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Estonian and Norwegian Sheep Wool as a Textile Material

Properties and Possibilities for Use Based on the Example of the Wool of Six Sheep Breeds

ABSTRACT
In Estonia, up to 90% of local wool is not adequately valued, while in Norway, due to the well-functioning wool-buying and -sorting system, a large part of local wool is used purposefully. However, both countries have room for improvement in terms of the better usage of local wool. This article provides an overview of the Estonian-Norwegian wool research conducted in from 2020 to 2023 and its main results. During the study, wool was collected from three Estonian and three Norwegian sheep breeds, semi-worsted yarn was made from it, and knitted and woven fabrics were produced. Wool, yarn, and fabrics were tested in numerous ways. The paper presents the main test results and suggests how wools with a wide range of qualities can be used in innovative ways to create textiles. The smart use of materials is based on the possibilities offered by medium-sized production and knowledge about local wool.

Keywords:
local sheep breeds, testing of wool properties, wool value chain.

INTRODUCTION

In the cold Nordic climate, sheep's wool is the oldest and most valuable source of textile material. Today, the extent of the use of wool varies greatly from country to country and depends on support systems and existing value chains. An excellent national wool-collecting and -grading system has been developed in Norway because of the importance and wide usage of local wool. In Estonia, on the other hand, meat has become a more important sheep product, in comparison to which wool has regressed to the status of an annoying by-product, and most of the wool is destroyed. The purposeful use of wool is a problem in most of the Nordic and Baltic countries (Haugronning, 2022). The better use of wool helps preserve traditional sheep breeds, which is important in ensuring biodiversity. The traditional sheep breeds are sustainable grazers, and they help to maintain cultural landscapes, sustainability and craft heritage.

To increase the valorisation of local wool, the project 'Estonian and Norwegian local sheep's wool, conducting research and creating educational materials for textile students of higher education' (2020–2023) was carried out. The leading institution of the project was the University of Tartu Viljandi Culture Academy (UT VCA) and its partners: TTK University of Applied Sciences and Muru Woolmill from Estonia, as well as the University of South-Eastern Norway (USN) and Selbu Spinneri from Norway. The project was funded by the European Economic Area/Norwegian Higher Education Cooperation Program. The purpose of the project was to introduce the excellent properties of wool and encourage craftsmen and designers to use more domestic wool. A special feature of the project was the collaboration between craft practitioners, wool processors and industrial fabric testers. The project included tests of wool, yarn and fabrics made of wool from six sheep breeds from Estonia and Norway. The main goal of the tests was to obtain new information about the properties of the wool from different sheep breeds and the fabrics made from it, which will enable these materials to be used as efficiently as possible.

Historically, wool was mainly used in the production of clothing and interior textiles. Today, finer wool finds use easily, and it is problematic to find use for coarser single- and double-coated wools (Alsborn, 2022). Still, coarsely fibred, uneven or soiled wool is increasingly used in the production of technical textiles (Johnson et al., 2003). The notion that there is no good or bad wool is becoming more and more common. It is possible to find a suitable application for all fibres. The research carried out in this project mainly focused on fine, medium and uniform wool, which is suitable for textile production. A series of tests were completed to map the different properties of the wool from different sheep breeds and thus better understand the potential usage areas of various wool types.

This paper provides an overview of the tests performed during the project and indicates certain possibilities regarding how wools with a range of qualities can be used in innovative ways to create textiles. The smart use of materials is based on the possibilities offered by small or medium-sized producers and very good knowledge of local wool.

ESTONIAN AND NORWEGIAN WOOL: PRODUCTION AND USAGE

As of 31.12.2021, there are a total of 65,658 sheep in Estonia, including 31,466 ewes; 26,304 ewe lambs and 7,888 rams. A total of 31 breeds are registered in the The Agricultural Registers and Information Board (ARIB) registry, but many of them are represented by only a few individuals. There are only seven breeds with more than 1,000 sheep. The two most common of these are the Estonian Whitehead and Estonian Blackhead sheep. They are followed by the Kihnu native sheep, the oldest local native breed, which has only recently been officially recognized. However, the largest number (30,728) of sheep in Estonia are various crossbreeds (Põllumajanduse Registrite ja Informatsiooni Amet). When we divide sheep according to their wool, the only local breeds with double-layered wool are the Kihnu native sheep and Estonian native sheep. As of the beginning of 2022, the amount of wool in Estonia is 130 tons. About 90% of it lacks sufficient valorisation (Matsin et al., 2022).

