, and b) the weight of the product before and after working it. With these two measures we can reasonably estimate the time spend on making a shirt, even though we did not make the shirt from start to end. Every experiment was repeated several times -if at all possible- to ensure more stable values. The target number of repetitions was at least four or five. In some cases repetition was not possible for practical reasons. For instance we only did one weaving experiment. Setting up the loom five times and then weaving fabric for five shirts would have been an insurmountable task.

The production time for a shirt is only really interesting if we have an idea of the use life of it. A high investment in time and materials may not be a problem if the product is very durable. This is a difficult question to assess, but we have made an attempt in chapter 6.

Finally chapter 7 will summarize and discuss the findings of this report, giving an assessment of the time and effort put into making a shirt in the Viking Age.

Is time of the essence?

Experimental archaeology has always generated great interest, not only among archaeologists but also among the general public and many experiments have been carried out from the very beginning of archaeology as a discipline (Cunningham *et al*. (eds.) 2008). Nilsson, Lubbock and Evans carried out experimental work concerning stone and Pitt-Rivers was the first to test ancient digging implements, but the range of experiments dealing with different materials has been very wide indeed (Coles 1974).

Time studies, as the one we are presenting here, are almost invariably part of such work. Probably not least because time is a straight forward variable to measure. There are however good reasons to question the validity of such studies. In an important paper on the nature of experiments in archaeology, Reynolds (1999) dismissed time studies altogether, claiming it to be "*signally valueless to record the time taken to achieve an end product*" (Reynolds 1999: 388). The reason is that the human factor is all important in such studies. The time taken to perform some task is highly reliant on the skill and motivation of the person doing the work. And we can measure neither skill nor motivation of prehistoric people. We can only confirm this point. It has been very obvious throughout our experiments that no matter the level of motivation, the team of archaeologists and student never achieved the practical skills, and therefore speed, of the trained artisans from the Viking Centre. This was especially true for the more complicated tasks such as spinning and weaving. We have therefore been careful in timing such tasks only for the skilled workers. We can also see that in the few instances where we have found comparable experiments in the literature, our results differ from these. The human factor unquestionably makes it difficult to measure time.

To this human factor come more simple physical difficulties. The combined time taken to achieve a complex task is also dependent on the structure of the site where the work is done. The total time taken to plough a field depends not only on the type of soil and vegetation on the field, but even more simply on the distance between the farm and that particular field. Such things can hardly be measured for prehistoric conditions, and at least no general answers can be found. The only formally correct answer to the question of how long it would take to make a Viborg shirt is therefore that it would depend on the individuals doing the work, and the site where they did it. Thus far we agree with Reynolds.

But the strong dismissal by Reynolds of the value of time studies is negated somewhat by the fact that only a few pages further into the same paper, he actually uses time to explain the difference between prehistoric and recent farming. When comparing prehistoric farming to that of Britain in 1950, the output per area unit was found to be much the same, but he qualifies this observation by explaining that input time differed (Reynolds 1999: 393). A given plot of land was much more labour intensive in prehistory than in the 1950s for the same output. So although very difficult to measure, time is of undeniable importance in studies of prehistoric technologies, and we can probably not do away with it altogether.

What we can do is perhaps to take the pragmatic approach of applied science, rather than the strictness of “pure” science. Through experiments we can achieve a “best estimate”, given a certain set of conditions. An estimate, which is validated not only through establishing as controlled and strict experimental regime as possible, but especially through repetition of the experiments by other people and under other conditions. By this approach we achieve statistical reliability by establishing a range of possible answers. Since the prehistoric reality that we are trying to approach was in fact also a range of values, the answer thus achieved would actually even be more correct than the result of any one set of experiments.

It that respect experimental archaeology may not be very different from other types of archaeology, or basically from any type of empirical science. The excavation of any given settlement informs us -more or less- on the structure of that particular site. The patterns we observe are the product of a complicated set of human decisions. But if we investigate settlements more broadly, then each individual excavation can reasonable be regarded as a statistical sampling experiment in our investigation. Because of their complexity and variation no single settlement can inform us on how “settlements” looked at a given time in prehistory. A comparative approached is always advisable.

But it is still important to remember that archaeological experiments are performed by modern people. We therefore want to stress that in the following we do not investigate how much time it would have taken to make a Viborg shirt in the Viking Age. That question cannot be answered. We investigate how much time it would take us to make one, using Viking Age technology. And that is a question we can answer.

Experiment and experience

Structuring our work around this question was also a practical way of organizing the work. As already explained above, the wider aim of the project was to explore flax processing and the knowledge hereof gained through the daily activities at Ribe Viking Centre. The validity of such work is possibly best substantiated in an important clarification presented briefly by Reynolds in his 1999 paper. Here he introduces a distinction between three different forms of work with prehistoric technologies. The formal *experiment* is one thing, or actually several different things, but to this comes *experience* and *education* (Reynolds 1999: 394).

In a sense the difference between experience and education can be said to be whether the learner is externalized. So basically whether the experimenter is trying to learn himself or whether a gained experience is passed on to others. This obviously changes the practical premises for the work substantially, but is also a qualitative distinction between gaining new knowledge and passing that knowledge on to others. Not denying the importance of education, it is experiment and experience that are the important aspects for research internal purposes, and therefore have spurred more debate.

The distinction between experiment and experience in archaeology seems intuitively correct, and needs to be explored further. It has also become increasingly clear that while "experiment" represents an important type of archaeological investigation which follows the principles of laboratory work in the sciences, "experience" is an equally important key to understanding past processes and materials (Cunningham *et al*. (eds.) 2008).

We can certainly ascribe to this view. Our work with flax and linen has given us an understanding of the processes and technologies, that there was no other way to obtain. One example is the linen clubs. Most archaeologists mention them – in passing – as an alternative to the breaker, when presenting flax processing in prehistory. Having tried we can safely say that they are not. In fact we had severe difficulties in getting them to work at all in breaking the flax.

Reynolds claimed that there is "*a great gulf between the experimental and the experiential*" (Reynolds 1999: 394). That may be, although experience is often achieved through experiment. But we must maintain that even experience produces valid and qualitative new scientific knowledge which is important to the understanding of prehistoric man **-** and woman. It is not least in this context that the following work must be understood.

2. FLAX DURING THE VIKING AGE

The introduction stated that flax and linen was important during the Viking Age. The purpose of this chapter is to substantiate this claim by presenting an overview of our knowledge of flax and linen during the period. This to provide a general background to our work, but also more specifically to explore the tools and techniques that we know from the period. Any serious work with prehistoric technology will obviously have to use that technology, and therefore an overview is needed. A part of this is also to map out what we do not know. There are tools and techniques which are not -or cannot be- found in the archaeological record, and this is important to know when assessing any experiment.

One main difficulty in studying the archaeology of flax is that plant remains are only rarely preserved in the ground, at least in Northern Europe. Organic remains are in general rare in archaeological excavations, but there is an added difficulty with flax. In the ground, flax is best preserved in a basic environment, whereas most soils are slightly acidic. The opposite is true for wool, which is better preserved in an acidic environment. We can therefore assume that wool is overrepresented in the archaeological record. The many well preserved pieces of clothing that are found in Northern European bogs are thus invariably of wool. It is for this reason that the linen shirt from Viborg is so unique.

Flax before the Vikings

In the Near East flax textiles predates by several millennia any other textile materials used by man, like silk, cotton and wool. The earliest archaeological finds of flax in the form of seeds at the site Ali Kosh in Iran (7500-6700 BC) (Helbæk 1969). At Çayönü in South-eastern Turkey (7000 BC) not only seeds have been found, but also the oldest known piece of linen cloth (Braidwood & Braidwood 1993). The cloth was wrapped around a piece of antler, and the piece therefore preserved. *Linum bienne*, the wild ancestor of *Linum usitatissimum*, grows naturally in the foothills of Kurdistan, Iran and Iraq, and it is generally assumed that the plant was first domesticated in this area during the 8th millennium BC (Renfrew 1969). From the 7th millennium BC flax is found on sites across the Near East. Fragments of cloth found in a cave at Nahal Hemar in Israel are dated to 6500 BC (Barber 1991).

From the Near East the knowledge of flax spread into the Mediterranean and Central Europe between 5000 and 3000 BC. Egypt became a centre for flax production in antiquity, and both *Linum bienne* and *Linum usitatissimum* has been found. There are numerous finds of both seeds and textiles, not least because of the warm and dry climate which favours the preservation of organic materials. A linen industry developed and linen had many uses, not least including the wrapping of mummies, from which large amounts of fine quality linen is know. To this come for instance wall paintings inside several tombs, where the growing and processing of flax and linen is depicted at all stages. The tools used in ancient Egypt were not much different from those we know from even recent historical times.

The literary sources later in antiquity also emphasize the Egyptian flax. In his *Natural History*, Pliny the Elder becomes almost over joyous in his praise of the "*plant which brings Egypt in close proximity to Italy*" (Pliny *Hist.Nat*. XIX.i.3). This in the form of sails, which were exported from Egypt. Strangely he also describe that Egyptian flax is not the strongest (Pliny *Hist.Nat*. XIX.ii.14), but still the most profitable to grow. Sails are made from a coarse fibre, and therefore not the best quality of flax, but should preferably be strong. Pliny may have been writing about the finer types here.

Some of the first archaeologically known evidence of domesticated flax in prehistory came from the Neolithic lake dwellings from Switzerland and Germany. Here both the tools and the flax itself have been preserved on several sites (Vogt 1937; Barber 1991). While these early European finds are *Linum bienne*, the *Linum usitatissimum* takes over during the last millennium BC.

Danish finds

The spread into Europe took place along two routes, a Central European through the Danube area, and an eastern across Russia (Helbæk 1960). Through of comparison of seeds, Helbæk assumed that the first flax came to the Danish area came through the eastern route.

In the Danish archaeological record seeds occur much earlier than textiles, and it is generally assumed that flax was first used for oil production and only later for textile fibres (Helbæk 1960). The earliest finds of flax (*L. usitatissimum*) is a single seed found at the Bronze Age settlement at Bjerre in Thy, Northwestern Jutland (Robinson 1995: 14). Seeds become more abundant in the settlement finds through the Pre-Roman Iron Age, and are also found in the stomach content of bog bodies (Helbæk 1951; 1959; 1960).

The find of carefully cleaned flax seeds in a pot at Stoustrup, Eastern Jutland (1st century BC) led Robinson (1993) to conclude that flax had been cultured to be used for consumption, not fibre production. This interpretation follows those of Helbæk. This argument presupposes that the division between the *Humile* and the *Vulgare* variants of *Linum usitatissimum* had already taken place quite early. Mannering (1995) has reasonably argued that it is difficult to imagine that the fibres were not used at all, seeing that the plant was grown anyway. One could also propose that the carefully cleaned seeds were to be used for producing a good fibre crop, rather than for food, as flax is very sensitive to weeds.

There is little evidence to support this however. The earliest pieces of linen cloth are from the Early Roman Iron Age (0-180 AD), and with only seven finds on three sites they are not exactly abundant (Hansen & Høier 2001). Especially when one considers that Roman Iron Age graves are well represented in the Danish archaeological material. The few finds and their context on relatively rich burial sites could lead to the conclusion that they are Roman import (Hald 1950).

It is only from the Germanic Iron Age that linen cloth becomes more abundant in the graves. In the early part of the period, rather few graves are known at all, and therefore textile finds are generally very rare, none of which are determined as flax. But this changes from the Late Germanic Iron Age. In her seminal work on the prehistoric textiles from Scandinavia, Bender Jørgensen (1992) has noted a general increase in the tabby weaves through the period (Figure 9). While virtually all linen cloth is made in tabby, not all tabby weaves are linen. An actual determination of the material has only been possible for some of the finds. Nonetheless the general impression is that linen cloth becomes increasingly important in fashion through the period (Bender Jørgensen 1992: 164ff).

The lack of grave finds from the Early Germanic Iron Age is countered somewhat by the excavation of settlements with retting wells from the period. The settlement Seden Syd was dated to Late Roman and Early Germanic Iron Age. A total of 14 houses and no less than 33 wells were excavated. Stalks from flax were found in three of the wells, and in at least one of them, the layer of flax was overlain by several stones, which may have weighted the stalks down (Andresen 2005).

Bender Jørgensen (1992) links the increased presence of tabby weaves in the graves with the emergence of the sunken huts (in English also called pit houses or even grubenhäuser, with a German expression). They are small huts, dug partially into the ground, and start to appear on the settlements from the Late Roman Iron Age. They become increasingly common through to the Viking Age. The sunken huts had many different uses, but one of them was weaving, which is witnessed by the regular presence of loom weights for warp weighted looms in them. It is assumed that these huts were especially suited for the working of linen, as a slightly moist environment prevents the linen from becoming brittle while working (Zimmermann 1982).

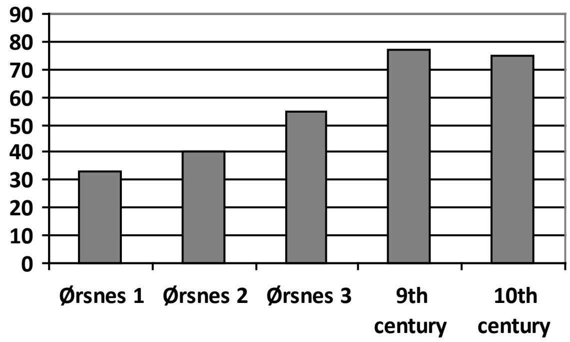

Figure 9. The proportion of tabby weaves in Danish graves from the Late Germanic Iron Age (Ørsnes phases 1-3) and the Viking Age (9th – 10th centuries). (Bender Jørgensen 1992: 164)

Viking Age textiles

Danish finds

During the Viking Age, Bender Jørgensen (1992) assumes that as many as 40% of all textiles found in Denmark were made from linen. It should again be underlined, that this is based on an observation of the proportion of tabby weaves in the finds, together with an assumption that half of these textiles were linen ones. If nothing else then this assumption at least makes statistical sense. In a probability space with two choices, the chances to select one or the other should be fifty-fifty, if there is no evidence to the contrary. It is of course a weakness of the study, but one can appreciate the technical and economic challenges if extensive fibre analyses should have been done.

As we shall show later in this chapter there is evidence to corroborate the claim that flax and linen was important during the Viking Age. This means that we can use the known tabby weaves to assess the quality of the linen from the Viborg shirt. As already described both the weaving and the thread was very regular, and the thread count measured to 22/12. In Bender Jørgensens investigation (1992: 83ff), there were 144 textile fragments in 72 graves from the 9th century and 169 fragments in 67 graves from the 10th century. Of the total of 313 textile fragments 239 (76%) were tabby weaves. Of these 239 finds, 54 were imprints inside oval brooches, which are left as part of the manufacture process. These textiles were not used by the deceased, but by the bronze founder making her brooches. There seems to be very few changes in the textiles from the 9th to the 10th centuries.

The majority (80.4%) of tabby weaves are Z/Z spun, as is also the Viborg shirt. Most of these textiles have a balanced thread count, most commonly between 10 and 20 threads, but all qualities are represented. But apart from these weaves, Bender Jørgensen (1992: 85) also sees a “middle” group of weaves with a warp count of 20-25, and a “fine” group with more than 25 threads in the warp. Both these types are unbalanced with lower weft counts, the “fine” type being the most unbalanced. Although Bender Jørgensen (1992: 86) generally considers linen to belong to the balanced weaves and the unbalanced more likely to be of wool, the fabric of the Viborg shirt falls well in to the “middle” group. We can therefore describe the fabric of the Viborg shirt to be of a good, but not particularly fine quality. If anything it falls in the lower half of the “middle” group.

Most of the known textiles are found in graves. There is one obvious problem with this material. Linen itself is very rarely preserved in the ground, but that goes for most textile and organic materials in general, unless there are special conditions to preserve them. Where textiles are mostly preserved are in the corrosion products around metal objects. Pure logic would then dictate, that there is a greater chance of finding textiles in graves, the more metal objects are found in them. The picture we get from grave found textiles is therefore biased towards the upper strata of society (Hägg 1985; 1987). Bender Jørgensen mentions herself (1992: 83) that for the Danish Viking Age graves, a majority of textile remains are found in connection with oval brooches and that therefore there is an overrepresentation of straps in the material. Oval brooches were not universally used in the female dress during the Scandinavian Viking Age (e.g. Skaarup 1976). This actually means that what is described in Bender Jørgensens work (1992), and here, on the proportion and different types of textiles may mainly reflect on the upper part of the dress of upper class women during the Viking Age.

Towns

Another type of bias can be found in the graves from the towns, like Birka in Sweden, Haithabu in Denmark and Kaupang in Norway. Towns were something completely new in Scandinavia when they emerged during the Viking Age, but their effect on social and economic structures were the same as most anywhere in the world. It is a small and select section of society that we see in the towns. Because of this one must be careful about generalizing from these finds. With the large materials from especially Birka and Haithabu these finds are difficult to ignore, and there seems to be important knowledge to be gained from these finds.

The social bias is possibly especially visible at Birka in Sweden. At the burial site in Birka the majority of graves were cremation graves, probably containing the remains of the more common people on the site, but there is also a group of richer inhumation graves. No less than 169 graves contained textile fragments, of which about 70 graves had plant fibres. Most of these were flax but a few were also made from hemp. All but one were tabby weaves, and were generally balanced weaves with a thread count of 15 to 20 threads per cm. The linens were mostly white or unbleached, but a few were dyed. The oval brooches in Birka have produced many textile preserved straps, most of which are from linen. (Geijer 1938).

A relatively large proportion of the graves had pleated linen. The pleats would typically have a depth of 2-3 mm. In pleating linen, its stiffness is used, and the fibres broken through a mechanical process by every turn of the pleat. Pleating is mainly found in the 10th century graves, and less so in those from the 9th century (Hägg 1974).

Pleated linen is rare outside Birka, and it has been suggested that it is imported from Russia (Geijer 1938). One recently published piece was indeed found with oval brooches in Pskov, Russia, close to the Estonian border (Zubkova *et al*. 2010). Another piece was found in grave 5/1964 in Haithabu (Hägg 1991: 209). There are also a few examples of pleated wool, like Vangsnes in Norway (Holm-Olsen 1976), something that may change the interpretation of these pieces being imported. Interesting about Haithabu is that textiles are found not only in the graves but also in the town and in the harbour (Hägg 1984; 1991). The textiles from the graves are generally finer than those from the town and the harbour, and with a larger proportion of tabbies (73% in the graves vs. 25% in the town and harbour). It is interesting that the proportion of grave found tabbies is much the same as that from other graves in Scandinavia, but that there is a difference to the other contexts. One could speculate that people were buried in their best clothes, and that this involved more linen than the daily clothes. If this is true, then the relation of textile types between the graves and the settlement becomes key in understanding the use of linen during the Viking Age. There were no linens found among the textiles in the harbour. These textiles were often tarred and probably used for caulking and other maintenance work on the ships, and generally interpreted as the remains of daily working clothes of seamen and workers. Hägg (1984: 218) therefore suggests that linen was a sign of status. This seems substantiated by the finds. As part of her reasoning, she also argues that linen is not warm enough, and therefore an addition to the clothing. To this one could answer that the summers here on the border between Southern Scandinavia and Northern Germany can be quite warm, and that fashion anyway cannot be explained through any physiological logic.

But the evidence seems quite compelling, that the use of linen was different from that of wool. Linen may not have been reserved for a very high social level of society, so linen should not be understood as a social marker as such. But is it reasonable to interpret these differences such that the linen would represent people wearing their "Sunday best". This interpretation makes sense for the fine qualities of fabric and the many tabbies in the Viking Age graves.

Apart from the textiles, the excavations at Haithabu revealed more than 2900 flax seeds and 2600 fragments of seed capsules. A small pile of shives also indicate the processing of flax fibres (Behre 1983: 24-27)

In Birka charred remnants of bread were also found in no less than 37 cremation graves. Analyzes have shown that at least four of the breads contained flax seeds. Most of the bread was baked from barley, but the flax seeds are all found in wheat bread, one of which also contained naked barley. Wheat makes a finer bread, and it is possible that the flax seeds were put in to make an even finer and more tasty dough (Hjemqvist 1989: 262, 272).

Production sites

That linen may have been considered a finer cloth than wool, but not necessarily reserved for a select few in the upper class, seems to be suggested by the production sites. These sites indicate a high and specialized production of flax during the Scandinavian Viking Age.

Næs

Foremost among these sites is Næs in South-western Zealand, which was excavated in 1997-1999 (Hansen & Høier 2001). On a headland a small farmstead dating from the second half of the 8th century to the 10th century was found. On the site there were four main houses, of which at least three were not contemporary. There were also 16 smaller houses and no less than 69 sunken huts. The site is places on a promontory close to the shore, and there would have been access from the sea. The finds from the site indicated that in addition to being a farmstead, trade was also carried out on the site and it was interpreted as a landing site.

The sunken huts were relatively small, generally around 3×3.5m, but the size varies from 2 to 4 meters. In the layers filling the huts various items were found which would be typical for a settlement, like bones and pottery, but also tools and personal items were found. In almost all of them were found loom weights, spindle whorls or both (Hansen & Höier 2001: 64). The connection between sunken huts and textile industry therefore seems relatively well established here.