In Norway, there are 15 times as many sheep as in Estonia. A total of 1 million breeding females are kept during the winter (Norsk sau og geit). There are three types of short-tailed sheep: the Gammel Norsk Spælsau (Old Norwegian Spæl sheep); the Gammel Norsk sau (Old Norse sheep) and the two variants of Spælsau, white and pigmented. The other sheep breeds are long tailed, and in Norway, they are defined as crossbred sheep; this is because of their origin in crossbreeding local and imported sheep, mostly in the late 1800s. The wool of these sheep is uniform. Norway produces an estimated 3,500 tons of wool per year. The wool that is delivered directly to the spinning mills is not counted in the wool statistics, and this must be kept in mind when considering the numbers regarding wool production.

MATERIAL GATHERING AND PREPARATION FOR TESTING

Three Estonian and three Norwegian sheep breeds were selected, their wool was collected and yarn and woven and knitted textiles were made from the wool. The Estonian sheep breeds were the Estonian Whitehead (EV, Figure 1), Estonian Blackhead (ET, Figure 2) and the Kihnu native sheep (KM, Figure 3). These breeds were chosen because Whitehead and Blackhead are historical Estonian sheep breeds and Kihnu native sheep are the oldest local breed.

FIGURES 1, 2 AND 3. The Estonian Whitehead sheep (Figure 1, photo by K. Tambet). The Estonian Blackhead sheep (Figure 2, photo by P. Veersalu). The Kihnu native sheep (Figure 3, photo by T. Mägi).

The Norwegian sheep breeds included in this project are the Blæset sau (Sheep with white stripe in the face, NB, Figure 4), Gammelnorsk spælsau (Old Norwegian Short-tail Sheep, NS, Figure 5) and Gammel-norsk Sau/Villsau (Old Norse Sheep/wild sheep, NV, Figure 6). The wool of the Norwegian sheep breeds was sorted by colour. There were two colours for each sheep breed. This made it easier to separate the yarn types and also made it possible to compare the quality of the fibres and yarns of different colours.

FIGURES 4, 5 AND 6. Blæset sau (Figure 4, photo by M. Espelien). Old Norwegian Short-Tail sheep (Figure 5, photo by A. Espelien). Old Norse sheep (Figure 6, photo by A. Espelien).

In the context of the following testing, it is important to note that three of the six sheep breeds included in the project have single-coated wool (the Estonian Whitehead sheep, Estonian Blackhead sheep and Blæset sau) and three have double-coated wool (the Kihnu native sheep, Old Norse sheep and Old Norwegian Short-tail sheep).

The wool was processed into yarn by two project partners: Selbu Spinneri in Norway and UT VCA Vilma wool mill (Figure 7). Both mills use a semi-worsted technique for making yarn. Two different types of yarn were produced: a thicker yarn for weaving (two-ply: 315 m/100 g) and thinner yarn for knitting (two-ply: 360 m/100 g). All yarns were made with a medium-high to high twist in terms of both spin and ply.

The fabrics were handwoven in USN and UT VCA. All fabrics were cut in half, one half of which was tested without finishing and the other half of which was tested with finishing. The density of the fabrics was 8 threads/cm in the warp and weft, and the threads were woven with a 2/2 twill weave. The width of the fabric without finishing was 54 cm in the reed, and the total length was 500 cm.

All knitted textiles were produced at UT VCA. All samples were knitted on a Brother hand-knitting machine (Model 323) at density 6. Two fabrics were knitted from each yarn. The shorter (1,000 rows) of these went into testing without felting, and the longer of these (1,200 rows) was felted before testing. The width of the textile was 198 loops.

All woven textiles were treated in the same way, in Norway. The woven fabrics went through a mechanical finishing process in a wet state, with a shrinkage percentage of 7%. The fabrics became softer and slightly denser after washing and light waulking. All the knitted textiles were finished together at UT VCA. The fabrics were felted with a semi-industrial washing machine, an Electrolux S556, which had a capacity of 10 kg. In total, the fabrics weighed 4.1 kg. Approximately two-thirds of the machine was filled at this weight. Normal wash was selected for the washing machine program: normal colour at 40°C, which lasted 42 min. ProFit Wool detergent was used in 0.25 ml amounts.

FIGURE 7. Samples of wool, sliver and yarn from six sheep breeds. Photo by M. Anton.

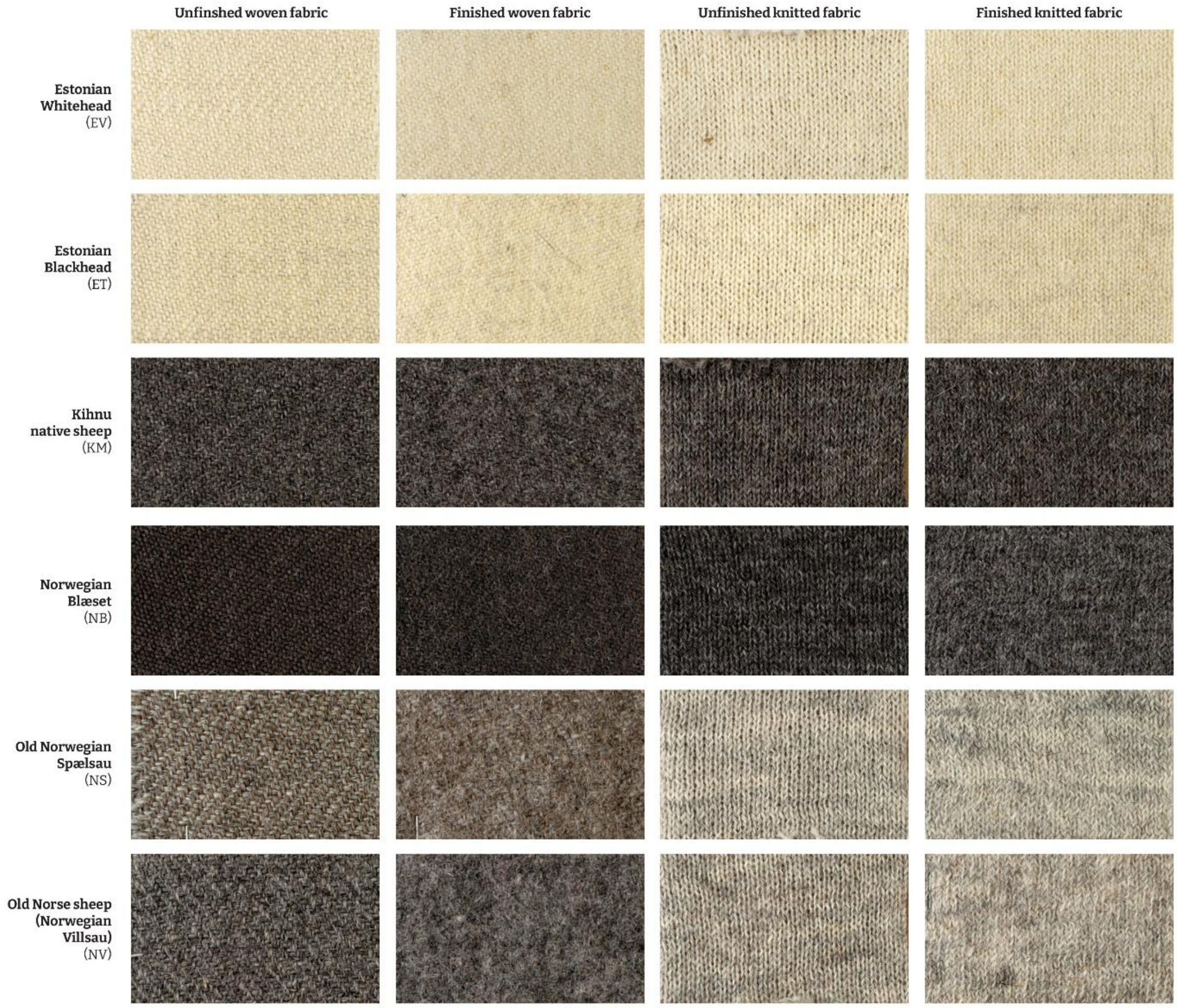

FIGURE 8. Samples of unfinished and finished woven and knitted fabrics. Photo by M. Anton.