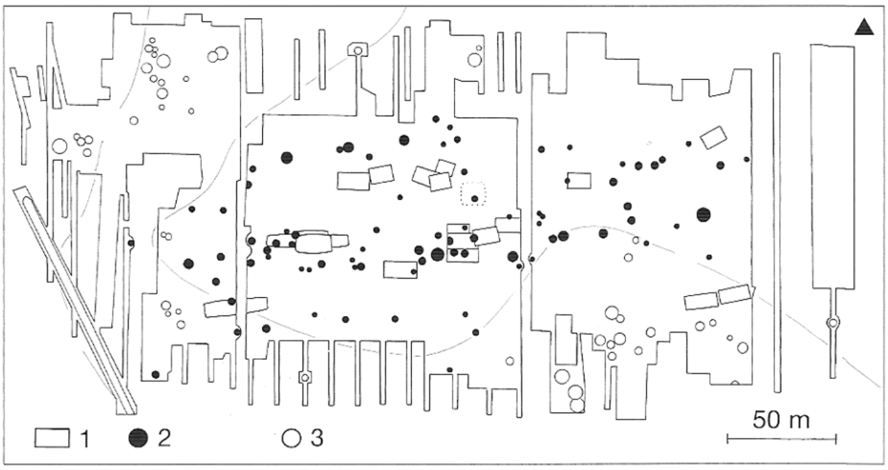

Figure 10. The excavation at Næs. 1. Houses. 2: sunken huts. 3: Wells. (Hansen & Höier 2001: 60).

This connection was further confirmed by the find of 57 wells on this site. Most of them were removed some distance from the main habitation area and situated on lower ground where the ground water is highest. This meant that the wells were usually very well preserved, often with wooden constructions holding the sides still in place. 57 wells for supplying drinking water are by far too many for a settlement of this size and when a bundle of what turned out to be flax fibres were found at the bottom of one of the wells it was determined that most of these wells were probably for retting flax. According to Hansen & Höier (2001: 69) this could also explain their being placed relatively far away from the houses as the retting process would stink rather badly. But in fact the divide seems more to relate to topography and water levels such that most houses are situated above 5 m a.s.l. and most wells below. A long canal was also found, test pits indicating that it could have been up to 300m long. It had 2 wells in the bottom and sediments showed that it had sometimes been filled with water. It is likely that this canal was used in the flax industry going on at the site but the precise function is unknown.

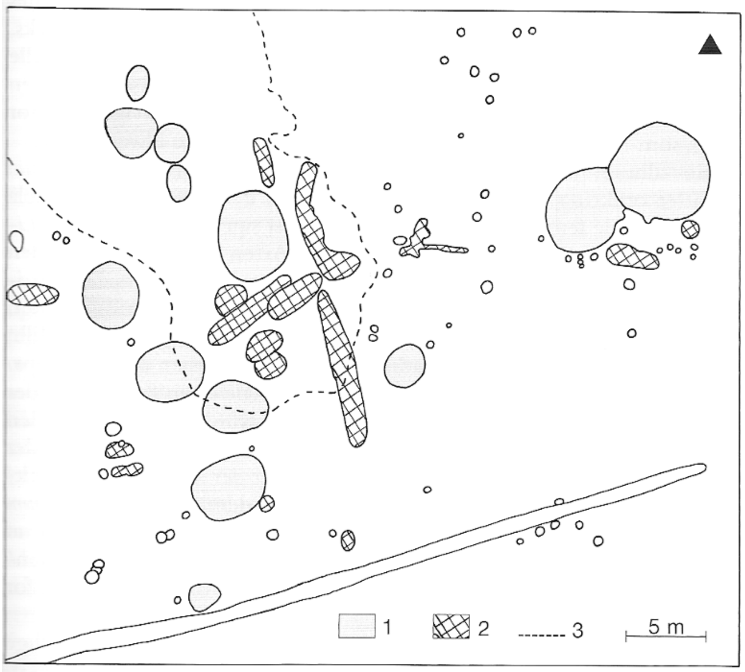

Figure 11. Wells and breaking pits in the southwestern part of the excavation. (Hansen & Höier 2001: 71).

Immediately around the wells long ditches were also excavated in one area of the site. These ditches could be up to 12 m long and about 1 m wide, but are generally smaller. Charcoal showed that fire had been lid in and around these ditches and they were full of fire cracked stones. It was thought that these ditches could have been used for drying flax prior to breaking. Although somewhat misleading such constructions are historically known as “breaking pits”. Usually a fire was lit in the bottom of such a pit and then a grid of wooden rods or something similar was laid out and the flax was placed on top of this grid. Drying flax over an open fire can be a tricky business as it is important that the heat is not too low. At the same time the flax should obviously not catch on fire. The breaking pits at Næs with the large number of fire cracked stones could indicate a way of controlling the temperature of the fire. Once stones have been heated they give off an even heat and by minimal stoking they can keep the same temperature for a long time, so by using stones the fire would be less open and the risk of fire smaller (Hansen & Höier 2001: 70f, 81) . The close spatial relationship between retting wells and breaking pits shows that this is a specialized production area, and that transport between activities was minimized. The low lying areas are otherwise not the place where one would expect to find fire related activities.

This is a significant find. The fact that it is a landing site is in itself interesting enough, showing a small site which has played a part in the local trade networks of the Viking Age. In secondary context, mainly in the backfilling of the sunken huts, traces have been found of bronze and iron working. Fragments of soapstone and whetstones, which was imported from Norway, are also found here. But it is the evidence for flax production which makes this site stand out. It can best be interpreted as a specialized site for the production of a cash crop, which was made for being exported by ship.

In that respect one could argue that the nearest parallel to this site are the cotton plantation of the American South. In fact the structure of the site, with one “great house” and several smaller huts and work sheds is even fairly typical for those plantations, and certainly one of the authors of this report has seen that exact structure many times on the sugar plantations in the former Danish West Indies (Ejstrud 2008). One could stretch the analogy even further, because although it is not a very prevalent thought in the Scandinavian discourse on the Viking Age, it was at least to some extent a slave based society. But this is pure speculation and there is no way of knowing to that level of detail the economic or social structures behind the production of flax at Næs.

Parallels

Fortunately there are also closer parallels. Although not very common, breaking pits and retting wells have been found on a number of sites across Denmark. One reason why they are relatively rare is that pits and wells are not always excavated on sites, because they are very time consuming and within the realms of rescue archaeology not always prioritized very high (Andresen 2005).

Retting wells have been found in a few locations around Denmark (Table 1). This type of feature is perhaps the easiest recognisable of all features and objects used in the flax working processes apart from spinning and weaving paraphernalia. Retting wells can easily be mistaken for ordinary wells for drinking water, but sometimes the sheer number of them in one site can be a clue that they most likely were used for something else, e.g. as in the case study of Næs above. Otherwise botanical analyses can indicate their use as retting wells and sometimes, as also happened at Næs, bundles of flax can be recovered at the bottom of these wells (Hansen & Höier 2001). These retting wells are used for water retting.

If dew retting was used in a location this would not leave any traces as no constructions or features are necessary to use an area for dew retting. The same applies if the water retting took place in a stream where no constructions of any kind had been added to facilitate the process.

Place name	Parish no.	SB no.	File No.	Dating
Frydenlund	08.08.03 Fraugde	82	OBM 8916	Late Bronze Age/Early Pre-Roman Iron Age
Seden Syd	08.08.09 Seden	7	OBM 9882	Roman/Germanic Iron Age
Helstedgård SV	08.08.09 Seden	8	OBM 5740	Late Roman Iron Age
Hvissinge Vest 2	02.02.04 Glostrup	10	NM/Kamr BO251-1061	Germanic Iron Age
Mårhøj	16.05.09 Tolstrup	3, 28	HOM 1350	Roman Iron Age
Næs	05.04.03 Kastrup	39	SVM 7546	Germanic Iron Age/Viking Age

Table 1. Known retting wells in Denmark. Source: Arkæologiske udgravninger i Danmark

The number of retting wells on each site can vary from a few to quite a large number as on Næs. Some wells may be empty and then possibly used for drinking water or maybe just emptied before the abandonment of the site. It is very clear that the discovery of retting wells is dependent on the proper excavation of the wells. Five out of the six sites are dated to the expected period between the Roman Iron Age and the Viking Age.

There is an exception, though. In 2005 retting wells and features believed to be breaking pits were found at Frydenlund on the island of Funen. The area contained 52 wells and about 100 pits in different sizes and botanical samples indicated that the wells had been used for retting flax. The area was surprisingly C^{14} dated to the Late Bronze Age/Early Pre-Roman Iron Age (800-350 BC) and this is the earliest find of flax production in Denmark. (Runge & Henriksen 2007). In light of what we otherwise know of prehistoric flax production in Southern Scandinavia, this is a very early date, especially when considering the almost industrial scale of the production. One problem with these results is that Frydenlund is in fact a continuous settlement from the Bronze Age through to the Middle Ages. Considering the lack of any other evidence for flax production during this period, it is more than likely that these dates are the result of contamination.

Breaking pits have also been found, sometimes in combination with retting wells, sometimes on their own (Table 2). When only breaking pits are found it could mean that the people obtained flax ready to be broken from somewhere else or that they retted it themselves using dew retting, which would not leave any archaeological trace as no constructions are necessary for this process. When breaking pits are found on a site where no retting wells are found it can be hard to interpret them correctly. Several things may help with the proper interpretation; botanical analyses of the bottom layers, the presence of charcoal and heat affected rocks in the bottom of the pits and signs of further textile production e.g. in the form of spinning whorls. Even so, not all pits with charcoal can be interpreted as breaking pits as they may of course have had many other uses.

These sites, though not all from the Viking Age, and not all showing a production to the same scale as on Næs, demonstrates that flax production took place across the country, and that the features in the form of wells and pits does not change much over time.

Dedicated retting wells are not necessary, if conditions otherwise permit retting. This demonstrated in for instance in the lake Skånsø near Skive in northern Jutland (Odgård 2001). The lake had been used for retting of hemp from 600 to 1800 AD, and for retting of flax from 1000-1400 AD, possibly even earlier. In Dallund Lake on northern Funen, pollen showed the growing of flax nearby from the Middle Ages and onwards (Rasmussen & Bradshaw 1998). Seeds and seed bolls from flax in the sediments could be evidence of retting, although these parts of the plant would normally be removed before retting.

Place name	Parish no.	SB no.	File no.	Dating
Leca 4	14.03.08 Vissing		KHM 1114	Late Roman Iron Age
Hvissinge Vest 2	02.02.04 Glostrup	10	NM/Kamr BO251-1061	Germanic Iron Age
Kragehave Ødetofter	02.02.13 Torslunde	104	NM/Kamr BO251-1049	Recent
Vester Egesborg	05.04.12 Vester Egesborg	17, 35	NÆM 1997:120	Late Germanic Iron Age/Viking Age
Spansbjerg and Kjeldgård	13.08.01 Asmild	104,107	VSM 100G; 869F	Germanic Iron Age/Viking Age
Mårhøj	16.05.09 Tolstrup	3, 28	HOM 1350	Roman Iron Age
Mathildelund	08.02.02 Barløse	81	OBM 9208	Recent
Moeskjærgård 111	14.10.06 Hørning	53	KHM 0017	Recent
Elmegård	01.05.10 Vinderød	27	GIM 3264	Recent
Bredebjerggård 8	02.02.07 Høje Tåstrup		TAK 1180	Germanic Iron Age
Møgelkær	17.01.09 Rårup		HOM 444	Recent
Frydenlund	08.08.03 Fraugde	82	OBM 8916	Late Bronze Age/Early Pre-Roman Iron Age
Løve Sydøst	03.02.05 Gierslev	80	KAM 2005-012	Post Medieval (Recent)
Bytoften	15.04.06 Mårslet		FHM 4534	Recent
Højlund Spangsdal 1	13.08.01 Asmild	133	VSM 09199	Late Iron Age
Statoil 2007, Area D	03.01.10 Årby	445	KAM 2007-023	Viking Age
Kristinebjerg	17.03.04 Taulov		VKH 6841	Unknown

Table 2. Sites with breaking pits in Denmark. (Source: Arkæologiske udgravninger i Danmark; supplemented by Boddum & Wåhlin 2009; Jensen 2004; Måge 2006).

Outside Denmark, a parallel to Næs may be Löddeköbinge in south western Scania. This site was a landing site with 35 sunken huts, of which most contained tools for textile production. Only one flax seed is found in one of the sunken huts, though (Andersson 1999:24; Robinson *et al*. 1991: 59-87). From western Norway linen has been found in a sunken hut from Stedje in Sogndal. A lump of charred linen could be separated into 17 different layers during conservation. Other finds, including 72 loom weight, 15 spindle whorls, a bronze needle and a bone needle, shows that this was indeed a weaving hut (Mortensen 1998: 188-195).

Århus

These Scandinavian finds are in many respects parallel to the finds from the excavations of Århus Søndervold (Andersen et al. 1971). Here there are no traces of retting, but instead several remains from the spinning and weaving of flax. Central here is the sunken hut CME, where two balls of linen yarn were found together with the cut off warp end from a loom, and several textile fragments. The material could not be determined but at least three pieces were almost surely made from linen (Figure 12). The textiles were preserved because the hut was destroyed by fire. There was also a loom weight, and what was interpreted as two heckles (Andersen *et al.* 1971: 139). We have followed this interpretation, but they may in fact be combs for wool. The hut was small, but other artefacts in it, such as horse gear and personal items, indicated that the inhabitants of the hut were not exactly poor – or at least that they lived among wealthy people’s possessions.

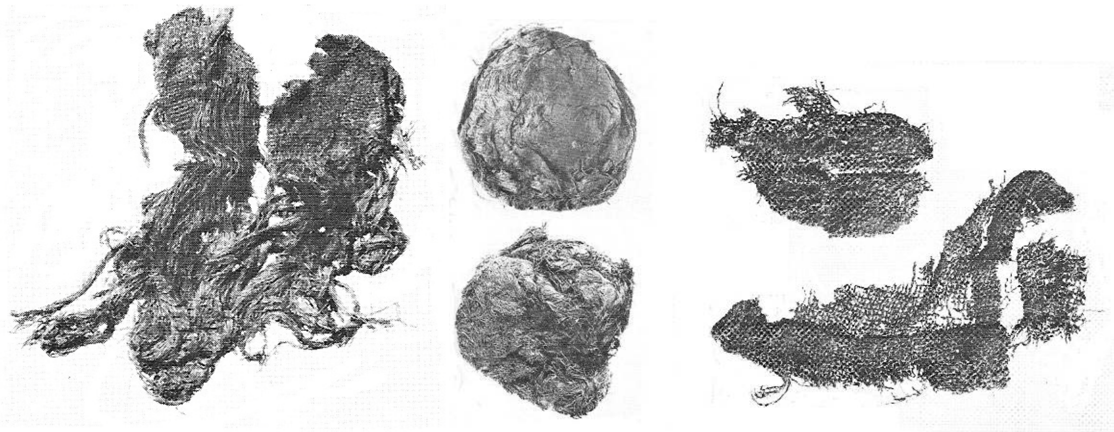

Figure 12. Textile remains found in hut CME, Aarhus. (Andersen et al. *1971*). Not to scale.

Discussion

Aarhus is obviously different from the rural sites at Næs or Löddeköpinge, in that it was a town proper. But both of the latter sites are interpreted as landing sites, and in that respect they are near parallels to the site in Aarhus. They are found in a context of specialized production and long-distance trade for linen. The finds from Aarhus are not extensive enough themselves to be interpreted as anything than local production, but with the find context of a Viking Age town, they still belong to the same sphere.

The other production sites can not all be interpreted in this context. But what one can possibly conclude from the discussions above is that linen was connected to higher status -or just considered "finer"- than wool during the Viking Age. With this status, and with the general development of trade and transport networks, which characterize Viking Age society, an economic niche developed, where some sites specialized in the production of linen. The sunken huts with loom weights indicate that linen was traded in the form of finished cloth. If specialization to this degree was common, there is no reason to assume that even fine linen cloth was imported, unless there is direct evidence for import. This has otherwise been suggested even for the fabric of the Viborg shirt (Fentz 1988). The weavers at such specialized sites would have had ample opportunity to develop the necessary skills for making a high quality product, had there been a demand for it.

These interpretations would stand stronger, if more attention was paid to wells and pits in archaeological excavations. Clearly the archaeologists on Funen have been alert to this type of find, and therefore there are several sites from this island. Applying basic market theory to the notion that linen was a high status commodity which was in demand during the Viking Age, we predict that similar sites can be found all over the country. The examples from Skånsø and Dallund illustrate how botanical evidence is also important in mapping out the history of linen production.

Of more direct consequence to this study, we can expect that if linen production was indeed a specialized craft during the Viking Age, then even the experiences artisans who participated in our work will most likely not be able to keep up. We will probably overestimate time.

Tools

What we can do is to make sure that the tools we use in our experiments are as close as possible to those used during the Viking Age, at least minimizing that variable. The purpose of the following is therefore to present the sources that the tools we have used in our experiments are based on. In this section we have relied heavily on Behr (2000), who has compiled an excellent overview over textile related tools from medieval Denmark.

Rippling

The ripple comb is a simple tool through which the stalks are pulled to loosen the seed bolls. Other methods can probably be used to achieve this, but the ripple comb is already known from both wall paintings and actual finds in Ancient Egypt (Vogelsang-Eastwood 1995: 19), and is apparently known throughout history.

In medieval layers from Bryggen in Bergen, Norway, 23 crude wooden combs were found, that could possibly have been used for rippling. They were made in two pieces. The comb itself with 5-10 cm long teeth, and a shaft which was attached perpendicular to the comb in a small hole (Øye 1988).

The types that are known historically have either wooden or metal teeth. They come in a variety of shapes, and there are different ways of fixating the comb while working. But essentially this tool has a single row of large teeth, though which the stalks are pulled. It should therefore not be difficult to replicate.

Breaking

To our knowledge no flax breakers have been found in Scandinavian Viking Age context. Several sources state that the breaker is an invention from the 14th century (e.g. Baines 1985: 6; Derry & Williams 1993: 96). According to Behr (2000) however, a breaker from Poland is mentioned by Nyberg, in one paper dated to 800 AD (Nyberg 1967) and in another to 1000 AD (Nyberg 1989). It is not entirely clear whether it is indeed the same breaker. To this come the much older fragments from Feddersen Wierde, as already shown in chapter 1, which at least have a striking resemblance with later flax breakers

We do know the hand breaker well from later periods, as it was used domestically until relatively recently. The breaker has the form of a stand on top of which one or more moveable blades are attached in one end. A handle in the opposite end allows the worker to beat down the blade on the flax. Wooden pieces on the stand forms a slot in which each blade can fall. It is reasonable to assume that a similar tool was used during the Viking Age, especially considering the age of the Feddersen Wierde pieces. But basically any tool that will break the stalks without breaking the fibres will do for this purpose.

An entirely different tool is known in the form of mallets, or “linen clubs” as they are mostly known in the Scandinavian languages. Already Pliny described that flax was broken with a mallet against a stone (*Nat.Hist.* iii.18). From the ethnological and historical material such “linen clubs” are known from all over Scandinavia. They are relatively small wooden mallets, typically 20-35 cm long. Similar mallets are found in Viking Age context. Two made from beech were found in the Norwegian Oseberg burial (Figure 13) (Brøgger & Shetelig 1928). They were found along with other textile tools and therefore interpreted as flax beaters (Sjovold 1966). Mallets can have many uses, and unless they are found in connection with other tools for textile production it can otherwise be hard to attribute a specific function. Similar tools are found at e.g. Trelleborg (Nørlund 1948), Haithabu (Schietzel 1970: 86) and Lund (Nilsson 1976: 249).

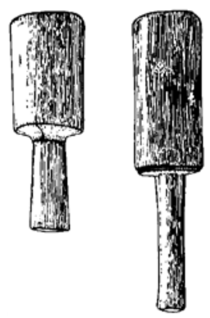

Figure 13. Clubs from the Oseberg find, Norway. After Andersson 2003.

Scutching

The scutching process involves movable constructions made of wood and for this reason it rarely leaves traces in the archaeological record. From Medieval Denmark at the site of Boringholm two knifelike wooden objects were found and these are thought to be scutching knives. They are about 60 cm long, with a blade on one side only and they are dated to the middle of the 14th century (Behr 2000). These tools are not from the Viking Age and even though some evolution always takes place these specific tools, if they are indeed scutching knives, are quite basic with a very specific function.

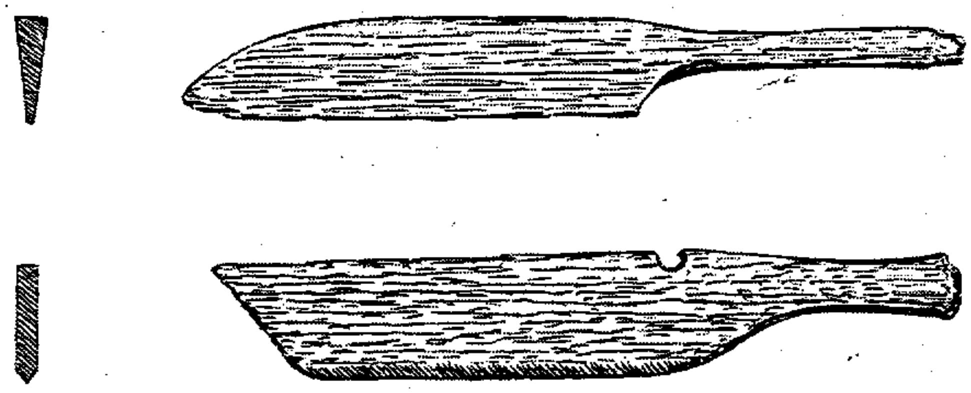

Figure 14. Scutching knives from Boringholm. About 60 cm long. After Behr 2000.

Closer in time, but further away in place, a possible scutching knife is know from the 8th century in Elisenhof, Germany (Nyberg 1989: 83), and from the 10th century onwards in Novgorod (Sherman 2008). Like with the other tools, the knives are very similar to one another and to those tools know from ethnological and historical collections across Northern Europe. The tool should be unproblematic to replicate. Its use is more difficult to reconstruct. In our experiments it has been used with a scutching board; a vertical wooden board on a stand over which the flax can be scutched. In fact the board may be a later invention. The oldest illustration of the board is a Flemish calendar from the late 16th century (Åström 1952). Instead the flax may have been scutched over the knee, as is known from medieval illustrations (Nyberg 1989: 84).

Heckling

Two possible heckling combs were found in the excavations at Århus Søndervold (Andersen *et al*. 1971). The best preserved was constructed of a hollow box of 1mm thick sheet iron with two rows of iron teeth around a wood handle. These teeth, which measure 7.5cm in length, are arranged in two staggered rows with twelve teeth in the outer row, and eleven in the inner row. The distance between the teeth is 3-5mm.

In Fyrkat a simpler type is found (Roesdal 1977: 28). It is a rectangular plate med only a single row of teeth. This may be well a wool comb.

Similarly constructed heckles were also found in Norway during the Viking Age. One comb was moderately larger than the Århus Søndervold find, with 29 teeth arranged in rows of fifteen and fourteen teeth each at 6-7cm long (Petersen 1951). Another comb was of a slightly different construction, featuring 20 teeth in one row, which were attached to an iron plated, round piece of wood. The teeth of this comb were slightly curved inwards towards the presumed handle of the comb (Petersen 1951), much the same as seen in the heckles from Århus. Several other heckling combs have been found from around Norway, many with a wooden base, and all with varying numbers of teeth and arrangements (Petersen 1951); however, the general construction of evenly spaced iron teeth set in two rows appears to be a fairly common style around Scandinavia during the Viking Age.

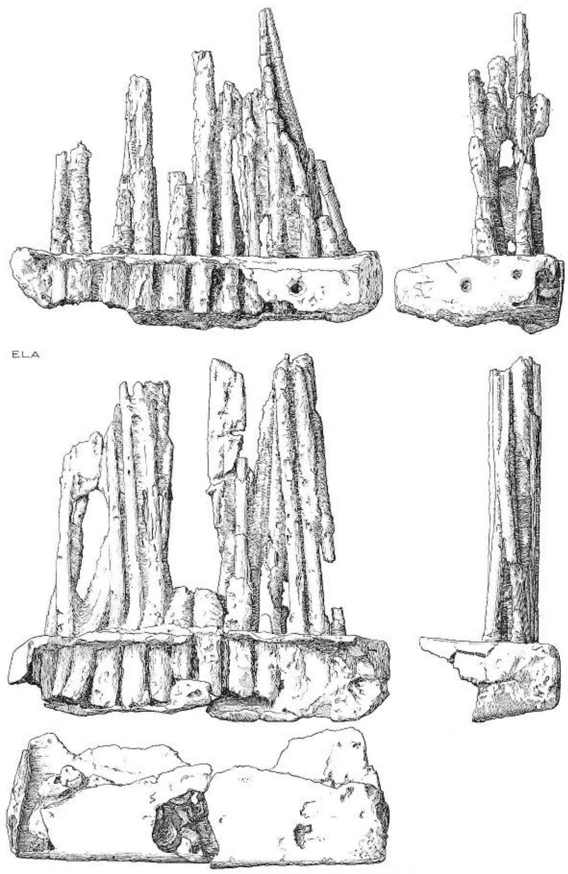

Figure 15. Possible heckle from Århus Søndervold. After Andersen et al. *1971: 138.*

It has been speculated that these heckles could also have been combs for wool (Hoffmann 1988). In the following trials we have considered them heckles.

Spinning

Spinning requires a spindle and a distaff to attach the fibres to while spinning. The distaff is simply a long stick around which the heckled flax can be wrapped. From Gammelbyen in Oslo, Norway, several distaffs were found, of which one was fully preserved. It is a 25.5 cm long stick. Several notches are made to hold the fibres in place. 16 cm of the one end is cut into a square shape. Fragments of five other similar distaffs are also preserved. They are preserved to a length of 16-24.5 cm but must originally have been up to 30 cm long (Øye 1988).

From the archaeological record, a wide variety of spindle whorls can be seen. The basic construction of the spindle followed the same format, the spindle shaft and the whorl. However, there was a range of variations amongst these two elements, each contributing to a slightly different performance for the drop spindle (Andersson 1998). The spindle shaft could be made in a range of sizes, for example, spindle shafts at Hedeby were found at lengths between 9.8 and 21.5cm (Andersson 2003). The whorl is an item commonly found at Viking era sites, and their range of variation is also extensive. Whorls could be made of stone (particularly soapstone), antler or bone, ceramic, and wood (Andersson 2003). Trends in spindle whorl styles can be seen within settlements and periods, such as the apparently mass-produced ceramic whorls found at Haithabu (Andersson 2003) and the strong presence of conical shaped whorls from Århus

Søndervold (Andersen *et al*. 1971). However, on the whole, whorls ranged in size and weight from find to find, site to site and between regions, suggesting that drop spindles were produced on a local or even individual basis (Andersson 1998, Walton Rogers 2000). In Jutland during the 9th and 10th centuries the conical whorl dominated however, and it spread eastward during the 10th and 11th centuries. After *c*. 1200 it is not known in the Danish finds. Christensen (1984) saw the spread of the conical whorl as a reflection of a stronger cultural unity between Eastern and Western Denmark during the Viking Age.

Figure 16. "La Fileuse" ("The spinner"); oil painting by William-Adolphe Bouguereau, 1873. The distaff and hand spindle goes back a long way in female history. Although stylistically different, similar pictures can be found in classical and medieval iconographic sources across Europe.

Weaving

Weaving is the manufacture of cloth through interlacing two perpendicular systems of yarn. The *warp* runs lengthways and is set up first, while the *weft* runs across the fabric, and is added through the process. Weaving is normally, but not necessarily, done on a loom of some kind.

The most important type for this period is probably the warp weighted loom. A tubular loom was also found in Oseberg (Hald 1950), but would otherwise leave few traces. Its use can mainly be identified through the edges on woven cloth. The warp weighted loom is much more common to identify in archaeological excavations, because the loom weights are often preserved.

The warp weighted loom works by suspending the warp from a top beam and keeping it taunt by weighing it down with the loom weight. By leaning the loom slightly a natural shed is created in the warp. This shed can be shifted through the use of heddles. The loom is described in more detail in chapter 5. The archaeological evidence lies mostly in the weights.

The loom weights have several different forms through prehistory. The most common types are made from clay or ceramics, but other materials were used as well, especially stone. Typical shapes are pyramidal, conical or doughnut shaped ceramic type. When made from clay these types would have a hole in them, while stone types could have the warp wrapped around them.

In her studies of the warp weighted loom, Hoffmann (1974: 20f) has also looked at the weight of the loom weights from various archaeological finds. It varies from 150 to 1000 grams, but in general was around 500-750g. She also notes that stones are used as weight, as often as the ceramic types. Important here is the mentioning of the loom from the Faroe Islands, which is kept at the National Museum in Copenhagen. Stones were use as loom weights, and they were the heaviest weights recorded anywhere. This loom was set up to make a very fine type of linen.

The warp weighted loom seems to disappear in Denmark during the 12th century, as no loom weights are found after this century (Behr 2000: 73).

In her publication of the Viborg shirt, Fentz (1988) also suggested that a linen fabric this fine would better have been woven on a horizontal treadle loom. This is interesting, as the Faroese loom mentioned above is actually set up for fine linen. It is also interesting because there is much archaeological evidence connecting the warp-weighted loom to linen production. We shall discuss this further in chapter 5. The only possible evidence of a horizontal loom during the Viking Age is a pulley block which has been interpreted as belonging to a horizontal loom (Schietzel 1970).

The two types of looms, the horizontal and the warp weighted, were both used at least through the 11th and 12th centuries. While they may both be secured in the ground by digging in the uprights, the warp weighted loom would stand at an angle to the floor. Correctly positioned profiles could therefore possibly help determine the presence of looms in an archaeological excavation, regardless of *in situ* loom weights.

Beaters

To the warp-weighted loom is also needed a tool to beat the weft firmly in place. In Denmark only few such beaters have been found. Two iron fragments from Viking Age Aggersborg has been interpreted as such (Behr 2000). In Norway a larger number is known. Petersen (1951: 285ff) mentions 283 iron beaters, normally 60-80cm long. From Northern Norway another 40 examples made from whale bone are also known. The examples made from bone are often heavier than the iron ones. It is interesting to note that the iron beaters have often been misinterpreted as swords. This goes even for well preserved ones. It is easy to imagine the difficulties in interpreting such tools from normal graves.

Other tools

There are more tools involved in textile production than those mentioned here. Needles and needle holders (in the form a small bone) would be required to make the shirt. Cutting the fabric would also require scissors or knives. These are all well known types (Petersen 1951).

To wind up the yarn the Oseberg find has again delivered beautiful examples of tools. Replicas of the yarn reel are made and used at Ribe Viking Centre (Figure 17).

Figure 17. Reel used at Ribe Viking Centre.

Linen smoothers made from glass, and are 6-8 cm rounded pieces. They have been particularly associated with linen, but were also used on wool (Behr 2000: 100). These tools were used up to the 18th century and were then fitted with handles. For the Viking Age textiles they have been especially associated with the pleated linens mentioned above. But they have been in general use to smooth the cloth, especially along the seams.

Finally the linen cloth only gains by a good beating. Historically and archaeologically known washing bats would have been useful implements, not only for doing the laundry, but also to make the linen cloth more pleasant to wear.

3. FIELD EXPERIMENTS

Growing flax

Agricultural experiments have a long tradition in experimental archaeology. The trials done in Draved, Denmark, made for pioneering work (Steensberg 1979), as did the ploughing experiments done in Lejre (Hansen 1968; 1969). With the continuing experiments at e.g. *Butser Ancient Farm* in England, in what is now called the *Land of Legends* in Lejre, Denmark, and in many other similar centres around the world, there is a vast and continuing experience in basic farming methods. Indeed the Viking Centre in Ribe is growing crops every year, at least partially using Viking Age methods. Typical for such work, however, most of it is unpublished; it is mainly done as display activities for tourists and not as formal experiments. Admittedly, this is also partly true for the experiments described in this chapter.

It is important to stress that the cultivation of flax as such is not a theme in these experiments. The variable we are examining throughout this report is *time*. At the very early planning of this project, we even considered doing away with this part of the trials, simply starting the process from the harvested flax. But with an active farm running at the Viking Centre, with fields and animals, we decided to pursue this aspect too. The agricultural aspect of flax processing is an integral part of the process towards the finished linen, and certainly part of the time that has to be invested in making a garment. So we had to factor this in.

The early stages of the work with the flax fields took place as part of the preparations for the tourist-season of 2010, and before our experiment actually began in earnest. This part of the work was not supervised by University staff or students, and took place before the research plan was finalized. Therefore the initial work is not strictly timed, but the times given are based on estimates from the Centre’s staff. As these estimates build on many years of experience working at the centre, these estimates are probably relatively precise. Especially when one considers the character of such experiments.

There are obviously many unknown variables in experiments of this kind. Already the first ploughing experiments showed how the time spent depended much on which soil was worked (Hansen 1968;1969). Breaking through grass is very difficult, while a well tilled field poses fewer problems. The time needed for tillage is then always dependent on a specific historical context. It would vary depending on the outline of the fields, on crop rotation systems, on specific tools and techniques that we may not know of today, and certainly of the people involved, their skills and dedication. Therefore experiments like this can never give more than an estimate.

The fields

Four fields were laid out for this experiment, each one metre wide. Due to the outline of the site, the length of the four strips varied between 13.6 and 14.6 metres along the outer edges. In all, the fields covered 56.3 m^2.

The flax fields were part of a larger tilled area, where various crops are grown. Immediately around the flax was rye, oats, beets and celery. The oats had large patches of grass in it, and was used for grazing the cattle also kept by the Viking Centre.

According to the Danish Soil Classification (Madsen *et al*. 1992), the soil in the area where the Viking Centre is situated is classified as Coarse sand (FK 1); the worst category of arable land in that system. This is not a good soil to grow flax – or basically anything- on, and historically this part of Denmark has relied mainly on animal husbandry. Nonetheless some tillage has always taken place near the farms and villages, and this would also have been the case around Viking Age Ribe. If linen fabric was not exclusively imported, but also produced locally, then people living here would have had to make do with the soil they had at hand. In the historical sources, farming practices here have relied on relatively limited arable fields with locally adapted systems of rotation and manuring. In this way even a bad soil can produce an acceptable crop (Frandsen 1983).

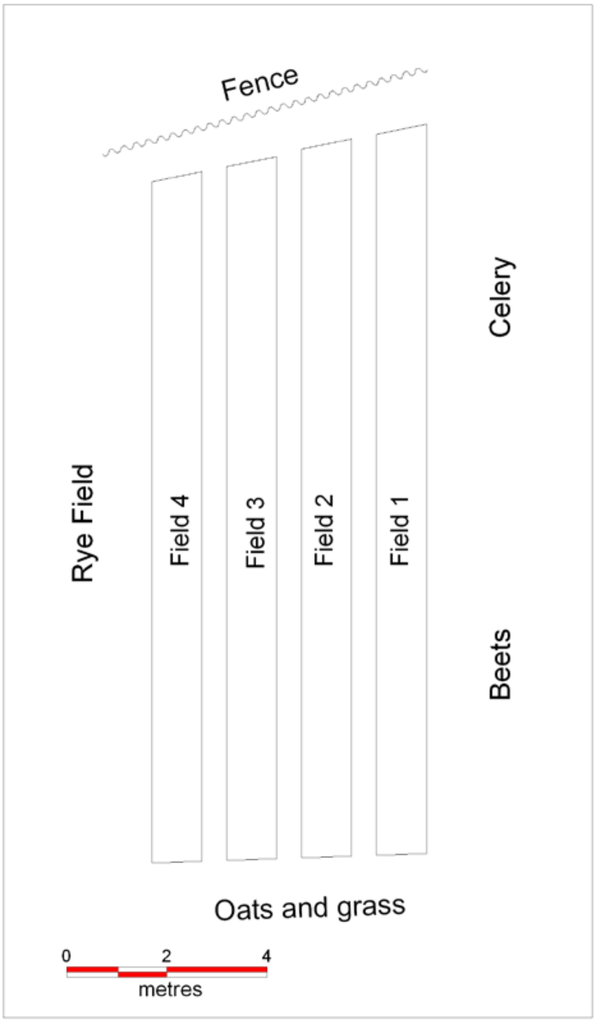

Figure 18. Outline of the experimental fields. Scale 1:150.

The maps of the soil classification are made at a regional scale of 1:50.000, and cannot distinguish soil differences at the local level. The land area classified at FK1/Coarse Sand, on which the Viking Centre is situated, covers a contiguous area of 1329 km^2 south and east of the town of Ribe. The Danish Soil Classification serves its purpose of classifying all arable land across the country. But during the experiment it became obvious that the soil differences could be observed even at a very local level. Across strip 2 and 3 a local pocket of coarse sand was ploughed up during the preparation of the field (cf. Figure 25). This area was also very visible during the growth season and harvest, as the plants in this area were noticeably less developed than those on the rest of the area. It may be concluded that in general the soil in this area is not the best for growing flax, but that we even hit a very bad spot across fields 2 and 3.

In preparation of the Danish Soil Classification, a soil sample was taken about 240 m south of the site. It had a content of 61% coarse sand, 30% fine sand, 3% silt and 2% clay. Humus was calculated to 3.24%. There were no traces of calcium in the soil. Other soil samples in the vicinity show similar values, so this sample is probably also representative for the soil at the Viking Centre.

The entire area, including the flax fields, was fertilized with cow dung on the 12th of April 2010. The manure was subsequently ploughed down with a tractor. For comparison field 1 was even fertilized with modern NPK (21-2-10) fertilizer in addition to the natural manure. After ploughing, the field was raked 4 times over.

Although the preparation of the fields was done using modern methods, the staff has previous experience in ploughing with an ard, using the Centre's two steers. Based on these experiences, the total estimated time to prepare the soil with original methods would be around two hours, for manuring, ploughing and harrowing all together.

Weather conditions

Weather is obviously important when assessing agricultural experiments. Weekly weather is reported by the Danish Meteorological Institute by towns, so the local development of weather during the growth season could be monitored quite closely.

Continuing from a cold spring, temperatures were slightly below average through May and June (weeks 18-25). Rainfall was low but stable during this period, and in general growth conditions were favourable for Danish plant production through the early part of the growing season 2010. From late June and into July (weeks 26-30), weather became warm with weekly averages just below 20°C, allowing crops to ripen. Through August (week 31-34) heavy rains set in. This caused lodging in our fields, and in general damaged crops throughout Denmark, delaying harvest by several weeks in parts of the country.

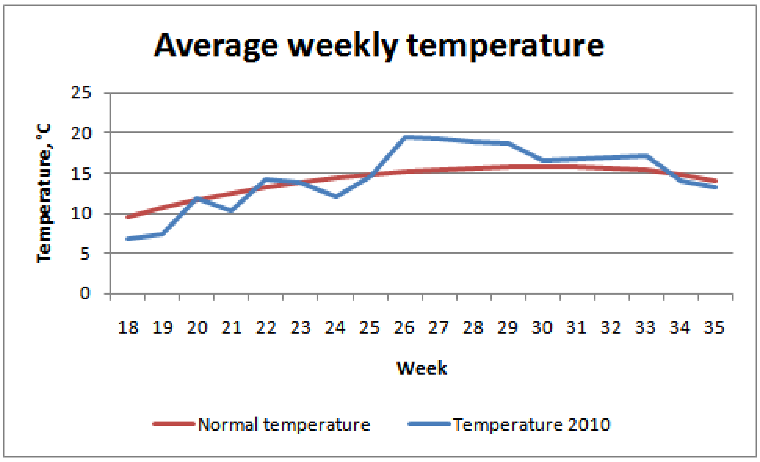

Figure 19. Average weekly temperature during the growth season. Source: www.dmi.dk.

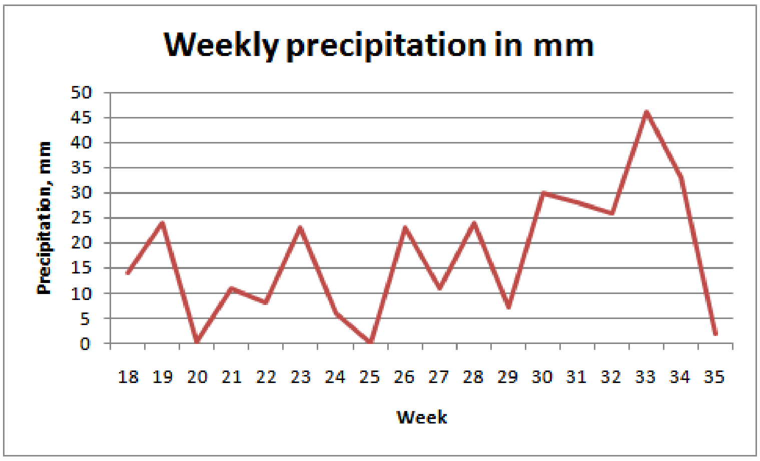

Figure 20. Weekly precipitation during the growth season. Source: www.dmi.dk.

To summarize, the growing season 2010 started off late, but weather was very favourable once it got going. Flax is hardly grown commercially in Denmark, so we cannot compare to any statistics for this crop, but predictions for Danish grain production were very optimistic during the early part of the season. This changed quite suddenly in August when heavy rains damaged the crop, and made harvest difficult. Grain production in Denmark was the lowest since 1994. Flax is found to be susceptible to water stress during the growth season, and soil water content should be ample. Excessive rainfall in the late part of the growing season, as actually happened in 2010, can lead to a flush of tillers and leaves, causing an unwanted effect for fibre flax, and uneven ripening (Diepenbrock & Iwersen 1989). We did not observe significant tilling in the flax grown in 2010, though.

Sowing and weeding

To obtain the necessary density of the flax plants, sowing must be done close to the ground. Sowing was done on the 6th May 2010 - a relatively windy day, which did not make this work any easier. A Danish saying describes that "*Flax must be sown at a crawl, while buckwheat must be sown in a run*" (Skougaard & Hansen 1983: 20). The meaning is that flax must be sown very densely, while buckwheat benefits from a low seeding rate. With the strong wind on that day, our flax was indeed sown at a crawl (Figure 21).

Figure 21. Sowing the field.

1650 grams of seeds were used, giving a relatively dense rate of 293 kg/ha. Modern recommendations for fibre flax is typically around 110-120 kg/ha (Pallesen 2009). Sowing the field took around half an hour.

During the early part of the growth season, the field needs weeding. This was done by the Viking Centre staff as part of the daily work at the site, and not supervised by University staff or students. Therefore the time for this part had to be estimated from information given by the staff working the fields. The fields have been weeded four times, each time approximately 6 hours of effective work. In all an estimated 24 man-hours were therefore invested in the weeding. This is a substantial part of the entire process (Figure 22).

Figure 22. Weeding the fields.

Growth

During the growth season, the difference between field 1, with the modern fertilizer, and the other three fields was very visible (Figure 23). The plants on field 1 grew faster and denser, were generally taller and had a distinctly darker tinge of green to them. The sand pocket across the field, especially in rows 2 and 3 was also very visible. The growth was limited in this area, and bare soil was visible between the plants even late in the growing season. A comparison of a number of 10x10 cm test areas across the fields did not show any significant differences in numbers of plants per area unit. The visible difference in density was a question of the growth of the individual plants, not of the number of plants growing.

Figure 23. Fields 1 and 2 on July 7 2010. The difference in colour is clearly visible, the fertilized Field 1 to the left being darker.