It is important to note that, although the collection and processing of materials was intended to be completed using the same principles and methods, there are aspects of the results that differ from country to country due to differences in local methodologies. These differences are mainly related to the gathering and processing of wool into yarn. For example, in Estonia's Vilma wool mill, wool was collected from specific sheep, but in Norway, a larger amount of wool was collected from a larger number of non-specified sheep. In Norway's Selbu Spinneri, two different colours of wool were used for the same breed so as to be better able to keep the yarns apart, but the colours may have slightly different properties, so conclusions drawn for one yarn cannot be generalised to the entire breed. On the other hand, choosing only one colour would not be representative, and the mixing of colours to obtain a more general result would also be difficult. There are significant differences in wool quality between sheep of different colours due to their different colour genes.

There were also several differences in the yarn-processing procedures. Although both wool factories use a similar semi-worsted technique, UT VCA's Vilma wool mill does not use a fibre separator to remove the coarse outer wool hairs, nor does it finish the yarn with a conditioner (water vapour conditioning). The Vilma mill used a Ramella spinning system for the project, while Selbu Spinneri used the Belfast spinning system. However, it is still possible to effectively compare the properties of the wool from the sheep of one country with wool from the sheep of other countries.

It is not possible to directly compare the finished woven and knitted fabrics, because the treatment was done on different bases. While all knitted fabrics were felted using the same temperature, time and washing-machine program, the woven fabrics were waulked based on the size of each piece of the fabric. It was not possible to measure the temperature or time during the waulking, as the waulking equipment and process was low tech.

TESTING THE TEXTILE MATERIAL

As part of the project, all tests were performed in the textile testing laboratory of TTK University of Applied Sciences. It is not a certificated laboratory, but it followed international standards in most of the tests carried out within the framework of the project.

For the results of the tests to be comparable, the conditions for performing the tests were very important. During the testing, conditions were, on average, as follows: temperature 26±2 °C and relative humidity 44±4%. Standard conditions are temperature 20±2 °C and relative humidity 65±2% (Standard EVS-EN ISO 139:2005 Textiles–Standard atmospheres for conditioning and testing). The test conditions were different from the standard conditions, but the probability that this affected the test results to an appreciable extent is very small. It is also important to note that the test conditions were the same for all fabrics used in this study and that, thus, the test results for different fabrics are comparable.

The sampling was performed according to Standard EVS-EN 12751:2000 Textiles–Sampling of fibre, yarn and fabric materials for testing. The accuracy achieved in recording the test results is also determined based on the testing standards used. The typical rules apply:

1. The readings are recorded using the smallest division of the measuring scale of the device.
2. If a very different result from the others is obtained during the experiments, it is still recorded in order to later investigate its specificity and decide whether to consider the given result or not.

The following tests were performed in the project according to the standards:

- Linear density of fibres
- Fabric weight (EVS-EN 12127:2000)
- Tensile strength of yarns (EN ISO 2062:2009)
- Tensile strength of fabrics (EVS-EN ISO 13934-1:2013)
- Tearing strength (EVS-EN ISO 13937-2:2000)
- Abrasion resistance (EVS-EN ISO 12947-1:2001; EVS-EN ISO 12947-2:2016; EVS-EN ISO 12947-3:2001)
- Pilling (EVS-EN ISO 12945-2:2020)
- Air permeability (EVS-EN ISO 9237:2000)
- Elongation

MAIN FINDINGS

The limited space available for this article does not allow us to highlight and analyse all the results of the tests. A choice has been made in this regard because it is possible to produce yarns with different properties and use them as wisely as possible to make various textiles. A more detailed overview of the testing can be found in the study material prepared during the project (Matsin et al., 2023).