To describe the differences in growth, the height above ground was measured for 15 plants spaced evenly across each of the four rows (Table 3). From these measurements it is clear how field 1 stands taller, the average height being 12.4 cm -or 19.6%- taller than that of field 3, which was the lowest. There were obviously two factors in play here, the modern fertilizer on field 1 improving growth here, and the very sandy soil across fields 2 and 3 limiting it. Still the unfertilized field 4 was visibly different from field 1 in terms of colour and growth. This difference was more marked during the early part of the season

.

Height, cm	Field 1	Field 2	Field 3	Field 4
50-54	0	2	5	0
55-59	0	3	3	0
60-64	1	6	4	3
65-69	5	2	2	6
70-74	4	2	1	4
75-79	4	0	0	2
80-84	1	0	0	0
Average	71.9	62.1	59.5	68.9

Table 3. Height distribution of 15 plants from each field as measured on July 20 2010.

While the NPK-fertilized field 1 showed good growth rates and more regular growth during the season, it became clear why it may not be a good idea to fertilize this crop excessively. Towards the end of the growing season, heavy rains set in, pretty much destroying the rye field next to the flax. Lodging was also heavy on field 1, while it was less of a problem on fields 2 to 4. In the end, all fields were able to right themselves, but it took longer for the heavily fertilized flax to recover from lodging. Also the stalks on field 1 were coarser, and less useable for spinning. In conclusion on field 1, heavy fertilizing of flax is not a very good idea.

Harvesting

Harvesting is done by pulling the entire plant from the ground, and no tools are used. In fact the correct term is “pulling”, not “harvesting”. The taproots do not extend very deep into the soil, so they are not difficult to loosen from the ground with one hand. Any excess soil is shaken off the plants, and the crop is bundled when the other hand is full, using a few plants to wrap around the bundle.

The four fields were pulled on the 2nd of September 2010. Due to various circumstances, including the weather, this was somewhat later than we had originally planned. The plants had already reached a ripe state, whereas it is beneficial to harvest the flax young. This does not influence much on the further experiment, as the flax used further on were crops from previous years. The state of ripeness of the plants will not significantly influence the time used to harvest and process them. There is however an effect in the recorded yields, as the plants were allowed a longer growth period.

Each strip was harvested separately in timed sets of 2 metres. The crop from each 2 m section was also weighed separately. Two persons worked together to harvest each field (Figure 24, Table 4).

Figure 24. Hans Jørgen Jakobsen and Lars Jensen harvesting field 1.

Field	Time (min:sec)	Harvest (kg)	Grams per min.	Grams per m^2
1	34:33	17.148	496.3	1184.5
2	24:31	12.470	508.6	876.6
3	26:04	10.900	418.2	782.5
4	29:44	14.026	471.7	1025.4
Total	**114:52**	**54.544**	**474.8**	**968.6**

Table 4. Harvesting the four experimental fields. Weight of green plants.

In total, 115 minutes were used to harvest 54.5 kg of flax. Since two-man teams were timed, the measured time must be doubled, making the sum close to 4 man-hours (3h 50min) to harvest 54.5 kg of flax plants. There is a linear trend between time spent and amount harvested across the four fields, so that 400-500 grams of plant can be harvested per minute. Field 3, with the lowest yield, also had a noticeably lower amount harvested per minute than the other three fields.

One section of the fields fall lies far outside the linear trend between time and amount harvested. The first two meters of field 4 were used to establish the working and recording procedures. Therefore it took 6:00 minutes to harvest this area, whereas the projected time, based on the other sections, should have been 3-4 minutes. This extra time is not factored out again in the numbers, although it would have an impact on the grams harvested per minute, which could have been somewhat higher in field 4. Omitting this first section, 515.6 grams per minute was harvested from this field.

The layout of the fields in narrow strips had a visible impact on the crop, as the plants growing along the edges of each row were considerably thicker than those harvested further in. While the narrow fields were practical for a controlled experiment, and made weeding easier, they did affect the final product. The effect on our experiment as such is fairly limited, however, as this flax was not used in the further processes.

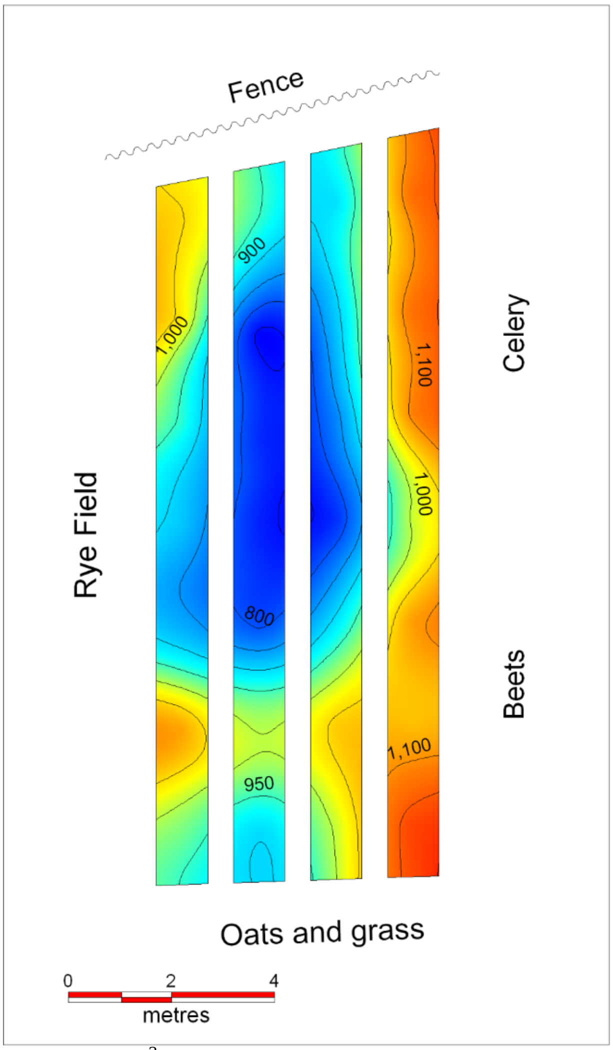

Figure 25. Yield in grams per m^2. Here interpolated using Inverse Distance Weighting. The contour lines show increments of 50 gram per m^2. The sand pocket in the central part of the site stands out clearly on this map. Scale 1:150.

Drying

The crop was immediately hung up on to dry in the wind and sun. The Danish expression for this process translates to “weathering” (Da: “vejring”). According to Robkin (1979) the seeds may still ripen during this process, but most authors agree that it is better to pull the flax green, to get better fibres, and then leave a small proportion of the field unpulled, to let the seeds of this last part ripen on the stalks to produce seeds for next year. In our case, the crop was relatively ripe, but still needed to dry out.

The racks for hanging up the crop were placed in the immediate vicinity of the fields, giving a short transport time. Transport time is an obvious confounder of experiments like this, and can hardly be factored in, as it would depend on the outline of each individual site. Rotation of the crops would even mean that transport times varied from year to year. After harvest the flax bundles were stacked right outside the field, some 15 meters from the rack on which they were hung.

Figure 26. Lars Jensen, Birgit Thomsen, Amanda Appel and Sara Gjerlevsen are hanging the flax bundles up to dry. The bundles from each of the four fields are kept separate. Note the lost stalks in the foreground.

It took four people 13 minutes to hang up the harvested flax. In all 52 minutes of work, although one especially interested tourist took up a considerable amount of one worker's time (this "loss" was timed as well), so that the total was 46 minutes of actual work.

Rippling

When rippling the flax, the upper part of the stalks is pulled through a rippling comb, to remove the capsules containing the seeds. This was done by two people, one doing the actual rippling, the other preparing the bundles by removing the bands around them and laying them out conveniently next to the person rippling. Even though the stalks used to secure the bundles cannot be used in spinning, because the fibres are broken, they are still rippled, to extract the seeds. While the capsules were weighed from all four fields, the rippling was only timed for fields 2 and 4. In total the weight of the capsules made up for 13.6 kg, or 25% of the total weight of the freshly pulled flax plants.

Field	Time (hour:min)	Capsules (grams)
1	-	4535
2	0:50	3089
3	-	2811
4	0:49	3168
Total	**1:39**	**13603**

Table 5. Rippling the flax. Time and output.

As part of the process, the capsules were collected in sacks, one for each field, and the stalks re-bundled. The total time spend for these processes was about 1 hour 40 minutes, which should be multiplied by two, as two persons were working together in this process. The person not doing the actual rippling also found ample time to register and photograph the experiment, so the total time is possibly exaggerated. On the other hand, some time is needed to set up the rack. This did not take long, although we did not time it, but would then outweigh the slight exaggeration of time in the rippling itself.

Figure 27. Amanda Appel rippling the flax.

Note that there seems to be little difference in the time spent on the two fields even though there was a substantial difference in amount harvested. This may be because we harvested in 2m sections, meaning that the number of bundles from each field is much the same (2-3 from each section). If this interpretation is correct, then handling the bundles is as much of a factor -in terms of time- as the actual rippling itself. One may also note that the time spend on rippling is close to twice that of harvesting the plants.

While fields 1 and 3 were not timed, the almost identical times used to ripple the stalks from field 2 and means that we can estimate the total man-hours used to 6 hours 36 minutes for the entire four fields.

As a final part of the rippling process, seed production was measured for each of the four fields. 100 grams of capsules were taken out from each field and cleaned. The weight of the seeds was then measured (Table 6).

Field	**Seeds (grams = %)**
1	42
2	49
3	65
4	52
Average	**52**

Table 6. Weight of seeds from 100 grams of capsules taken from each field.

On average 52% of the weight of the capsules were seeds. Strangely, there seems to be an inverse linear relationship between seeds and plants harvested. The highest proportion of seeds came from the field with the lowest yield of stalks and capsules. One interpretation could be that the seeds themselves have a relatively stable size and number, while the size of the capsules varies with the general growth of the plant. The number of capsules per sample was not counted.

With 25% of the weight of the freshly pulled plants being capsules, and 52% of the capsules consisting of seeds, about 13% of the fields should be left for seed production, while the rest could be pulled green. Percentages were not used in the Viking Age, so more likely there was a rule of thumb that e.g. 1/7th of the field should be left unpulled until mature.

After drying and rippling the yield in dry stalks from the four fields were:

Field	Stalks (kg)	Loss, %	Loss -capsules, %
1	7.478	56.4	40.7
2	6.053	53.4	38.8
3	5.258	51.8	35.0
4	6.841	51.2	37.0
Total	**25.630**	**53.4**	**38.2**

Table 7. Yield in dry, rippled stalks. This is compared to the weight of the freshly harvested plants (Table 4) and omitting the weight of the capsules (Table 5).

The total loss was about 50-55% of the weight of the freshly pulled plants. Omitting the weight of the capsules, the loss was about 35-40%. These numbers also includes stalks lost during handling and processing. This is a noticeable loss, even before the treatment of the flax has begun.

Conclusion

Flax is a beautiful crop. Light blue flowers grow out every morning, only to be shed later in the day. Next morning the field is then covered in a new set of flowers. As such it is a very decorative addition to the crops grown at the Viking Centre, and also attracted much interest from the audience visiting the Centre during the season. It was natural for students and staff to participate in the presentation of the project to interested visitors, although this was always a balance of timing sets for the experiment and presenting the experiment.

In all, the time budget for growing 54.5 kg of fresh flax, or 25.6 kg of dry stalks, is summarized on Table 8.

Stage	Process	Time (hour:min)
Preparation	Manuring	~0:10
	Ploughing	~1:00
Growing	Sowing	~0:30
	Harrowing	~1:00
	Weeding	~24:00
	Harvesting	3:50
Post-processing	Drying	0:46
	Rippling	~6:36
Total		37:02

Table 8. The total time budget for growing flax in 2010. Times marked ~ are estimated. The sum is therefore also an estimate.

The total is about 37 hours of work, although it is important to stress the character of estimate of this number. To this must be added time for transport, depending on the distance between fields, racks and storage. As discussed in the introduction, this is time that can never be quantified outside a specific historic context. However as shown with the example of Næs (chapter 2), there it at least some evidence that transport between processes was minimized.

The Viking Centre is placed in a part of Denmark, which has some of the worst soils for growing flax – or basically any crop. We expected the yields to be on the low side of what is possible. Low yields are *a priori* countered somewhat by the additional fertilizing of field 1, which did indeed have a higher yield in kg / m^2. This field however produced flax that was virtually useless for further processing, due to coarse and weak fibres, and since it was only in for comparison, should rather be omitted from further calculations.

The yield we produced overall was equivalent to 9866 kg / ha in fresh plants. Omitting field 1 the yield was 8939 kg / ha. After drying and rippling the numbers were respectively 4551 kg / ha and 4339 kg /ha in stem dry weight.

Such numbers can normally not be compared to those from modern agriculture, as farming techniques in general have changes considerably during the 20th century, and yields overall increased dramatically. A general problem in comparison is also that the units vary, so that different measurements are made. It is interesting, however, that in modern experiments in central Italy, Rosini and Casa (2003) reported yields between 5.6 and 6.1 t/ha for autumn sown flax, and only 1.9-4.1 kg / ha for spring sown flax. This measured stem dry weight, so yields were measured after drying and rippling. In contrast, average yields is 6.8 t/ha in France and 6.6 t/ha in Belgium (Weightman & Kindred 2005). Northwest European flax is spring sown, illustrating the effects, not only of soils, but also of different climate regimes across Europe. Latvian researchers have reported modern straw yields of 3.3-7.5 t/ha (Komlaveja *et al*. 2010).

For Danish conditions the yield is normally in the range of 5-7.5 t/ha using conventional methods (Pallesen 2009). However numbers may vary substantially. In an experiment done in 1994, Pallesen (1996) reported a yield of 2281 kg/ha in stalk dry weight. Growing conditions for that year were particularly dry.

These are modern data. Turner (1972) gave the yields for *scutched* flax in Scotland during the late 18th century to vary between 13 and 50 stones per acre (204-785 kg / ha) with an average around 440-550 kg / ha. The average for Ireland 1892-1892 was 429.0 kg / ha (Anonymous 1893). These numbers are fairly close, although separated by a century and from different parts of the British Isles. To compare these historical numbers to the values given above, we have to estimate the loss caused by processes up till the scutching. Based on the later experiments, a reasonable estimate would be that the scutched fibres weigh about 20% of the dried stalks. These yields would then be equivalent to an average of 2200-2750 kg/ha for Scotland and 2145 kg/ha for Ireland in stem dry weight.

When compared to the historical numbers, it seems that even in less than favourable soil conditions, we secured a rather good crop during our experiments. Even the meagre looking fields 2 and 3 seem to have produced an above average yield. There may be several reasons for this discrepancy. We have cultivated a relatively small plot of land, meaning that the field could be given more attention that a larger, commercially cultivated area. We did also harvest the flax relatively late, meaning that growth has been allowed to continue longer than what is beneficial to produce a high quality fibre. Our measured yield may therefore be higher than what is good for the crop. On a similar note, fertilizers are likely not to have been used at all, meaning that even on fields 2-4 we have produced a larger, but lower quality crop. Historically, manuring did not take place every year, but mostly at specific stages of a crop rotation cycle. Since flax is sensitive to high N-levels, reducing quality if too high, no or only limited manuring should take place on flax fields. In our case the soil is of a very bad quality, so at the onset it has been assumed that some fertilizing was necessary.

The high yield should therefore be understood in quantitative terms as harvested plant material. The quality of the crop for fibre production was actually very low, and the fibres mostly suited for making tow.

We are therefore probably on safer ground if we use the historical data as a proxy value when assessing the areas needed for flax production. Although there is still a massive loss during the process from the harvested flax to the woven linen -as we shall show in later chapters- these numbers mean that even relatively small plots of flax would cover a household’s domestic need for clothing. Based on the numbers from Scotland and Ireland, some 20-25 m^2 would suffice to produce a Viborg shirt. This means that from our four test fields enough linen could be produced to make slightly more than 2 Viborg shirts, had the quality been better.

The main conclusion of these experiments is possibly that much experience has been gained, and that we should continue our experiments with farming flax in coming years. One main change should be the omission of any type of fertilizers, possibly producing a better quality of flax. With the sensitivity to weather of this crop, it is also important to have longer time series than just the yield from a single year. As flax is grown annually at the Centre anyway, there is at least at good basis for further experimentation.

4. From Plant to Yarn

With one exception the flax grown in 2010 was not used in the further experiments. Instead we used four batches of flax grown at the Centre in 2008 (batch 1) and in 2009 (batch 2-4). Most of the experiments described in the following actually took place while the flax described in chapter 3 was still growing in the field. It was therefore very practical to have the crop from previous years available, as is possible in an established institution such as Ribe Viking Centre.

Retting

Retting is a fermenting process where the flax is allowed to rot slightly. The process dissolves the glue binding the fibres together. This glue consists of lignin and pectin and keeps the plant tissues together.

As already mentioned in chapter 1, there are two main ways to do retting; **water retting** and **dew retting**. When water retting, the flax is laid out in stagnant or slow running water, held down by stones or other heavy objects, ensuring that the flax is completely under water. A number of bacteria work to dissolve the plant glue. These bacteria develop spontaneously from germs in the soil so it is not surprising that many different micro organisms have been isolated during the retting process (Tanner 1922; McClung 1956; Bjørn 1974; Sing *et al.* 2008). The bacteria active in this process are all anaerobe (*Clostridia*). Some of these are important pathogens, such as *Clostridium Botulinum* and *C. perfrigens*, both of which has been proven active in the retting process and can cause dangerous diseases. This could explain the ban against retting in watering holes, which is found in early modern bylaws, such as those from Sønder Jernløse in 1598 and Rønninge in 1601 (Bjerge & Søegaard 1906).

The variety of bacteria found active in the retting process seems to indicate that they vary according to soil type and climate, and that every region will have its own set of retting bacteria. It has been found that it is the combination of different bacteria that make retting possible. Experiments with isolated bacteria have been performed and it was found that no bacterium on its own would initiate the retting process (Jacobsen 1958). The bacteria decompose the plant pectin, leaving the fibres, but if the retting process is continued for too long cellulose fermenting bacteria and fungi develop and the fibres are also destroyed (Sing *et al*. 2008). It is important that the retting is not stopped too soon or too late. If the flax is allowed to ret for too long the fibres will have rotted and be useless. If it is retted too little it will not be possible to separate the fibres from the shives. However, the retting process can be stopped and started again by drying out the straws to stop the process and laying them out to start it up again. This means that it is better to allow the retting process to be cut short rather than letting it go on for too long as the retting can always be started again if it should turn out that the flax is not yet ready for breaking. Once the retting process is done the straws must be dried out completely before they are processed further.

Because of the toxins and microorganisms that develop, it is best to change the water regularly before it is too contaminated. Retting is faster in very contaminated water but it can easily get out of control and is easier to handle when changing the water. A bucketful of old retting water can be added to speed up the process slightly when retting a new batch. The warmer the water, the faster the retting process will be, but care is needed as the retting can be very quick. After about 1 or 2 weeks when the flax starts to stink it is taken out of the water and rinsed in cold water to stop the process, and then dried out completely (Møller Hansen, K. & Høier, H. 2000).

When dew retting, the flax is laid out in a very thin layer on a field and flipped circa every other day so the bacteria from the ground reach all the straws (Jacobsen 1958). If the weather is dry it is flipped less often. A long stick which is slightly bend at one end is uses flip the stalks over the root end, making sure that all the fibres are aligned with the root in the same end. The roots are kept on the plant so the bacteria will not dissolve the glue in the actual spinning fibres.

Figure 28: Laying out the flax for water retting.

Figure 29: Laying out the flax for dew retting.

Dew retting can be done any time of year but the best time is from August to October when the weather is hot and moist, which creates a good climate for the retting fungi. It can be hard to tell when the retting is done but is usually takes 4-8 weeks, depending on humidity and temperature. The straws change colour to a lighter, more silver gray colour and the individual straws are easy to break by rubbing whereby the fibres will appear. Once the retting is done the flax is set out to dry in the sun. It has to be very dry so it is important that it is not stacked together (Højrup 1972).

Retting has a big influence on the quality of the fibres. If the flax is retted too much then it will affect both the strength of the fibres and the colour, whereas the fibres will contain shives if the flax is retted too little. Generally the flax can vary a lot in colour depending on the growing conditions and the retting method; water retting gives a more white colour but can also produce a yellowish or greenish colour whereas dew retting gives a gray fibre (Behr 2000; Jacobsen 1958).

Figure 30: The dew retting area.

The experiments

Dew retting

The experiment of retting ran over several weeks during the summer of 2010. Several batches were laid out for dew retting on a grassy area and these were weighed before and after retting.

Each batch was laid out separately in a very thin layer with all the root ends in the same direction. Each batch was flipped over the root end a different number of times, circa every other day, to ensure the even spread of the bacteria from the ground that initiate and continue the retting process. It was flipped over the root end using a long stick that was placed underneath the straws and then lifted to flip them. The flax was laid out in parallel rows, making sure that there was enough room to flip the first row over.

Batch	Retting time	Initial weight	Final weight	Remaining %
1	3 days	3400g	3077g	90.5
2	8 days	2436g	2254g	92.5
3	8 days	2497g	2089g	83.7
4	36 days	1453g	1131g	77.8
Total	**-**	**9786g**	**8551g**	**87.4**

Table 9. Results from the dew retting.

The flax in the 3rd batch took 6 minutes to lay out for retting with 2 people working and about the same was true for the 4th batch. The area covered by the straws was 2.45x7.05m but as an extra length is needed to ensure enough space for flipping the stalks this area should be approximately 3.10x7.05m. It took about 1 min 20 sec to flip a row 7 m long. A 6 m long row from batch 4 took 1 minute even to turn.

Water retting

During a later stage of the project, we decided to try water retting as well. An artificial pond, placed in the goose pen at the Viking Centre, was emptied for water and cleaned, and then filled with fresh water from a nearby stream. The geese were temporarily moved. For these experiments we used the flax that was grown during the 2010 season, which by this time was rippled and dry.

Unfortunately there was no time within the project to process these plants further. While we did measure the weight of the bundles before retting, and monitored water quality, the project ran out before we could process the results further.

Discussion

The batches took different amounts of time to ret as some retting had been going on during storage. The 1st batch only took 3 days because it had been stored for so long in a humid place. The fibres were already slightly mildewed when they were taken out of storage to begin retting. The 4th batch was generally finer in quality than the rest and this is probably the cause of the longer retting time needed. The 4th batch had been stored differently, in a drier place so no previous retting had been going on.

During the retting process the flax lost some volume, ranging from 7.5% for batch 1 to as much as 22.1% for batch 4. This batch had to be moved during the retting process, due to bad weather, and that could have caused some of the extra loss. Some straws were probably left on the field from all batches, but the decaying process itself and the subsequent drying out of the straws also contribute to the loss.

Although the first three batches were already pre-retted due to the way they were stored, we may have been somewhat impatient in taking them back in. The relative differences in loss, and the low quality of the product in the further processes indicate that this may have been the case. If this is true, then batch 4 would yield the most precise result, also in the following experiments, in spite of the extra loss that may have been induced by moving this batch.

The retting process is quite a passive process in that once it is laid out on the field or in the water for retting it is basically left alone. If it is retted on a field it must be flipped every so often but in general the work is left to the microorganisms until the flax is retted. As far as work load is concerned the retting process is probably the least demanding of the many processes. If water retting involves the digging of wells, then this process is obviously much more time consuming. But the wells can probably be maintained for several years, so although the wells would require regular maintenance the initial investment in time is levelled out by a long use.

Breaking

Breaking is a process in which retted, dried flax is broken up in order to separate spinning fibres from the woody bits of the straws called shives. The breaking can be done at any time as long as the flax is completely dry. The flax can be dried in a number of different ways, but the best way is over a breaking pit. Usually the pit consists of a hole with a low-burning fire in it. Rods are laid out over the hole and the flax is spread out on these rods. The flax straws are turned every now and then to make sure that the straws dry out evenly. The flax could also be dried on a sunny day e.g. by spreading it against a wall and turning it over, but this method is less effective than a breaking pit (Højrup 1972).

The process

Once the straws are dried, they can be broken. The breaker we have used here is based on later examples, but these tools have hardly changed much, as discussed in chapter 2. The process is in reality quite simple, and involves heavy pounding with the breaker. The purpose of the process is to break the woody parts of the stalks so that they can be removed in the following processes. A handful of flax is placed in the breaker and the moveable top blade is brought down hard onto the flax. When the flax is jammed between the blades it breaks. The flax is broken from top to root until the entire length is well broken. During the breaking the bunch is twisted and turned to ensure a maximum number of breaking points. Once in a while, the bundle can be snapped in the air to remove the worst of the shives. (Højrup 1972).

Figure 31. The breaker.

A "linen club" or mallet can be used to break the woody fibres of the straws by beating them systematically over the edge of e.g. a wooden stump or a stone. It has been suggested that the clubs were used first and then the breaker, or that perhaps the clubs were used earlier in time before the breaker was invented (Hald 1950). Using replicas of the mallets from Oseberg (Brøgger og Shetelig 1928), we have also tried this method.

The experiments

Flax from the 1st batch was broken using both the club and the breaker. Due to an error only about half of the 1st batch was weighed after breaking. This half weighed 512 g. The 3 first batches were dried in the sun or by a warm oven while the 4th batch was dried over a breaking pit.

Batch	Weight before breaking	Time (minutes)	Weight after breaking	Remaining %	Grams per hour
1	3077 g	56:00	512 g (only about half was weighed)	-	-
2	2254 g	133:00	396 g	17.6	1017
3	1871 g	137:27	536 g	28.6	817
4	1131 g	95:17	556 g	49.2	712
Total	**8333 g**	**421:44**	**2000 g**	**28.3**	**862**

Table 10. Results from the breaking tests.

The 2nd batch of flax weighing 2254 g after retting and drying was broken using the breaker in 133 minutes, dwindling to a weight of 396 g. This batch of flax has a slight source of error connected to it. At an earlier date it was attempted to break this batch but as the drying proved insufficient, it was set by for drying again until a later date. A few handfuls had been broken and scutched on the earlier date but these were weighed in with the rest of the batch before breaking begun the second time. The weight was then 1577 g. The weight after retting had been noted, 2254 g, but as discovered for the next batch some loss of material also takes place in the drying process prior to breaking and this amount was consequently not measured completely for the 2nd batch.

The 3rd batch was broken using the breaker. Before breaking the flax was weighed to 1871 g. This indicates a loss of 218 g in the drying process. The amount of loss in the earlier batches is unknown as the weight after drying, but before breaking, was not recorded for any of the other batches.

Figure 32. Amanda Appel breaking flax from batch 4. The breaking pit is seen in the background.

The 4th batch which had been dried over a breaking pit was broken far more thoroughly than the rest. The fibres came out easier and the straws were generally much easier to break. A lot of shives were still present on the fibres but the result was far better than breaking with no prior drying over a heated pit and as indicated in the table above less material was lost during the process. This indicates that the drying pit was a very important feature in the flax production.

We spend increasingly more time on breaking the flax, though. The increase in time per kg is close to 25% from batch 2 to batch 4. This could be because we knew the following processes better, and therefore knew which kind of product had to come out of the breaking process.

Some of the flax from batch 1, as well as a few handfuls of batch 4 were broken using the club. When using the club the fibres were hung over the edge of a wooden stump and beaten with the club one handful at a time. This took about 1 minute 30 seconds for a skilled person and 4 minutes 41 seconds for a student who tried it for the first time. In spite of the forced drying, it was still very difficult to achieve an acceptable result.

Discussion

The process of breaking causes a massive amount of loss in the work material. As much as 71.4% of the material was lost in the 3rd batch and 82.3% of the 2nd batch. For the 4th batch about half of the material was lost during breaking, exactly 50.8%, even though we did not correct for any loss of material between the processes. This indicates that a large amount of flax was needed to produce relatively little broken flax at the end of this stage. It is however characteristic that the well retted and thoroughly dried batch 4 had the least loss.

During the experiment it was found that the breaking process did not yield satisfactory results, and we had to adjust. A lot of shives were left on the straws, but even though more time was used for each handful the result was only marginally better. In the end the team took to breaking the last shives in each handful by hand before scutching.

Especially the linen club was found unfit for the breaking process as it often only just flattened the straws without breaking them properly. As the linen club is mentioned as an alternative to the breaker in almost all literature we had encountered, this surprised us somewhat, and send us through the literature again. These tools were used up until recently and apparently there are scores, if not hundreds, of them preserved at the historical museums across Scandinavia. We finally found an ethnological description of their use from Dalarna, Sweden (Dalgård 1916). The description is not entirely easy to follow, because it uses special and local expressions for the tools and products, which are not always defined. But according to this description, the club was used as an additional treatment *after* breaking. The club is mentioned in connection with two different products. First as an extra processing of straws that were initially difficult to separate from the seed capsules. And later as to remove shives from the tow.

While we found the club difficult to use, Pliny mentions it as used for breaking flax. In an overview paper on the Swedish domestic linen production, Jirlow even mentions that it was still used instead of the breaker in some areas of Sweden (Jirlow 1924: 147). This may be a misunderstanding, as one of the areas he mentions (Dalarna) is where the above description is taken from.

It was later found that the club could also be useful in another process of flax growing and processing; viz. smashing the seed pods to separate the seeds from the pods in preparation for storage and/or consumption.

The use of a breaking pit proved important. While it is possible to break flax after having just dried it in the sun, the warm stalks from the breaking pit worked much better.

This experiment was hampered somewhat by errors in measuring and weighing. For the first 2 batches no weight was taken before commencing, but since the weighing of the 3rd batch indicates some loss of mass this should be done in future experiments of this kind. The measurements of the 1st batch are also problematic since only about half of it was weighed at the end of the process. These errors were primarily due to the inexperience of the team performing the experiments and are easy to fix for future experiments by making a plan stating exactly when and how everything should be measured and weighed at each stage.

Figure 33. After breaking. Note the amount of waste on the ground

Scutching

Scutching is a process in which the shives are removed from the broken flax. There are several ways to do scutching. You can shake the shives off, scrape them off using a knife-like tool, pull the fibres between 2 sticks or use a scutching knife and board; a knife-like tool and a vertical board-like stand, respectively

.

Figure 34. Scutching knife and board.

When using the scutching knife and board you grab a handful of fibres about 1/3 from the top and leave the root end hanging over the edge of the scutching board. Then you use the scutching knife to "beat" the shives off by swiping it down the scutching board. You turn the bundle once in a while to get all the shives out and finally scutch the top end, while holding on to the root end. Once in a while the bundle is "opened" so the innermost fibres are on the outside so they can be scutched (Møller Hansen, K. & Høier, H. 2000; Runge & Henriksen 2007).

The experiments

Scutching was done using a scutching knife and board. It took about 3 minutes to scutch one handful. Only about half of the 1st batch was weighed after breaking. The 1st batch was scutched and of the 512 g portion 387 g was left. From the entire 1st batch there was only 817 g left, a considerable waste from the original 3400 g that was laid out for retting.

No time was taken for the 2nd batch as interested tourists distracted the scutcher to the point of negligence. This was a drawback of performing the experiments in an environment where the direct contact with the public is of great importance and sometimes this would take precedence over the exact measuring of time. Usually the team would subtract time spent on interacting with tourists from the results but in this case that was not possible.

The 3rd and 4th batches were fully scutched and documented.

Batch	Weight before scutching	Time (min:sec)	Weight after scutching	Remaining %	Grams per hour
1	512 g (/ ?g)	67:00	387 g (/817 g)	75.6	459
2	396 g	-	312 g	78.8	-
3	536 g	52:56	369 g	68.8	608
4	556 g	52:48	465 g	83.6	633
Total	**2000 g**	**172:44**	**1533 g**	**76.7**	**557**

Table 11. Results of the scutching tests.

Figure 35. Amanda Appel scutching under the guidance of Birgit Thomsen.

Discussion

For the 3 timed batches it appears that a quite consistent pattern emerges. 7.6 g was scutched per minute in batch 1 while 10 g was scutched per minute in batches 3 and 4. The slightly lower number in batch 1 is probably due to the learning curve as batch 1 was the first to be scutched by the team. The loss of material during this process was slightly different from batch to batch. Batches 1 and 2 were consistent with respectively 24.4% and 21.2% lost while batches 3 and 4 are the high and low mark of these experiments with respectively 31.2% and 16.4% lost. The small(er) loss of material in batch 4 is probably an indication that this batch has been processed better in the previous breaking stage.

There was a limited amount of waste in this process, compared to the breaking process, probably due to the fact that so much of the waste products had been separated already but also due to the seemingly inefficient way of performing this task. A lot of shives were left on the fibres even after they had been scutched for a long time and often the shives would just be beaten flat instead of falling off, leaving a large amount of waste to be taken out during the next process of heckling. Perhaps other methods of scutching should be tried in other experiments to see if these are more efficient or more time should be spent scutching each handful, although this was tried to some extent and did not seem to help too much.

Heckling

Heckling is the sort of safety net in the whole flax production process. It can, and should correct all the mistakes and issues which were not dealt with during the previous steps. If, for instance, the flax was not properly retted and it was difficult to remove the majority of shives from the fibers, or the flax was not thoroughly broken, heckling will still be able to draw out the usable fibers for spinning. The quality of the fibers also becomes most apparent during heckling. Well processed fibers will come out long and resilient, those which were not fully retted or dried before processing will break easily and become badly tangled. Ideally, fibers before heckling should be largely free from shives and this process should only serve to detangle, smooth and separate the long and short fibers. However, this is rarely the case, and therefore the process more often becomes a rescue mission rather than just a tidying process.

The tool

All that is required for the heckling process is a heckle and some muscle. The comb used for this experiment is based on the heckling comb found at Århus Søndervold, a 10th century Viking settlement. We then assume that it is indeed a heckle and not a wool comb.

Figure 36. The heckling comb used in this experiment.

The process

Heckling requires a certain amount of finesse which can only be achieved after quite a lot of practice. The flax post-scutching and pre-heckling may at best be characterized as messy, and at worst may resemble badly chewed hay. The amount of shives which still clings to the flax fibers is dependent on many other factors before heckling (such as the way in which the flax was retted or how thoroughly it was broken), however, through heckling it is possible to remove a significant amount of the remaining shives and tow and smooth the fibers for spinning. The quality of the heckling will determine the quality of the fibers and ultimately the thread that is produced. The longer and smoother the fibers are, the finer the thread that will be produced. For this experiment, we have determined that only very fine thread would have been used in the weaving of the Viborg shirt, and thus, our experimentation was oriented on deriving the finest fibers possible through this process.

To begin heckling, the heckler should find a table on which to work, and then secure the heckling comb to the surface with a peg (this is not necessarily necessary, but it really helps give leverage on the harder knots), the comb teeth should point away from the heckler. If the comb cannot be fastened to the working surface, the comb should be held in the less dominant hand, while the dominant hand pulls the flax through. However, it is easier and more effective to use both hands to guide the flax during this process. Next, take a good sized handful of the scutched flax, there is no definite amount which works best, it all depends on the size of the comb, the standard to which the flax was processed up to this point and the skill of the heckler. The heckling batch should be enough to spread thinly and evenly through the comb teeth. If the flax was not well scutched, less flax should be taken per batch, as it will be quite a struggle to strip off the remaining tow, and too much flax will only cause the whole batch to stick firmly in the comb and break off the fibers. After the batch is determined, starting at the tip of one end spread the flax across the comb and press it into the teeth. Gently, but firmly, pull the flax through.

This process is much the same as combing out long hair, jerking the flax will only cause more knots and will break the fibers, resulting in a coarser thread when spinning. Gently comb from one end inwards toward the middle of the batch, and then start the process again from the other side.

Figure 37. The flax is pressed into the teeth of the comb, and pulled through.

It should be noted that this process produces a considerable amount of waste. This should be saved for a second heckling, which will produce shorter fibers for a coarser thread. The remaining waste will mostly be tow and shives and makes an excellent fire starter.

Figure 38. This shows the products of the heckling process: waste (tow with shives), short fibres for coarse thread and long fibres for fine thread.

The experiments

In total we performed six different heckling tests, the first two of which were done with pre-heckled, purchased flax; the last four were done on the batches of flax we had been working with throughout the project. The modern processed flax had already been schutched, and the purpose was more to do some trial runs, and to learn how to separate out long and short fibres in the process.

Test Number	Initial Weight	Time	Final Weight	Remaining %	grams/ hour
Batch 1	43 g	10 minutes	36 g	83.7%	258
Batch 2	312 g	-	103 g	33.0%	-
Batch 3	247 g	64 minutes	146 g	59.1%	232
Batch 4	465 g	73 minutes	207 g	44.5%	382
Total	**1067 g**	**147 minutes**	**492 g**	**46.1%**	**308**

Table 12. The results of the scutching tests.

At first glance, the results of these trials appear to range all over, with no particular pattern. However, as has been stated, there are many extenuating circumstances surrounding each of the trails which magnify themselves greatly within the data.

Batch 1 was the first batch of flax which had been fully processed during this experiment; it was also the smallest batch of flax which was heckled. It was a well handled, if small batch throughout the previous processes, and therefore yielded a high percentage of fibers. The data from Batch 2 is hard to use and compare, as this batch was heckled by the experimenters as well as visitors to the project, and thus the quality of the heckling differed greatly from person to person and no firm time stamp was recorded for this particular batch. From this batch it can be seen though, that even untrained hecklers can produce some amount of usable fibers, though a well practiced heckler can produce twice as much. Batches 1 and 3 are the most comparable in terms of grams/hour production. Despite being five times the amount of Batch 1, proportionally Batch 3 was processed in around the same amount of time. This suggests that an experienced heckler will develop a rhythm, which can process flax at a relatively steady rate over time. The last trial, Batch 4, was performed towards the end of the field experimentation and the flax from this batch had waited a considerable amount of time between retting and processing. Whereas the other batches were broken, scutched and heckled fairly contiguously, Batch 4 was left to wait a long time before processing, and thus the fibers were more damp than would be desirable, and less fibers could be separated out from the sticky tow. This is reflected in the percentage yield of finished fibers from starting flax. However, the rate at which the flax was processed was not hugely different from Batches 1 or 3, showing that despite being a bit damper and difficult to heckle, a heckler will usually be able to keep up a certain rate of production.

Discussion

The desired product from our heckling trials was long, smooth fibers, which are the type required for producing the fine thread seen in the Viborg shirt. The quality of the resulting fibers, however, greatly depends on the previous processes and the skill of the heckler. A gentle, but firm hand is needed to free the fibers from the tow, straighten them and yet not snag or break them. Only practice and experience can allow a heckler to be able to feel the right pressure and pull needed. This process is by no means an exact science, however, from the trial results it can be seen that somewhere around 50% can be expected.

Spinning

Spinning is the ultimate test of all the previous processes. The quality of the thread produced hangs on the quality of the fibers which are extracted by breaking, scutching and heckling. Any tow which remains after these steps will be spun into the thread and ultimately woven into the cloth. However, within the process of spinning itself, there are many nuances which need to be closely observed in order to produce the desired quality of thread. For the purposes of this study, we hoped to spin a thread as fine as that seen in the Viborg shirt, about 22 threads per centimeter.

The tools

The tools required for hand spinning are quite basic, but effective in their simplicity. The flax fibers are initially attached to the distaff, which is, in essence, a smooth, straight stick. The main distaff used in this project is over a meter and a half tall and affixed to a heavy wooden base. It is not particularly portable, and so the spinner must stand stationary for the duration of the spinning process. However, distaffs can come in any sort of size, and for other spinning projects, a small portable distaff could be used.

Figure 39. Birgit Thomsen spinning. Left: Stationary distaff. Right: Portable distaff, for spinning on the move.

The tall, stationary distaff was well suited for the long and fine thread we sought to produce. For the shorter fibers, the small, hand-held distaff was the best choice for spinning. Unlike the long fibers on the stationary distaff, which are firmly bound onto the post, shorter fibers can merely be wrapped around the small distaff, much the same as cotton candy.

Figure 40. Attaching short fibres to the portable distaff.

After the fibers have been affixed to the distaff, they are ready to be spun with the use of a drop spindle. The spindle used for producing our thread is very simple: a thin shaft with a flat whorl around the lower end and a metal hook at the top of the shaft.

The hook is used to catch into the fibers and hold the thread onto the spindle. The whorl adds the needed weight to pull and tighten the fibers together, and keeps the spindle in motion.

Figure 41. Two spindles and their finished products.

The process

Spinning is a very delicate process which requires a high level of patience and concentration. After the flax has been heckled it, hopefully, is free of most of the remaining tow. Ideally, the fibers should be long, smooth and even, with little to no tow; this will provide the finest level of thread. However, in the likely chance that there is some stubborn tow left in the fibers after all the preceding processes, the fibers can still be spun, though the resulting thread and cloth may be a bit scratchy.

To arrange the flax fibers for spinning, a large bundle of same length fibers should be gathered and bound together with twine, ribbon or cord towards one end.

This cord should be long enough to wrap several time around the bundle. Next, this bundle is firmly affixed to a tall post, called a distaff, using the twine to wrap around and around the fibers and the post. The whole bundle is then flipped over itself, and its binding, and looks remarkably like a blond wig on a broom handle.

The flax is now ready to be spun. Find an area somewhere around halfway down length of the flax, and catch the hook of the spindle in a few fibers. Make sure the hook is well tangled into the fibers; otherwise the spindle will simply fall off as it spins. Pull gently on the spindle to extract the fibers to be spun. Next comes is the most delicate step in the spinning process. There will be a patch of fibers that comes out attached to the hook of the spindle; however, the thread itself requires only a few of them. The spinner must be very careful during spinning that she maintains control over how many fibers are being spun at any one time, otherwise the thread very quickly becomes chunky, uneven and loose. The best way to control the outgoing fibers is by positioning the fibers and fingers in a V shape. The fibers should be separated into a V at the end of the patch being spun, pointing down and directly going into the thread, similar to two tributaries converging into a river.

The pointer and middle finger are behind the fiber patch, and the thumb lies over the top, at the juncture of the fiber V. Using the thumb and fingers, it is possible to maintain a constant and even flow of fibers during spinning. Now that the spindle has been affixed and the fibers are poised for spinning, the spindle should start to turn. It is important to remember that though it doesn't particularly matter which direction the spindle goes in, the spinner should make sure that it always spins in the same direction; otherwise the thread will be un-spun. As the spindle turns, the spinner should use their other hand to gently pull the fibers at the tip of the V, just below the thumb allowing them to be spun into thread.

Figure 42. Long fibres bound to the top of the distaff.

As the thread is spun, the spinner should continually coat it with a thin layer of saliva; this will react with the natural binding agents in the flax and bind them together into a strong thread. Depending on how much needs to be spun, sometimes it is nice to have a bowl of water handy during this process. Once the spindle is set into motion, the spinning process goes quite quickly, and soon the spindle will hit the floor and stop. Unhook the thread from the hook of the spindle and wrap some of it firmly around the stick of the spindle, just above the wooden plate.