The collection of wool from the various sheep breeds showed that the properties and the wool quality vary considerably between individuals of the same breed. This may be due to a high genetic variation in each sheep breed or earlier cross breeding. There is also wool from young and old sheep, as well as ewes and rams, with varying properties. The different colours of wool also have different properties. All stages of the production of yarn, from sorting the wool and grading it to the finishing treatment, affect the yarn and the textile made from it. The properties of the yarn depend on the technical competence of the spinners, which involves both written knowledge and tactile skills.

Table 1 shows the most significant results (the highest and lowest) for all 24 fabrics, as compared to the same type of fabric from different breeds. Based on these fabrics' specific characteristics, there are recommendations for potential areas of use. The higher and lower values are related to the numerical values of the results and do not represent the best and worst values. Whether a value is good or bad depends on the intended use of the product and its expected properties.

TABLE 1. The most significant results of testing (the highest and lowest) for all 24 fabrics. EV- Estonian Whitehead, ET- Estonian Blackhead, KM- Kihnu native sheep, NV- Gammelnorsk Sau/Villsau, NB- Blæset sau, NS Gammelnorsk spælsau. W- woven, K-knitted, UF- unfinished, F- finished.

			HIGHEST RESULTS	LOWEST RESULTS	SUGGESTIONS FOR APPLICATIONS
EV	W	UF	Tensile strength and stretching in the weft direction	Abrasion resistance, elongation at break on the warp direction	For products that must be durable, abrasion resistance and elongation are not important.
		F	Tensile strength in the weft direction, tearing strength	Elongation at break on the warp direction	For products that must be particularly resistant to tearing.
	K	UF	Resistance to pilling, tensile strength in the warp direction, elongation at break in the weft direction	Air permeability	For products that must be strong, have an appearance that is resistant to use and be heat-proof.
		F	Abrasion resistance, tensile strength in the weft direction		For products that must be abrasion resistant.
ET	W	UF		Tensile strength in the warp direction, elongation at break, tearing strength in the warp direction	For products for which the tensile strength need not be high.
		F	Stretching	Resistance to pilling, tensile strength in the warp direction	For products that should be stretchy but not strong and for which a change in appearance during use is not important.
	K	UF	Abrasion resistance, tensile strength in the warp direction, elongation at break		For products that must be very durable, that is, abrasion resistant, strong and stretchy.
		F	Tensile strength in the weft direction, elongation at break		For products that must be strong and stretchy.
KM	W	UF	Abrasion resistance, tensile strength in the weft direction, tearing strength		For products that must be very durable, that is, abrasion resistant, strong and tear resistant.
		F	Abrasion resistance	Elongation at break and stretching in the weft direction	For products that must be very abrasion-resistant but not stretchy.
	K	UF	Tensile strength in the warp direction	Stretching in the warp direction	For products that must be strong but not stretchy.
		F	Tensile strength in the warp direction	Resistance to pilling, stretching, air permeability	For strong, elastic and dense technical textiles and interior fabrics.

NB	W	UF	Resistance to pilling, stretching in the warp direction	Tensile strength in the warp direction, air permeability	For products that should be warm, stretchy and pilling-resistant but not strong.
		F		Tensile strength and elongation at break in the warp direction, air permeability	For products that should be warm but need not be stretchy or strong.
	K	UF			For various uses, such as clothing fabrics and interior textiles.
		F	Stretching in the warp direction	Resistance to pilling, abrasion resistance	For products that should be strong but not abrasion resistant.
NS	W	UF	Tensile strength in the warp direction, elongation at break, air permeability	Tensile strength and tearing strength in the weft direction, stretching in the warp direction	For products that should be breathable, warp-stretched and strong but not elastic.
		F	Tensile strength in the warp direction, elongation at break, air permeability	Abrasion resistance, tearing strength and stretching in the warp direction	For products that should be breathable, stretchy and strong but not abrasion-resistant, elastic or tear-resistant.
	K	UF	Air permeability	Elongation at break in the weft direction	For products that should be breathable and not very stretchy.
		F	Air permeability, stretching in the weft direction	Resistance to pilling, tensile strength in the warp direction, elongation at break	For products that should be breathable but not strong or stretchy and whose appearance may change with use.
NV	W	UF	Air permeability	Resistance to pilling, stretching in the weft direction	For products that should be breathable but not stretchy and whose appearance may change with use.
		F	Abrasion resistance	Resistance to pilling, tensile strength, elongation at break and tearing strength in the weft direction	For products that should be resistant to abrasion but not strong or stretchy and whose appearance may change with use.
	K	UF	Stretching, air permeability	Abrasion resistance, tensile strength and elongation at break in the warp direction	For products that should be highly elastic and breathable but not abrasion resistant.
		F		Tensile strength in both direction and elongation at break in the warp direction	For products that need not be very strong or stretchy.

Comparing single- and double-coated sheep breeds, there were no significant differences in the properties of knitted fabrics, but there were some differences for woven fabrics. For example, the woven fabrics made from double-coated sheep breeds felted less than those made from single-coated sheep breeds. As a result, their air permeability was also higher. Additionally, the elongation of the woven fabrics of double-coated sheep breeds was significantly lower, especially for felted fabrics.

As a result of the tests, it can be concluded that the properties of the fabric are affected by sheep breed, wool quality, the structure of the fibres, the yarn and the fabric-making technique. The influence of the fabric-production technique may be the most significant. For example, yarn made from the wool of the Norwegian Spælsau sheep for knitwear was the strongest as compared to the other yarns, but the knitwear fabric made from the same yarn had almost the lowest tensile strength as compared to the other fabrics.

INNOVATION THROUGH A LOCAL AND SMALL-SCALE PRODUCTION VALUE CHAIN

The complete chain of wool production encompasses the journey of wool from shearing to finished product. Figure 7 shows the stages of wool processing in a simplified way. Although all the processes are the same, the roadmaps of wools at different sizes of production are slightly different. While, in large-scale production, many steps are carried out in various industries, which may be located far away from one another in different countries and the wool moves long distances from one place to another, the small-scale production chain is much more localised, and many of the processes are carried out within the same company.

FIGURE 7. The stages of wool processing

To determine the maximum use for wool, it is important that all parts of the wool-processing chain work, cooperate and have equal throughput. In Estonia, there is no centrally organised complete chain for wool processing. Wool is bought by various small companies for their own production, which is also the reason for the low level of wool utilisation there. In Norway, with the help of state subsidies and the cooperation of farmers, it has been possible to build a central wool-purchasing and -sorting system that supports all other parts of the value chain.

During the last 15 years, a parallel value chain has evolved, and small wool-processing plants, such as Selbu spinneri, have been established. These mini-mills buy wool either directly from the farmer or from the wool station and wash and process the wool in small batches. This makes it possible to keep the entire value chain in Norway, including wool scouring. The advent of small-scale wool processing also brings producer and consumer closer together, as the farmers can sell yarn made from their own wool after it is spun at a local spinning mill.

One of the aims of large-scale processing is to obtain large amounts of wool with similar properties. This helps to keep costs low and allows the use of the material in large industries, such as the bedding industry. On the other hand, large quantities lower the richness of the assortment and do not allow for the best usage of wools with various qualities. The prioritisation of wool with similar qualities also pushes aside the wool from smaller local sheep breeds that has either different colours or different properties. As seen from the test results, in some areas, double-coated fleeces can broaden the properties and quality of products made of wool. The new circular-economic approach to natural resources requires the maximum use of all materials. Small-scale local production contributes to this by allowing the use of wool and yarn with various properties in an optimal way.

CONCLUSION

Estonia and Norway have very different wool production value chains. While, in Estonia, most of the wool is not sufficiently valorised, in Norway there is a central wool-collection and -sorting system, helping to utilise most of the local material. During the project, wool from three sheep breeds from Estonia and three sheep breeds from Norway was tested as fibre, yarn and woven and knitted fabric, with and without finishing. The initially simple task of determining the properties of the wool from different sheep breeds was ultimately revealed to be complex and multifaceted. The results show that the wool from these breeds is indeed strong and can have many uses.

By comparing the results, it is possible to choose wool from the different sheep breeds and produce different materials for specific textiles. In any case, it will be important to proceed with product development that considers the results of this research, which will help to provide connections between the types of wool, their processing and the desired properties of the products made. The local small-scale wool industry supports the idea of a large variety of different types of yarn and is helping to develop innovative products.

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