With a good length of thread remaining, wrap once around the spindle stick below the plate and then several times loosely up the length of the stick and once around the hook. This is not a particularly delicate process, it is merely done to secure the thread to the spindle so that it doesn't fall off during spinning, which can break the fibers and severely slows down the process. As the spinning continues, it will be necessary to stop and wrap the thread every few seconds, so the spinner will quickly become familiar with how to best secure the thread and spindle for their way of spinning.

After a while, the patch of fibers which the thread was drawing from will begin to tangle above the V. At this point it may be hard to draw out the same number of threads as before. Now is a good time to find another location on the fiber wig. Stop the spindle and break off the thread at the base of the V. There should be a tail of un-spun fibers on the thread about two or three inches long which will be used to join this thread to a new area. As before, locate a nice patch of fibers and pull some into the V. Overlap the un-spun fibers on thread with some from the new location and gently start to spin, holding the joint together until it has been spun. Remember to use lots of spit to bind this join and always keep the spindle going in the same direction. Hopefully the join is strong and holds fast, if it does break apart as it is spun, don't worry, just find a new patch and try again.

Figure 43. The ever important V - this maintains a controlled flow of fibres during spinning.

Though the spinning process can be a bit delicate at the start, once the spinner has gotten into a rhythm it becomes easier to feel the subtle nuances of the process, such as the speed of the spindle, the amount of fibers needed for the desired thread and maintaining the perfect V.

The experiments

The goal of this study is to investigate the Viborg shirt, which was made of a fine type of linen. The threads for this shirt were very fine, at about 22 per centimeter of cloth. Long fibers of flax are needed for this quality of thread, and these were specifically extracted during the heckling process. Though we ran many spinning trials, both with novice and expert spinners, not all of the thread produced was the quality needed for this experiment (especially those of the novices). For these trials, we used the pre-processed flax fibers first seen in the heckling trials, instead of those we produced ourselves. The purchased fibers were much more regular and easier to work with, and therefore produced the level of thread we desired for this study.

Each of the spinning trials ran exactly one hour long, and done only by an expert spinner. With the knowledge that more than 10 km of thread had to be produced for an actual shirt to be made, it quickly became evident just how long of a process the creation of the Viborg shirt would have been.

Trial Number	Weight	Length	Running Length	Min. Run. Length	Max. Run. Length
One	10 g	52.33 m	5233 m/kg	4984 m/kg	5508 m/kg
Two	5 g	58.78 m	11756 m/kg	10687 m/kg	13062 m/kg
Three	8 g	59.66 m	7458 m/kg	7019 m/kg	7955 m/kg
Four	6 g	52.44 m	8740 m/kg	8068 m/kg	9535 m/kg

Table 13. The results of the spinning test. Four 1-hour trials.

It is clear that none of these trials produced the same results. It should be noted, though also quite clear, that with any handmade craft, there is some variation and irregularity throughout the product. The thread of the Viborg shirt is given as equivalent to a modern 20/1 thread (Fentz 1988). This gives a running length of 14000 m/kg. None of our trials reached that goal. The scales we had available for the trials could only measure to the nearest gram. To adjust for this imprecision, we have also calculated a minimum and maximum running length, based on ±0.5g of the measured. These numbers represent the maximum possible variation. In fact these corrections do not change the overall picture much.

Our test for fineness during the trials was simply to wind the thread around a flat stick between two marks 1 cm apart, and count the number of times the thread could go around between these marks. The actual running length could only be calculated at the end of each trial. The goal for the spinner was to make a "fine" thread, not to exactly hit the target of 14000 m/kg –which would have been impossible- or even to make the threads from the four tests the same. With variation it would be easier to estimate any relations between speed and fineness.

Trial One came out as the thickest, while trial Two turned out particularly fine. Trial Two does show that hand spinning can produce a thread comparably fine to modern threads. Trials Three and Four were relatively similar. On our simple measuring stick trial Four resulted in exactly the right dimensions of 22 threads per centimeter, while in fact it was off by 40%, when the running length was calculated.

In the four one-hour trials, our expert spinner could produce between 52.33 and 59.66 m of thread. The average is 55.8 m, and there is no discernable relation between the fineness and the length of the thread. It does not take longer or shorter time to make a finer thread.

Comparative case study

In 2006, a flax spinning trial was conducted by the Center for Textile Research (CTR) at the University of Copenhagen (Mårtensson *et al*. 2006). Twenty tests were conducted by two researchers, the aim of which was to see how long it would take, and how much thread would be produced by filling one spindle. It is difficult to compare their results with our own, as the aims of their research were based on a standard of measurement "one spindle full", and the data was presented according to the lengths of time to fill the spindle and varying weights per trial, with no connection on a test by test basis between the two. It is only from the total combined results of the trials that a comparison can be drawn to our experiments. From the combined results of ten tests performed by Anne Batzer, the running length was 9843.5m/kg and for Linda Mårtensson was 13284.4m/kg. The two spinners tried to make similar threads. These results are close to those which were achieved during Trials Four and Two of our study respectively, suggesting that the resulting thread for the CTR trials was of a similar quality to ours. The production rate of the CTR researchers, however, was down to about half of what was achieved during our trials. Batzer spun about 2.47g and 24.34m of thread per hour, and Mårtensson spun about 2.5g and 33.29m per hour.

Discussion

As seen in our trials, it is entirely possible to spin the fine thread required for the Viborg shirt using the tools of the period. However, these trials also proved definitively that this shirt was the product of an expert spinner. Though it is fairly easy to develop a good grasp of the techniques of spinning in a short amount of time, to produce a regular thread of such fineness requires a great deal of skill and practice.

General discussion

Admittedly this was probably a level of skill and practice that most any teenage girl would have acquired some 100-150 years ago. There is no reason to believe that this was any different 1000 years ago, during the Viking Age. What the different experiments have demonstrated is maybe especially the importance of doing experiments like this with skilled artisans. The practical work with the flax described here has been done under the guidance of Birgit Thomsen of Ribe Viking Centre, or for the difficult tasks directly by her. Had similar experiments been done solely by the team of archaeologists, the only result would probably have been a learning process. With the current setup out trials have at least better reliability.

There was still learning process involved, and reliability is no absolute term. Throughout the tests, batch 4 behaved differently than the other three. There are several reasons for this. First of all, batch 4 was the last flax we processed within each set, meaning that we had already some experience when we came to this batch. Secondly it was treated differently. The retting time was much longer and more within the range of what is recommended historically. The retting time was shortened for the other batches because some retting had already taken place during storage, and we assumed that it was enough. In hindsight they could probably well have used a few more weeks outside. This would have delayed the start of project, though. Apart from a better retting the breaking of batch 4 also happened after drying it over a breaking pit. This meant a palpable difference for the process, and we can see that the loss of material is much less. When summarizing the results, batch 4 is probably the most reliable, then. Comparing to the techniques described in chapter 2, water retting combined with fire drying would probably have been the best option, throughout. That is for another time.

Summary of results

The loss of material from **dew retting** varied from 7.5% in Batch 2 to 22.2% in batch 4. Batch was moved around several times, so some extra material may have been lost, but as discussed above, may have yielded the most precise result. The total loss for all four batches was 12.6%. The stalks were laid out in 6-7m long rows, two of which took in all 12 minutes to lay out, and then probably the same to take in. Turning the two rows took about three minutes. This was done every couple of days.

Water retting was tried, but only late in the process. Therefore we have few data on this process.

The **breaking** process gave a massive loss of material, as much as 82% for batch 2. The average loss was 71.7%. With more experience, the team used more time on breaking, so the time for batch 4 is possibly the most precise, although with the lowest amount lost. The speed was 712 grams/hour.

Scutching is best calculated from batch 3 and 4. The loss in material was 23.6%. The processing speed between batch 3 and 4 was very similar, and had an average of 620 grams per hour.

Heckling gave an average material loss of 44%, and could be done at an average speed of 308 grams per hour.

Finally **spinning** could be done at an average speed of 55.8 m/hour. There is also a material loss here, as there will still be some shives in the material. We estimate this loss at *c*. 10%.

5. WEAVING AND SEWING

Weaving

The kind of loom used in this experiment is a warp weighted loom. The loom at Ribe Viking Centre is a replica of an original from the Faroe Islands, called *Worsaaes loom* (Hald 1950). It has otherwise been questioned in the literature whether a finer linen in the quality of the Viborg shirt can be made on an upright loom (Fentz 1988). This especially because the inelastic warp treads will tend to break under the weight of the loom weights. But also because an upright loom tend to give an uneven pattern, while the fabric of the Viborg shirt was very regular. Instead Fentz suggests that a horizontal loom was necessary for making this cloth.

But if it is true that finer linens cannot be woven on an upright loom, then a whole chain of archaeological arguments starts to break. The increase in tabby weaves from the 7th century onwards is assumed by Bender Jørgensen (1992) to reflect an increase in linen cloth. In lieu of actual fibre analyses this claim is substantiated by the increasing number of sunken huts during the period. Many of these huts can be shown to be weaving huts, because loom weights are found in them. The argument is supplemented by Zimmermanns claim (1984) that the moist climate in these huts is especially beneficial for linen production. The warp weighted loom is therefore important for the current perception of the importance of flax in the Viking Age. It was natural to test its use for this type of fabric.

The process

When setting up a warp weighted loom the warp is attached to the cloth beam and is divided into two equal parts. This division happens naturally as every other thread will fall slightly forward to the others creating the shed. The front threads are hung over the fixed shed rod and weighed down with loom weights. The back threads hang straight down from the top boom and are also weighed down with loom weights. Then the heddles are tied onto the movable heddle rod. Every thread from the back is tied in its own individual heddle in order to be able to pull all the threads forwards during the weaving. The heddles are usually tied with one long thread that is knotted to the movable shaft for each thread in order to keep the heddles tight and the threads in order. Then the warp threads are ordered into small bundles below the shed rod and a crocheted line keeps these bundles in place. The same goes for the back threads. Each crocheted mask contains one or more warp threads keeping them in their place. It is important that the crocheting is not too tight as this line will be moved down the warp threads as the weaving progresses. Below this line the warp threads are ordered into larger bunches and attached to loom weights. The warp threads are longer than the finished cloth will be in order to leave enough length for warping of threads and hanging of loom weights during the weaving of the last part. This means that a lot of string is hanging loose under the loom weights and these are usually collected in bundles so they do not get in the way during the weaving and to keep them from getting too dirty from lying on the floor/ground.

Then the weaving begins. The shuttle on which the weft thread is rolled is simply a stick which is easy to pass through the shed. It is important that the thread is rolled up in such a way that it easily uncoils during the weaving, so it does not get stuck. Once the weft has passed through the shed, the ends of the weft are lifted up to touch the already woven material but the weft thread must not be tightened. It is left loose so it hangs down in the middle. It is important that the weft is not tightened too much at this stage as the cloth will then be too tight in the edges when the weft is beaten into place. Then the shed is shifted by moving the heddle rod. Once the shed has been shifted the weft is beaten into place using a beater. This instrument is a long, broad object which is flat on one side and has a ridge on the other. The flat side is turned away from the weaver and with a firm hand the weft is beaten up toward the woven cloth. The beater is pointed and it is the curved edge just before the point that is used to beat the weft. The weft is beaten in the same direction as it was woven. It is important that the thread is not pulled too tight on the edge as this will cause the fabric to shrink in the width. But it must not be too loose either as this will cause loops along the edges. As the weft is beaten the tightness is maintained making sure that it is not too tight and not too loose. As mentioned above the fabric will shrink in the width if the weft is pulled too tight and if it is left too loose it will cause small loops to be made in the fabric.

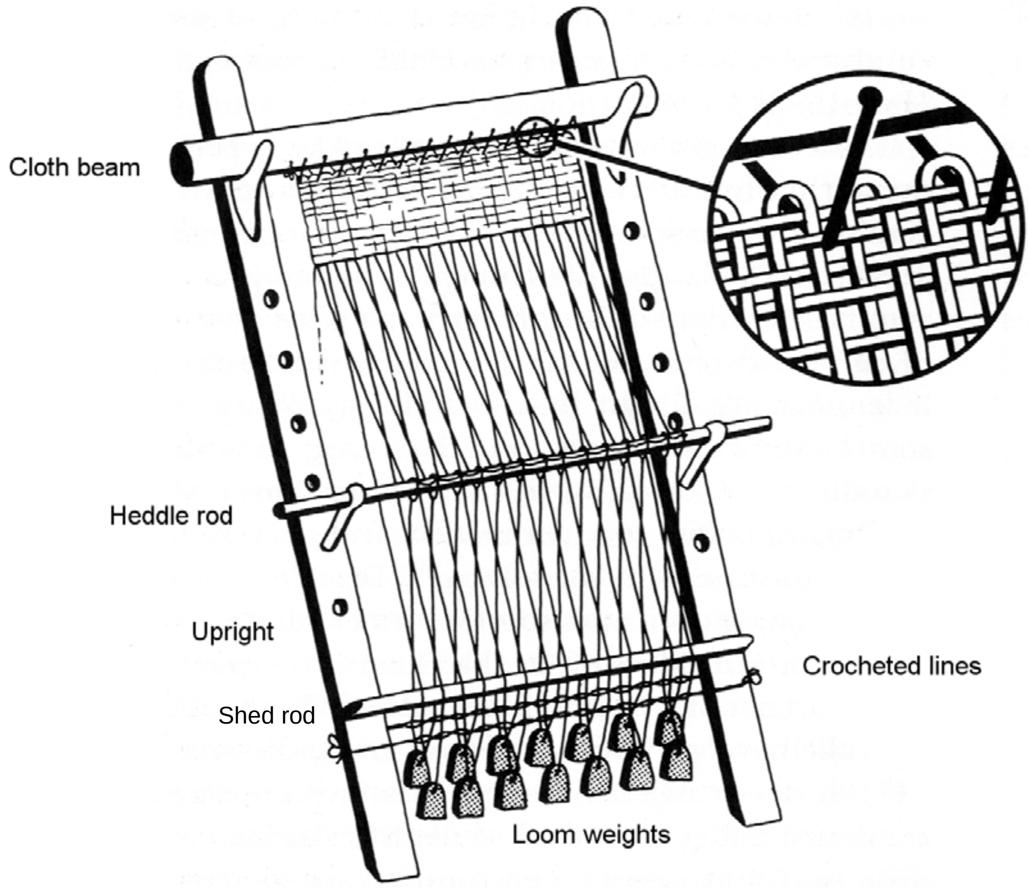

Figure 44. The elements of a warp weighted loom. Here from Jørgensen 1992.

Once a length of fabric has been woven it can be rolled onto the cloth beam. This is done every so often to ensure that the working area is in a proper position for the weaver. When it is time to lengthen the warp, the loom weights and the crocheted line must be moved downwards. The loom weights of the Viking Age are usually flat, round discs with a hole in the middle. The shape ensures that there is room along the loom for a proper amount of weights and the hole in the middle is fitted with a string which the warp threads are tied onto. This string must not be too thin as it will break the warp threads. When working with the loom weights the threads should be ordered so they do not tangle. This will ease the work of moving the crocheted line down.

Once the entire length of fabric has been finished the warp is cut and the fabric is taken off the cloth beam.

During the weaving a number of issues may arise but these are usually easily fixed. The most common problem is the breaking of threads. If the warp breaks a “weaver’s knot” (:sheet bend) is used to tie it back up. It can be tied together again using 2 knots or the thread can be replaced entirely from the top breaking point down. If 2 knots are used it is not necessary to untie and reattach the loom weight. If the weft breaks the end is simply taken out of the warp and left hanging loose. Then a new weft is started a little before the end of the old one causing a double weft for a few centimetres. The beginning of the second weft is also left hanging loose outside the warp. These two ends will poke out from the woven fabric but once a few shifts have been woven below these ends they are simply cut off close to the fabric. If a heddle breaks due to wear and tear it is simply replaced by a new one. The same goes for the loom weights. It is especially the loom weights on the back row of warp threads that are susceptible to damage as these are the ones being moved for every shift of the shed. Beating the warp may cause small holes in the fabric but these can be minimized by covering the same ground twice, essentially double-beating along the weft.

The experiment

The cloth was a simple tabby woven with 22 threads per cm in the warp and 12 in the weft. The threads used for this experiment were commercially available half-bleached linen with a thickness of 40/2 in the warp (a two-ply thread rather than the original one-ply, but of the same thickness) and 25/1 in the weft. (The first number indicates the thickness of the thread, the second the number of threads).

The weaving test was setup with the warp in full length and width (Table 14). 50 cm then woven, and the time for the entire length of 2.36m was calculated (Table 15). Like spinning this is specialized work. Therefore we were fortunate that Flemming Lundholm who is a weaver by profession and also works at Ribe Viking Centre could do this part of the work.

The warp was sewn onto the top boom and weighed down with 20 threads per loom weight, each weight weighing about 300-400 g, resulting in 116 loom weights in total. In the crocheted line 3 warp threads were contained in one mask.

Task	**Time (hour:min)**
Cutting the warp	2:40
Sewing the warp to the boom	1:30
Hanging the weights	3:00
Tying heddles	10:40
Crocheting the line	1:20
Total:	**19:10**

Table 14. Setting up the loom.

Task	**Time**	**Total time for the shirt (hour:min)**
Readying the weft	10 min/2.5 cm woven fabric	10:40
Weaving	4 cm/hour	59:00
Adjusting loom weights	1:15h/15 cm of woven fabric	18:45
Total time		**88:25**

Table 15. Results of the weaving test.

This weaving test shows that it would take 88 hours and 25 minutes to weave enough fabric for the entire Viborg shirt. Adding the time it would take to set up the loom this amounts to 107 hours and 35 minutes. This amount is excluding production of loom weights and string for heddles and crocheting. Loom weights tend to break quite easily and even though most would probably last for a couple of weavings it was necessary to have a number in reserve. The weights also need a string to tie on the warp threads. These strings would also be subjected to wear and tear during the weaving and would require some replacement. The string for the heddles and probably also for the crocheting is not reusable as it becomes warped and worn during the weaving. The left over warp threads can be used for sewing.

Figure 45. Weaver Flemming Lundholm working at the loom.

Discussion

During the weaving it was found that a width wider than the weavers shoulders was inconvenient for the workflow as it was impossible to pass the shuttle from one end to the other in one motion. Instead it was necessary to pass it through the shed as far as possible and then reach in a hand to hold it in place before stepping to the other side and reaching in from this side to grab the shuttle and pull it through. Widths of about 60cm would therefore be faster than the proposed width of 95 cm for the Viborg fabric.

A weft beater of oak was used but this was found to be unsatisfactory as the oak tended to splinter along the edges. Maybe a tangentially split piece of oak or another type of wood would perform better. Unfortunately, where we could find such beaters described in the literature, they are mostly only said to be made from "*wood*", which is hardly informative. The Norwegian beaters of iron and whale bone may make a better option.

Some holes and loose stripes formed in the cloth during the weaving. Some of these were caused by the beater and a number could be mitigated by "double-beating" and following the direction of the weft when beating. Some flaws are still visible but a number of these will disappear during washing when the cloth will "settle" so to speak. This however may confirm the second half of the argument against using warp weighted looms for this type of fabric. A horizontal loom would more readily produce an even weave. The main argument against this loom, that the thread would tend to break during the work, was not really found to be a problem.

A greater length of warp than originally intended was needed as it was discovered that the warp tends to buckle around the weft thereby using more thread than if it were hanging straight down. As some extra length is also needed for loom weights to be attached during the weaving of the final pieces, it is important to calculate plenty of extra length for the warp.

Figure 46. After the timed experiments. Sara Gjerlevsen working at the warp weighted loom.

Bleaching

Flax can be bleached in the sun. Both woven cloth and spun fibres can be bleached. Depending on the amount of time it is left out a lighter colour can be obtained. Straps are sewn along the sides of the cloth, so that it can hang suspended from sticks that are put into the ground. The bundles and fabric must be turned regularly in order to ensure an even bleaching. The fabric had been left out in the sun for 8 days.

Figure 47. A piece of linen cloth bleached on one side. The difference between the bleached and unbleached sides is very visible.

This process has otherwise not been investigated specifically. Straps must be sewn onto the fabric, which must then be laid out in the field and turned with regular intervals. Having been taken in, it needs to be washed. This will all take some time, but we have not timed it here. In fact the process may even have involved several stages involving steeping the fabric with lye, cleaning it with fresh water, and bleaching it in the sun. Such a process is lengthy and would require both some work and technical skills. It was beyond the realms of this project to go very far into these processes, which are primarily physical and chemical, and could very well merit further investigation. It is probably not least due to the pure white colour that linen has been so highly regarded, so this is not an insignificant part of the process.

Figure 47 should illustrate, that even the simple process of bleaching the cloth directly in the sun, using no other chemical agents than the occasional sprinkle of water, can produce an acceptable result.

Sewing

The Viborg shirt had detailed stitching on the front and back chest panels, an attached skirt open along the sides and a square neckline fastened with cloth bands. The exact length of the sleeves is not known from the remains. From the remaining pieces of the shirt, a pattern for reconstruction has been made (Fentz 1988; 1992). The final experiment to do in order to understand

The experiment

Our Viborg shirt reconstruction is based on the hypothesized proportions and pattern presented by Mytte Fentz in her 1988 publication *En hørskjorte fra 1000-årenes Viborg* and the more detailed sewing instructions in her *Vikingeskjorten fra Viborg* (1992). In this reconstruction, the pieces of the shirt are fit and cut from a piece of linen 236cm by 95cm, as best can be surmised from the selvedges on various parts of the shirt. As this sewing trial was run concurrently with the weaving trials, the fabric used for the reconstructed shirt is a modern, store-bought linen with a thread count of between 15-17 threads per centimetre. This fabric was chosen as there were few options for linen available, and this was deemed to be the best, if regrettably not a perfect, fit to the fabric of the original. As the weaving progressed, the difference between the hand-woven linen and that bought for the trial became highly apparent. In the reconstruction, there is a projected general seam allowance of one centimetre, which works well with a tightly woven material; however, due to the nature of the fabric used the seam allowances have been extended to around 2.5cm to compensate for excessive fraying. It is well known that linen shrinks significantly after its initial washing, yet the store-bought fabric shrank very minimally: from 150cm to 138cm in width and from 4m to 3.99m in length. Presumably this fabric was pre-shrunk, as is quite common with modern commercial cloth.

The pattern for our reconstructed shirt is sized directly 1:1 from the Mytte Fentz's pattern. The resulting dimensions were 52.6cm across the shoulders, 46.2cm across the waist, and 44.9cm down the length of the arms. As has been noted, 2.5cm were given for the general seam allowances, and proportionally larger allowances where noted and needed (such as at the hem). The pieces were laid out to best economize fabric, and selvedges were used, as in the original shirt. In total, it took around 35 minutes to lay out the pattern pieces, and a further 24 minutes to cut them out.

Constructing the shirt was a long journey in understanding both the nature of reconstructing from another reconstruction, as well as grasping the style of Viking Age sewing techniques. Due to initial misunderstandings of the decorative features on the front and back of the shirt, the seamstress cut each of the sections out as a separate piece, and spent somewhat over 3½ hours sewing them together. As the distinct pattern is only decoration, and serves no structural purpose, it was meant to be made by simply folding over a small section of cloth on the outer face of the shirt and tacking it down (Figure 48). However, as this misunderstanding caused no damage to the structure of the shirt, the decoration was tacked down as intended, and the time spent sewing together the individual elements together is not included in the total time spent in constructing the shirt.

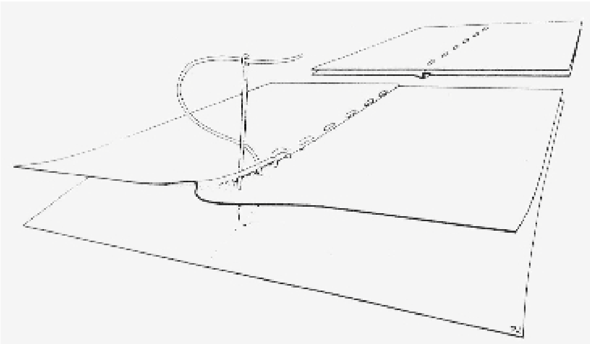

Figure 48. Pattern seam used to lock together the lining with the shirt.

Despite the initially complex looking techniques used in constructing the Viborg shirt, upon actual execution, each of the stitches used is logical and almost intuitive. The stitching on the shirt ensures that no raw edges are left exposed, thus preventing the fabric from unraveling and aiding in prolonging the life of the shirt. The construction of the seams allows for many layer of material to be fastened together without creating a bulking edging. For example, the side seams of the shirt have eight layers of cloth, yet they are smoothly joined together in one relatively flat seam (Figure 49a). The rather odd construction of the arms eye seams perhaps best illustrates the ingenious way in which the raw edges of the fabric were concealed. The edge of the arm and gusset are folded and stitched closed, and the folded edge is then attached to the body of the shirt. This compensates for the uneven number of pieces being sewn together (Figure 49b). Perhaps the most thorough seam is along the opening of the neck, in which the raw edges are folded over and sewn down before being entirely encased with the neckband (Figure 49c). The creator of the Viborg shirt was very thorough in even the smallest details of the shirt. For the less load bearing seams, such as the cuffs, hem and skirt sides, a very basic whip stitch is used; this stitch is both strong and quickly done (Figure 49d).

In total, the reconstruction of the Viborg shirt done for this experiment took 16 hours and 53 minutes to complete. The author, who sewed on the shirt, though fairly skilled in sewing by hand is by no means a great proficient, and was unfamiliar with many of the stitches used. Thus the time taken to complete the shirt could vary depending on the skill of the seamstresses and their familiarity with the pattern. However, the Viborg shirt is a highly detailed one, and regardless of the proficiency of the person sewing it, it would take a considerable amount to complete.

Other Reconstructions

The Viborg shirt is quite a popular pattern for reconstruction amongst historical re-enactors and Viking enthusiasts; however, it is rarely made to the original scale as the resulting shirt is too small for a modern adult male. Thus, it is difficult to compare this trial reconstruction with recreational reconstructions of the shirt. Our Viborg shirt reconstruction was a timed experiment which adhered closely to the construction techniques of the original shirt, whereas shirts made by individuals for personal use are rarely ever timed and may vary based on skill, patience or personal preferences.

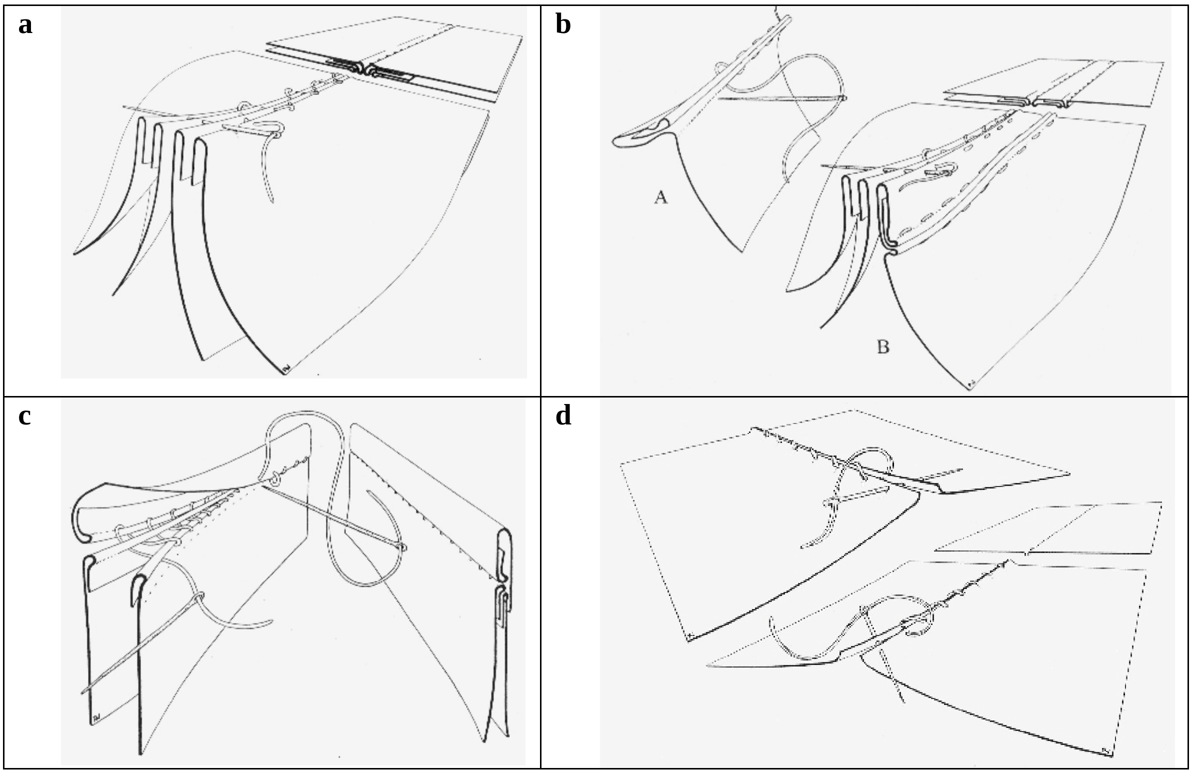

Figure 49. A selection of seams used on the Viborg shirt. After Fentz (1992).

Discussion

This reconstruction of the Viborg shirt, though perhaps not entirely proving the length of time needed to complete the shirt does, however, give a clear view of the intricacy and detailing that went into its construction. The good preservation conditions of the shirt have preserved the vital indications of its construction techniques, and therefore allow the reconstructors to produce a fairly authentic pattern of the shirt.

Figure 50. The finished shirt.

6. WEAR AND TEAR

Post production wear

Having worked all the way through the production stages of the making of a shirt, one question remains: How long would a shirt last? The short answer to that question is the same as in every experiment described so far, that it would depend entirely on the specific context of its use. How often the shirt was used, and in which situations it was worn.

Nonetheless the durability of the clothes is important in assessing what kind of effort was invested in linen clothing. While it would be rather difficult to make a formal experiment on this matter, the setting at Ribe Viking Centre allowed us to at least gather some experience. As already described in the introductory chapter, almost all male employees and pupils at Ribe Viking Centre wear a linen shirt every day. This means that although these clothes are only worn during opening hours, they are still exposed to a type of wear that it probably as realistic as it can be today.

Daily wear and tear

At the end of the tourist season, the shirts are all inspected and repaired as part of the centre’s winter activities (Figure 51; Figure 52). Occasional repair is also necessary during the season, but in general the linen shirts are made ready for next season during the late fall and early winter.

Figure 51. Linen shirts and dresses are being repaired after the 2010 season.

The entire stock of shirts was therefore examined in December 2010, when all repair work of this season had finished. This allowed us to map out the patches, both the number of them and where they had been put on.

A total of 48 shirts were examined. Of these 23 (48%) had no repairs. Some of these shirts were new, made for the coming season to complete the stock. The remaining 25 shirts were repaired to some extent, some of them quite extensively. The highest number of patches that was counted on any one shirt was 14. In some cases patches overlapped, and possibly an older patch could be completely hidden under a newer repair. The actual number of repairs on each individual shirt may therefore be larger.

Figure 52. Before repair. A linen dress is worn thin across the lower part, and a hole is torn. A patch from earlier years can be seen along the seam. This entire part was replaced.

While the number of patches may reflect more on the age of each shirt, it is possibly more interesting to look at the position of these patches. For this purpose a standard drawing of a shirt was made, based on one of them. For every shirt the patches were then measured in on a copy of the standard drawing. The shirts naturally had different sizes, but scaling them to the same standard eliminated this difference, which was practical for this purpose. They were also cut after slightly different patterns, but in practice the differences were minor.

The result can be summarized as a count of shirts that have patches in different areas (Figure 53).

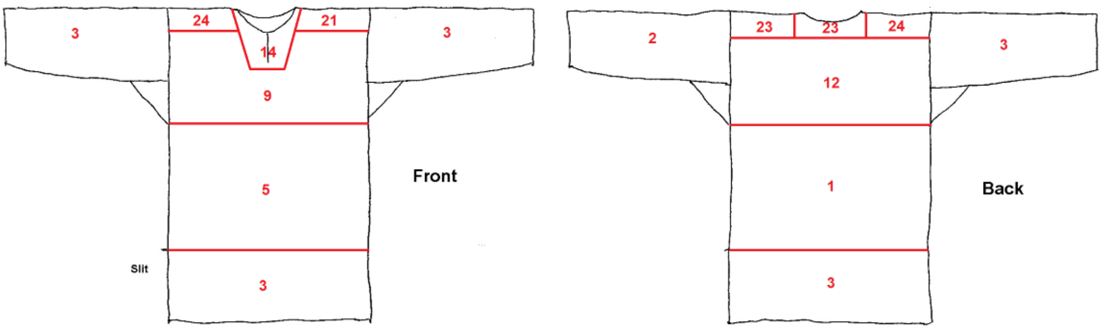

Figure 53. Number of shirts with patches in different areas.

It is clear from these numbers that the shoulders and necklines are the ones being the most worn. Almost all shirts with patches had at least one on the shoulders, and the back of the neckline. There are also a number of repairs along the upper back, and the chest area. Contrary to the expectations by Fentz (1988), there were no repairs at the gussets, under the arms. That may however be a question of the entire gusset being replaced, if this part had been in need of repair. But there were no signs of it.

Two of the shirts with heavy repairs on the front were marked “For a smith”, meaning that the especially heavy wear and equally heavy patches on these garments were connected to the work in the Centre’s smithy.

To compare to these numbers, the Viking Centre also has 54 woollen tunics. Of these only 3 were found to be repaired with small patches. Two patches were placed across the shoulder seam and one in the neckline. This could indicate that wool garments are more durable than linen ones. Unfortunately the comparison does not give a true picture. The woollen tunics are used for cold weather or special occasions, and then always over the linen shirts, so that they are not in direct contact with the body. The linen shirts are therefore exposed to daily use at the Centre, while the woollen tunics are not. The wear on these two sets of garments are therefore not directly comparable, although the difference immediately seems quite striking.

Anders’ shirt

The shirts analyzed above provide a cross-sectional sample of a number of shirts worn by different users during the tourist season. Some of them are relatively new, while others have been used for several seasons. As usual in cross-sectional studies, we have limited control over the individual variables, but get a view across many different use-wear situations. We had however access to one shirt, where the use situation was known. The shirt was also well worn, with few original pieces remaining (Figure 54).

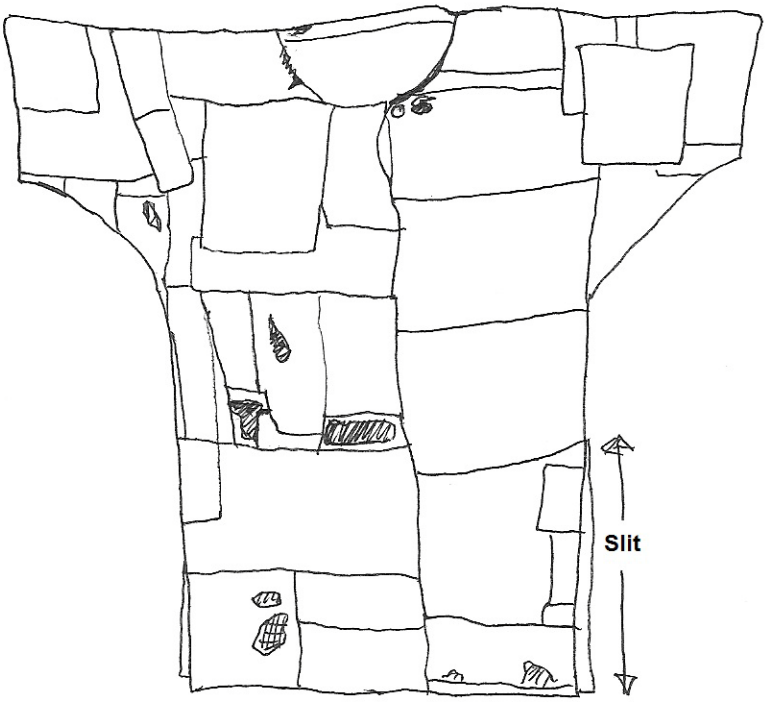

Figure 54. The front of Anders Buus Thomsen’s shirt. Crosshatched areas show holes. 1:10.

This shirt is sleeveless, and made for Anders Buus Thomsen, a carpenter working at the Centre. It was made from old linen sheets in 1996 and worn every year until 2008. It has been saved only because it is so unusually worn. As such it is not representative of the shirts used at the Centre, but can be used to show how a linen shirt used in manual labour and with continuous repair may end up looking.

The shirt is quite literally a patchwork, build up gradually through a decade. Only in two places is the original cloth still visible the rest is covered in patches, sometimes in more layers. In line with the findings above, the neck opening was the first area to be repaired, but also the belly area soon needed repair. This is especially because a carpenter would use this part of the body to support the wood he is working on, to have both hands free to work with.

The tunic from Bernuthsfeld

One archaeological find may come to mind when looking at this shirt. A bog find, and thus of wool, the tunic from Bernuthsfeld has the same patchy look (Schlabow 1976). It is a knee-long tunic with long sleeves and an asymmetrically placed slit on the left side of the neck opening. The tunic was found on a bog body, C^{14} dated to the late 7^{th} or early 8^{th} century.

What makes this find special is that it is made from no less than 43 patches (Figure 55). The patches were made from many different pieces of cloth, in many different weaves and qualities. The warp count varied from 8 to 18, the weft count from 6 to 12 per centimetre.

On first impression this piece looks much like the one shown above. But it fact there is an entirely different story behind it. The many patches on this woollen tunic are not repairs, but were put together like this from the start. So however interesting this find is in itself, the Bernuthsfeld tunic cannot be compared to the shirt produced by a decade of daily work at Ribe Viking Centre.

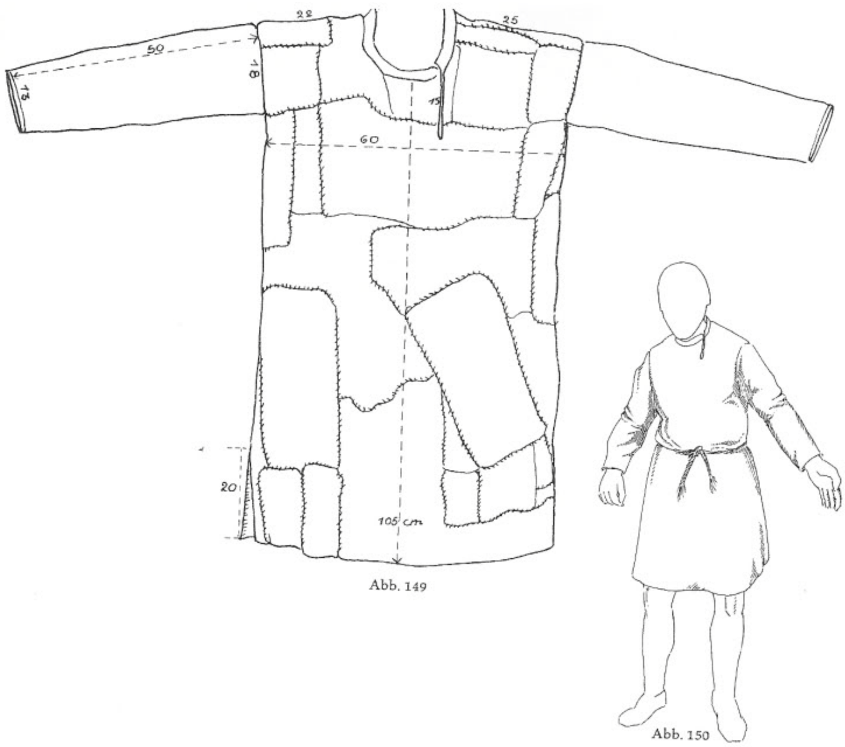

Figure 55. The tunic from Bernuthsfeld. (Schlabow 1976: Abb. 149, 150).

Conclusion

The reason why the linen shirts are first worn along the shoulders, neck lining and upper back could be that these are the areas, where the cloth is in constant contact with the body. The linen is exposed to sweat and fat on the skin, both of which are acidic. Linen is damaged by acids, and together with the constant friction this can explain the wear here.

This explanation could also explain the shoulder panels that are often found in the design of peasant's shirts across Europe. Such panels can often be elaborately decorated. But their main function may be to be easily replaceable parts in area that is worn quickly. In later years Ribe Viking Centre has started to put in shoulder panels from the start, when making these shirts.

The wear around the belly area is more likely a result of work activities, when heavy loads are supported against that part of the body.

The difference in wear between the linen shirts and the woollen tunics is marked, but as already explained the two groups of garments cannot be directly compared. There is however no doubt, that wool generally makes a more durable cloth than linen.

7. DISCUSSION

Making a Viborg shirt

In reproducing the Viborg shirt as accurately as possible, the hope has been to understand the techniques behind its manufacture and discover how long such an intricate shirt would take to be produced. To answer this main question we can now work our way backwards through the processes by combining the registered times and weights for each stage.

The result is summarized in Table 16. This table is based on the discussions through chapter 3-5. The result is then, that it would take about 355 hours to make a Viborg shirt. It can also be seen that 21kg of fresh plants must be harvested to make the 753 grams of thread needed to weave the shirt.

Process	**Weight at start, g**	**Remaining material, %**	**Processing speed**	**Time, hour:min**
Sewing	-	As measured from experiment		16:53
Bleaching	-	Estimate		1:00
Weaving	753	As measured from experiment		107:35
Spinning	837	90.0	55.8 m/hour	188:13
Heckling	1,815	46.1	308 g/hour	5:54
Scutching	2,376	76.4	620 g/hour	3:50
Breaking	8,412	48.3	712 g/hour	11:49
Retting	9,897	77.8	Estimate	1:00
Rippling	15,150	65.3	Half the batch	3:18
Growing	21,062	71.9	Half the batch	15:13
Total		**3.6**		**354:45**

Table 16. The total calculation of time needed for making a shirt, based on our experiments.

In our best estimate, the total time for making a shirt like this is then **300-400 hours**. This is based on our tests, as presented in this report. If we used the spinning speeds registered in the experiments done by CTR (Mårtensson *et al*. 2006), then the time would be close to 598 hours for Batzer and more than 482 hours for Mårtensson. The average for the two tests would be 540 hours. Averaging over all three spinning tests, the two from Copenhagen and ours, the total time would be 475 hours.

It is important to stress that all these are “correct” results. As already discussed in chapter 1, we do not and cannot measure how much time it would take to make a shirt in the Viking Age. We can only measure how much time it would take to make one experimentally. And the roughly 350 hours is then our best guess. 600 hours, as based on Batzers work, is an equally valid result. What these numbers do is to give us a broad idea of the workload behind the very small fragments of clothing, that archaeologist normally find in graves.

What this workload meant, in terms of Viking Age perception of the cloth, is more difficult to say. These are societies without wages as we think of them, but with slavery. This means that there is no simple relation between the time invested in an item, and its value on those markets, that did establish strongly in the Scandinavian economy during the Viking Age.

We can say that cloth production must have taken up a considerable time in daily life during the Viking Age. We have calculated these numbers on a single, and relatively small, shirt. The Viborg shirt was hardly made for an adult, and much larger garments were needed. We can understand from this work, why an unmarried woman in English is called a “spinster”. Spinning yarn and thread for an entire household has been a huge task.

It is interesting to note that the majority of time invested in a shirt is in weaving and spinning. Together these two activities account for more than 85% of the total time spent on the production. This must mean that although the processing of flax is much more complicated than that of wool, that extra work is still a small part of the total time spend on making garments. Although wool may be easier to work with than linen, even in spinning and weaving, the time spent for one piece of garment is hardly that different.

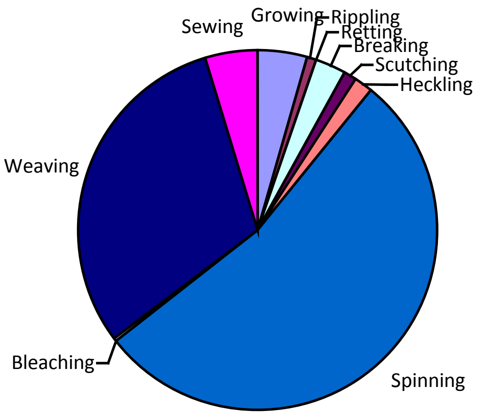

Figure 56. The relative use of time in making a shirt.

The material loss is also interesting. To make 753 grams of thread, more than 20 kg of freshly harvested plants had to be harvested, reducing the material by more than 96%. As shown in chapter three, we could harvest roughly 1kg per m^2. Seeing beyond the making of Viking Age shirts, such numbers do give a perspective on sails on Roman ships, or on the Vasa, which also carried linen sails. Vast areas were grown to make such items.

Lessons learned

More than anything else, this project has been a learning experience. It has been the first cooperation between the University of Southern Denmark and Ribe Viking Centre. It was also the first time for all parties involved that we undertook a larger project in experimental -or experiential- archaeology. Plain mistakes were made, and we have even chosen to be rather frank about it. That was all part of the learning process.

The project has not least been an opportunity for getting to know in practice the details of flax making. This is important knowledge, as simple misunderstandings and misconceptions can be weeded out. Initially we had the literature to guide us in choosing methods. The use of a breaking pit, with fire to force dry the flax stems before breaking was important, but we only tried that at batch four, because we knew from the literature that natural drying also works. We would suggest that natural drying should be preferred only in warmer and dryer climates than the Danish.

We also have to say, that the linen club did not work for us, and we have difficulties in seeing the relatively light types we know from Scandinavia used as breakers. Oppositely we did find that the warp weighted loom worked fine for producing fine linens.

Wool and linen Ribe Viking Centre

As explained in the introduction to this report, the staff and pupils of Ribe Viking Centre wear linen clothes daily during the tourist season. The purpose of the Centre's activities is to give an authentic picture of the Viking Age, with living people working in authentic environments, or at least as close to authentic as possible.

With authenticity in mind, our recommendation to the Viking Centre would be to replace the linen with wool. Following the interpretation in chapter 2, that linen was considered a "finer" type of cloth than wool, and the speculations in chapter 6 that linen is also less durable, it would be more realistic to imagine that wool was worn for daily activities. This is substantiated by the total lack of linen among the working clothes from Haithabu harbour, and the very high frequency of tabby weaves -and thereby presumably linen- in graves not only in Haithabu, but across Scandinavia.

A gradual change from linen to wool would not only be economically the most sensible solution for the Centre, but developing on chapter 6 would also allow for more realistic comparative tests between the durability of linen and wool. If a number of shirts of either material were used by people occupying the same work functions over one or more seasons, it would be interesting to see some documentation of the differences in wear and tear.

Concluding remarks

What seems immediately clear from the work presented here is that the cooperation between archaeologists and artisans was very fruitful. The historical visitor centres, such as Ribe Viking Centre, possesses knowledge which is important to archaeologists. Equally the historical centres are reliant on archaeology, ethnology and history to create realistic environments. There is rarely an impetus in the centres for making more controlled experiments or reporting the work, so that their knowledge is made available. Therefore the cooperation is important.

What has been characteristic for this project is possibly that it has utilized work and knowledge that was already going on in the centre. We have had to spend time doing the experiments, and there has obviously been costs connected to doing the research. But the project reflected an internal need in the centre to document current activities, rather than being a more or less artificial add-on to the daily work at the centre.

Doing these experiments have opened many questions on flax and linen, and we could easily formulate larger projects, that would consolidate these initial results. With the wide range of activities that is going on at the Centre, it is however also very relevant to continue the cooperation by investigating other practical aspects of Viking Age society, making the work and knowledge of the Ribe Viking Centre more accessible to others.

REFERENCES

Andersen, H. Hellmuth; Crabb, P.J.; Madsen, H.J. (1971): *Århus Søndervold- en byarkæologisk undersøgelse*. Jysk Arkæologisk Selskabs Skrifter 9. Højbjerg.

Andersson, E. (1998). *Textile Production in Late Iron Age Scania - A Methodological Approach*. NESAT 6. Gothenburg University Department of Archaeology.

Andersson, E. (1999): Tekstilproduktion i Löddeköpinge – endast för husbehov? *Löddeköpinge* RAÄ skriftserie.

Andersson, E. (2003): *Tools for Textile Production from Birka and Hedeby*. Birka Studies 8. Excavations in the Black Earth 1990-95. Stockholm.

Andresen, S.T. (2005): *Hør (Linum Usitatissimum) som kulturplante i Danmark og Sydskandinavien i jernalder og vikingetid*. Master Thesis, University of Århus.

Anonymous (1888): Flachs. *Meyers Konversations-Lexikon*, Band 6, 1888. Verlag des Bibliographischen Instituts, Leipzig und Wien: 6328.

Anonymous (1893): Flax Report of Ireland. *Bush Advocate*, Volume XI, Issue 847, 21 October 1893: 6

Arkæologiske udgravninger i Danmark 1985-2005. Kulturarvsstyrelsen.

Baines, P. (1985): *Flax and Linen*. Shire Album 133.

Barber, E.J.W. (1991): P*rehistoric Textiles*. *The development of cloth in the Neolithic and Bronze Age*. Princeton.

Behr, G. (2000): *Tekstilredskaber i det middelalderlige Danmark*. Master Thesis, University of Århus.

Behre, K.-E. (1983): *Erhährung und Umwelt der wikingerzeitlichen Siedlung Haithabu – der Ergebnisse, der Untersuchungen der Pflanzenreste*. Neumünster.

Bjerge, P. & M.T.J. Søegaard (1906): *Danske vider og vedtægter: eller Gamle landsbylove og byskråer*. Copenhagen.

Bjørn, I. (1974): *Oldtidsdragt – nutidstøj*. Rhodos.

Boddum, S. & Wåhlin, S. (2009): *Højlund Spangsdal I - landsby fra yngre jernalder*. Excavation report, Viborg Stiftsmuseum.

Braidwood, R.J. & L.S. Braidwood (1993): The joint prehistoric project. Annual report 1992-93. *Oriental Institute Annual Report* 1992-93. University of Chicago.

Brøgger, A.W. & H. Shetelig (1928): *Osebergfundet*, Bd II. Oslo.

Brøndegaard, V.J. (1979): *Folk og Flora 2. Etnobotanik.* (Hør; Linum Usitatissumum: 294-313).

Christensen, P. Birkedahl (1984): En lille brik: Den koniske tenvægts spedning. *Hikuin* 10: 321-326.

Coles, J.M. (1974): *Archaeology by experiment*. Scribner.

Cunningham, P., J. Heeb & R. Paardekooper (eds.) (2008): *Experiencing Archaeology by Experiment*. *Proceedings of the Experimental Archaeology Conference, Exeter 2007*. Oxbow Books.

Dalgård, W. (1916): Om linets odling och beredning. Några anteckningar från Djura kapellförsamling, Kopparbergs län.. *Fataburen* 1916: 14-20.

Daud, R. (1996): *Potential of nettle* (Urtica sp.) *as a Source of Fibre in Northern Montane Pakistan for Cottage Industry*. Dissertation, College of Home Economics, University of Punjab.

Derry, T.K. & T.I. Williams (1993): *A short history of technology: from the earliest times to A.D. 1900.* Courier Dover Publications

Diepenbrock, W. & D. Iwersen (1989): Yield development in linseed (Linum usitatissimum L.). *Plant Res. Dev.* 30: 104–125.

Ejstrud, B. (2008): St. Croix i fortid og nutid. In: L.N. Jørgensen (red.) : *Galathea 3. 2006-2007*. Dansk Ekspeditionsfond/Thaning & Appel: 339-342.

Fentz, M. (1988): En hørskjorte fra 1000-årenes Viborg. *Kuml* 1987: 23-45.
Fentz, M. (1989): Af skjortens saga. *Skalk* 1989,1: 7-11
Fentz, M. (1992): *Vikingeskjorten fra Viborg.* Viborg Stiftsmuseum.
Fentz, M. (1998): En hørskjorte fra 1000-årene. In *Viborg Søndersø 1000-1300 - Byarkæologiske undersøgelser*. Jysk Arkæologisk Selskabs Skrifter.
Frandsen, K.-E. (1983): *Vang og tægt. Studier over dyrkningssystemer og agrarstrukturer i Danmarks landsbyer 1682-83*. Bydg, Esbjerg.
Geijer, A. (1938): *Birka III. Die textilfunde aus dem Gräbern*. Stockholm.
Grömer, K. & I. Schierer (2005): *Textile Techniken und die Experimentelle Archäologie*. Scriptum, Wien.
Haarnagel, W. (1979): *Die Grabung Feddersen Wierde. Methode, Hausbau, Siedlungs- und Wirtschaftsformen sowie Sozialstruktur*. Wiesbaden.
Hansen, K.M. & Høier, H. (2001): Næs - en vikingetidsbebyggelse med hørproduktion. *Kuml* 2000: 59-89.
Helbæk, H. (1951): Tollund-Mandens sidste Maaltid. *Aarbøger for nordisk Oldkyndighed og Historie* 1950: 311-341.
Helbæk, H. (1959): Grauballemandens sidste måltid. *Kuml* 1958: 83-116.
Helbæk, H. (1960): Træk af høravlens historie. *Kuml* 1959: 103-129.
Helbæk, H. (1969): Plant collecting, dry-farming and irrigation farming in prehistoric Deh-Luran. In F. Hole, K.V. Flannery & J.A. Neery (eds.): *Memoirs of the Museum of Anthropology*, vol. 1. University of Michigan.
Hjemqvist, H. (1989). Botanische analyse einiger brote. In: G. Arwidssson (ed.): *Birka II:1. Systematische Analyse der gräberfunden*. Stockholm.
Hjørungdal, T. (1991): Det skjulte kjønn. Patriarkal tradisjon og feministisk visjon i arkeologien belyst med fokus på en jernalderkontekst. *Acta Archaeologica Lundensia*, Series altera in 8°, nr. 19.
Hodges, H. (1989): *Artifacts – an introduction to early materials and technology*. Duckworth.
Hoffmann, M. (1974): *The warp-weighted loom*. Oslo.
Hoffmann, M. (1991): Fra fiber til tøy – Tekstilredskaber og bruken av dem i Norsk Tradisjon. Landbruksforlaget.
Holm-Olsen, I.M. (1976): Noen gravfunn fra vestlandet som kaster lys over vikingtidens kvinnedrakt. *Viking* XXIX: 197-205.
Hägg, I. (1974): *Kvinnodräkten i Birka: Livplaggens rekonstruktion på grundval av det arkeologiska materialet*. Uppsala.
Hägg, I. (1984): *Die Textilfunde aus dem Hafen von Haithabu*. Berichte über die Ausgrabungen in Haithabu, Bericht 20. Neumünster
Hägg, I. (1985): Textilhistoria, statistik och källkritik. *Tor* XX: 259-278.
Hägg I. (1987): Textilhistoria, statistik och källkritik 2. *Tor* XXI: 283-296.
Hägg, I. (1991): *Textilfunde aus der Siedlung und aus den Gräbern von Haithabu*. Berichte über die Ausgrabungen in Haithabu, Bericht 29. Neumünster.
Højrup, O. (1974): *Landbokvinden. Rok og kærne. Grovbrød og vadmel*. Nationalmuseet.
Høst, O. (1982): *Danske kulturplanter*. DSR Forlag.
Jacobsen, H. (1958): *Studier over varmtvandsrødning af hør med særlig omtale af rensning og genanvendelse af vand fra rødning*. København.
Jensen, P.M. (2004): *Arkæobotanisk undersøgelse af formodet hørbearbejdningsgrube*, Højbjerg: Moesgård Museum.
Jirlow, R. (1924): Om linberedning och linspinning hos svensk almoge. En översikt till ledning för folklivs- och landsmålsundersökare. Fataburan 1924: 143-162.
Kers, J., P. Peetsalu, M. Saarna, A. Viikna, A. Krumme & A.Menind (2010): Preliminary Investigation into Tensile Characteristics of Long Flax Fibre Reinforced Composite Material. *Agronomy research* vol. 8: 107-114
Komlaveja, L., A. Adamovič & V. Stramkale (2010): Evaluation of yielding abilities of Latvian Flax varieties and future prospective. In: C.S.C. Marques dos Santos Cordevile & Luís Ferreira (eds.): *Treatment and use of organic residues in Agriculture*. 14th Ramiran International Conference, Lissabon.

Madsen H.B., A.H. Nørr & K.Aa. Holst (1992): *The Danish Soil Classification*. Atlas of Denmark I,3. Reitzel, Copenhagen.
Mannering, U. 1995: Oldtidens brændenældeklæde – Forsøg med fremstilling af brændenældegarn. *Naturens Verden* 1995: 161-168.
McClung, L.S. (1956): The Anaerobic Bacteria with Special Reference to the Genus Clostridium. *Annual Review of Microbiology*, vol. 10: 173-192.
Mortensen, M. (1998): "When they speed the shuttle". The role of textile production in Viking age society as reflected in a pit house from Western Norway. In: L. Bender Jørgensen & C. Rinaldo (eds.): *Textiles in European Archaeology*: Report from the 6th NESAT Symposium, 7-11th May 1996 in Borås. GOTARC Series A, Vol. 1. Göteborg: 188-195.
Måge, B. (2006): *Udgravning af huse og gruber med aktivitetsspor fra førromersk jernalder og ældre romersk jernalder*. Excavation report Vejle Museum, Vejle.
Mårtensson, L., E. Andersson, M-L. Nosch & A. Batzer (2006): Technical Report *Experimental Archaeology Part 2:1 flax*. Tools and Textiles-Texts and Contexts Research Programme. The Danish National Reasearch Foundation's Center for Textile Research.
Nilsson, T. (1976): Något om hushållet och dess inventarium. In: A.W. Mårtensson (red.): *Uppgrävt förflutet för PKbanken i Lund. En investering i arkeologi*. Archaeologica Lundensia vol. VII. Lund: 233-250.
Nyberg, G.G. (1967): Linodling och linnevävning i Själevad och dess grannsocknar 1750-1900. *Själevads hembygdsförenings Skriftserie* nr. 4, 1967.
Nyberg, G.G. (1989): Textilredskab av trä i det tyske Elisenhoffyndet från vikingatiden. *Laborativ Arkæologi* 3, 1989.
Nørlund, P. (1948): *Trelleborg*. Nordiske Fortidsminder. IV. Bind. 1. København.
Pallesen, B.E. (1996): The quality of combine-harvested fibre flax for industrials purposes depends on the degree of retting. *Industrial Crops and Products*, vol. 5,1: 65-78.
Pallesen, B.E. (2009): *Dyrkningsvejledning, økologisk spindhør*. Dansk landbrugsrådgivning, http://app4.landscentret.dk/DyrkVejl/Forms/Main.aspx?page=Vejledning&cropID=133 [Accessed October 2010].
Pliny the Elder. *The Natural History*. J. Bostock & H.T. Rilet (transl.) (1855). London.
Petersen, J. (1951): *Vikingetidens redskaber*. Skrifter utgitt av Det Norske Videnskaps Akademi i Oslo. vol. II. Oslo.
Renfrew, J.M. (1969): The archaeological evidence for the domestication of plants: methods and problems. In: P.J. Ucko & G.W. Dimbleby (eds.): *The Domestication and Exploitation of Plants and Animals*. Chicago: 149-172.
Renfrew, J.M. (1973): *Palaeo-ethnobothany – The prehistoric food plants of the Near East and Europe*. London.
Reynolds, P.J. (1999): The nature of experiment in archaeology. In: E. Jerem & I. Poroszlai (eds.): *The Archaeology of the Bronze Age and the Iron Age. Proceedings of the international archaeology conference, Szazhalombatta, 3-7 October 1996*. Budapest: 387-394.
Rowsdahl, E. (1977): *Fyrkat II: Oldsagerne og gravpladsen*. Nordiske Fortidsminder, ser. B in quarto bd. 3-4. København.
Robinson, D.E. (1993): *En sammenbrændt klump af hørfrø I et førromersk kar fra Stourstrup ved Fredericia*. NNU rapport nr. 5. København.
Robinson, D.E. (1995): *Arkæobotanisk analyse af bronzealder gårdsanlæg og marksystemer ved Bjerre Enge, Hanstholm, Thy*. NNU rapport nr. 15. København.
Robinson, D.E. H. Krongaard & I. Boldsen (1991): Bothanical analyses from Viborg Søndersø. A weaterlogged urban site from the Viking Period. *Acta Archaeologica* vol. 62: 59-87.
Rosini & Casa (2003): Influence of Sowing and Harvest Time on Fibre Flax (Linum usitatissimum L.) in the Mediterranean Environment. *Journal of Agronomy and Crop Science*, vol. 189,3: 191-196.
Runge, M. & Henriksen, P.S. (2007): Danmarks ældste hørindustri. *Fynske Minder* 2007.
Schietzel, K. (1970): Hölzerner kleinfunde aus Haithabu. *Berichte über die Ausgrabungen in Haithabu* 4. Neumünster: 77-91.
Schlabow, K. (1976). *Textilfunde der Eizenzeit in Norddeutschland*. Neumünster.

Sherman, H.M. (2008): From Flax to Linen in the Medieval Rus Lands. *Medieval Clothing and Textiles* vol. 4. Boydell & Brewer: 1-20.
Sing, Pande & Jain 2008: *Diversity of Microbes and Cryptygrams*. Meerut.
Sjovold, T.F.M. (1966): *The Oseberg Find and Other Viking Ship Finds*. Universitetets Oldsaksamling, Oslo.
Skaarup, J. (1976): *Stengade II. En langelandsk gravplads med grave from romersk jernalder og vikingetid*. Landelands Museum, Rudkøbing.
Steensberg, A. (1979): *Draved. An experiment in Stone Age Agriculture. Burning, sowing and Harvesting*. Copenhagen.
Steward, R.B. (1976): Paleoethnobotanical Report: Çayönü 1972. *Economic Botany* vol. 30, no. 3: 219-225.
Sändh, B. (1977): *Lin: odla, bereda, spinna*. ICA-Förlag, Västerås.
Tanner, F.W. (1922): Microbiology of Flax Retting. *Botanical Gazette*, vol. 74: 174-185.
Turner, W.H.K. (1972): Flax Cultivation in Scotland: An Historical Geography. *Transactions of the Institute of British Geographers*, No. 55 (Mar., 1972): 127-143.
Vogelsang-Eastwood, G. (1995): *Fra Faraos klædeskab. Mode i oldtidens Ægypten. Amsterdam/København.*
Vogt E. (1937): *Geflechte und Gewebe der Steinzeit*. Basel.
Walton Rogers, Penelope. "Stone Spindle Whorls." Craft Industry and Everyday Life: Finds from Anglo-Scandinavian York Vol. 17. ed. A. Mainman and N. Rogers. York Archaeological Trust. York: 2000.
Weightman, R. & D. Kindred (2005): *Review and analysis of breeding and regulation of hemp and flax varieties available for growing in the UK*. Report, ADAS Centre for Sustainable Crop Management/The Department for Environment Food and Rural affairs, Cambs.
Zienkiewitz, H. & K. Fröier (1979). *Linboken*. LTs Forlag, Stockholm.
Zimmermann, W.H. (1982): Archäologische Befunde frühmittelalterliche Webhäuser. *Jahrbuch der Männer vom Morgenstein* 61/1982: 111-144.
Zubkova, E.S., O.V. Orfinskaya & K.A. Mikhailov (2010): Studies of the Textiles from the 2006 Excavation in Pskov. *NESAT X, North European Symposium for Archaeological Textiles*. Oxbow Books
Øye, I. (1988): Textile equipment and its working environment. Bryggen in Bergen 1150-1500. *The Bryggen papers. Main series*, vol. 2. Norwegian University Press.
Åström, I. (1952): Några Linberedningsredskap. *Folkliv* XVI: 36-48.

FROM FLAX TO LINEN

Experiments with flax at Ribe Viking Centre

Bo Ejstrud, Stina Andresen, Amanda Appel, Sara Gjerlevsen & Birgit Thomsen

Edited by Bo Ejstrud

During 2010 experiments on the production of flax and linen were conducted at Ribe Viking Centre, in cooperation between the Centre and the University of Southern Denmark. The experiments included the entire production from growing the flax to working it into fibres and finally spinning, weaving and sewing.

This report documents the results of the fruitful cooperation between Centre artisans and University archaeologists. Following the process of linen production in all stages from flax seeds to a finished shirt, the project has investigated the broad range of crafts and activities that were important in textile production a thousand years ago.

Ribe Viking Centre & University of Southern Denmark
Esbjerg - 2011

ISBN: 978-87-992214-6-2

SYDDANSK UNIVERSITET
UNIVERSITY OF SOUTHERN DENMARK

Ribe VikingeCenter