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# Wool Yarn Characteristics Made from Wool of Six Different Estonian and Norwegian Sheep Breeds

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## Abstract

Wool as a natural fiber is of increasing importance nowadays because of its natural renewable source. In Estonia, up to 90% of local wool is not adequately valued, while Norway has a functioning wool buying and sorting system. However, both countries have room for improvement in the better use of local wool. The article provides an overview of the Estonian-Norwegian wool research conducted in 2020-2023 and its main results according to yarn and measuring its properties. During the research, wool was collected from three Estonian and three Norwegian sheep breeds, semi-worsted yarn of two different sizes was made from it, and knitted and woven fabrics, each with the same structure, were produced. The tensile strength and elongation of the yarns and fabrics were measured. The paper focuses on yarn characteristics such as tensile strength and elongation at break and brings up some possibilities about how the wide range of different sheep breeds wool qualities can be used in innovative ways of creating 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 the properties of wool yarns; Wool value; Heritages sheep breeds; Local wool production

## 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 the supporting systems and existing value chain. 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, next to which wool has regressed to the status of an annoying by-product and most of the wool is destroyed and insufficient attention is paid to increasing the value of wool as a renewable resource. Purposeful use of wool is a problem in most of the Nordic and Baltic countries [1]. But this is a problem also in other countries, like in Turkey where sheep farming has been mostly for the purpose of meat and milk production [2,3].

To increase the valorization of local wool, the project "Estonian and Norwegian local sheep wool - research and study materials for textile students in higher education" (2020-2023) was carried out. Project was funded by European Economic Area (EEA) Financial Mechanism 2014 2021 grants in higher education. The purpose of the project was to introduce the unique properties of wool and to encourage craftsmen and designers to use domestic wool more than before. A special feature of the project was the collaboration between craft practitioners, wool processors, and industrial fabric testers. As a part of the project, there were carried out a lot of tests of wool, yarns, 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 of different sheep breeds and the fabrics made from it, which would help to use different materials as efficiently as possible. The paper gives an overview of the test made of wool yarns during the project and brings up similarities and differences of Estonian and Norway wool according to different breeds.

Historically, wool has been mainly used in the production of clothing and interior textiles. While today finer wool finds use more easily, it is problematic to find use for coarser single and double-coated wools [2]. Coarser fiber and uneven, felted or soiled wool is increasingly used in the production of technical textiles and in technical applications [4–6]. The notion that there is no good or bad wool is becoming more and more common. It is possible to find the most suitable application for wool fibers with different properties. The research carried out in this project mainly focused on finer and medium, uniform wool suitable for textile production. There was a series of tests aimed to map the different properties of the wool from different sheep breeds to better understand the possible usage area of different wool types.




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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 PRIA (Agricultural Registers and Information Agency in Estonia) register, but many of them are very small in number. There are over a thousand sheep in only seven breeds: the most common of them are the Estonian Whitehead and Estonian Blackhead sheep. They are followed by the Kihnu native sheep: the oldest local native breed, only recently officially recognized. However, the largest number (30728) of sheep in Estonia are different crossbreeds [7]. Dividing 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 calculated amount of wool in Estonia is 130 tons. About 90% of it does not find enough valorization [8].

In Norway there are 15 times more sheep than in Estonia. A total of 1 million breeding females are kept during the winter [9]. There are 3 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 their origin is a crossbreeding between local sheep and imported sheep, mostly in the late 1800's. The wool of these sheep is uniform. Norway produces an estimated 3500 tons of wool per year. The wool that is delivered directly to the spinning mills will not be counted in the wool statistics, and this must be kept in mind when looking at the numbers in wool production.

## Materials and Methods

### Materials

Three Estonian (Estonian Whitehead (EV, Figure 1), Estonian Blackhead (ET, Figure 2) and the Kihnu native sheep (KM, Figure 3)) and three Norwegian sheep breeds (Blæset sau (Sheep with white stripe in the face, NB, Figure 4), Gammelnorsk spælsau (Old Norwegian Spælsau, NS, Figure 5), and Gammelnorsk Sau/Villsau (Old Norse Sheep/wild sheep, NV, Figure 6)) were selected to carry out the research. The choice turned out to be in favor of these breeds, because Whitehead and Blackhead are historical Estonian sheep breeds while Kihnu native sheep is the oldest local breed. The mentioned three sheep breeds are statistically the most cultivated sheep breeds in Estonia.

**Figure 1:** The Estonian Whitehead sheep. Photo by K. Tambet.

**Figure 2:** The Estonian Blackhead sheep. Photo by P. Veersalu.

The wool of Norwegian sheep breeds was sorted by colour - two colours from each sheep breed. This makes it easier to separate the yarn types, and also makes it possible to compare the quality of the fibers and yarns made of different colours.

When selecting the wool of Estonian Whitehead and Blackhead sheep, the sheep with the highest bloodline of the given breed were selected from the database kept on the breeding flocks. In the selection of Kihnu native sheep, the selection was based on sheep breeder Anneli Ärmpalu-Idvand's recommendations. The wool from the Estonian Whitehead sheep breed comes from 17 different sheep from 3 different herds. The wool from the Estonian Blackhead sheep breed comes from 21 different sheep from 4 different herds. The wool from the Kihnu native sheep breed comes from 10 different sheep from two different herds. All of them shear the sheep once a year, mainly in early spring, but some of them in summer as well. In total, 48 fleeces were used for making yarn.

Blak-brownish wool from the Norwegian heritage sheep breed named Norwegian Blæset was collected from classified from the wool station in Malvik, close to Selbu spinneri in Trondheim. Wool from the Old Norwegian Spæsaul, beige and grey, was collected from a farm in Kvikne, 200 km south of Trondheim. Old Norse sheep wool was collected from several different farms along the coast of Mid-Norway.

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 coat wool (Estonian Whitehead sheep, Estonian Blackhead sheep, Norwegian Blæset) and three have double coated wool (Kihnu native sheep, Old Norse sheep, Old Norwegian Spælsau).

**Figure 3:** The Kihnu native sheep. Photo by T. Mägi.

**Figure 4:** Norwegian Blæset. Photo by M. Espelien.

**Figure 5:** Old Norwegian Spælsau. Photo by A. Espelien.

**Figure 6:** Old Norse sheep. Photo by A.Espelien.

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

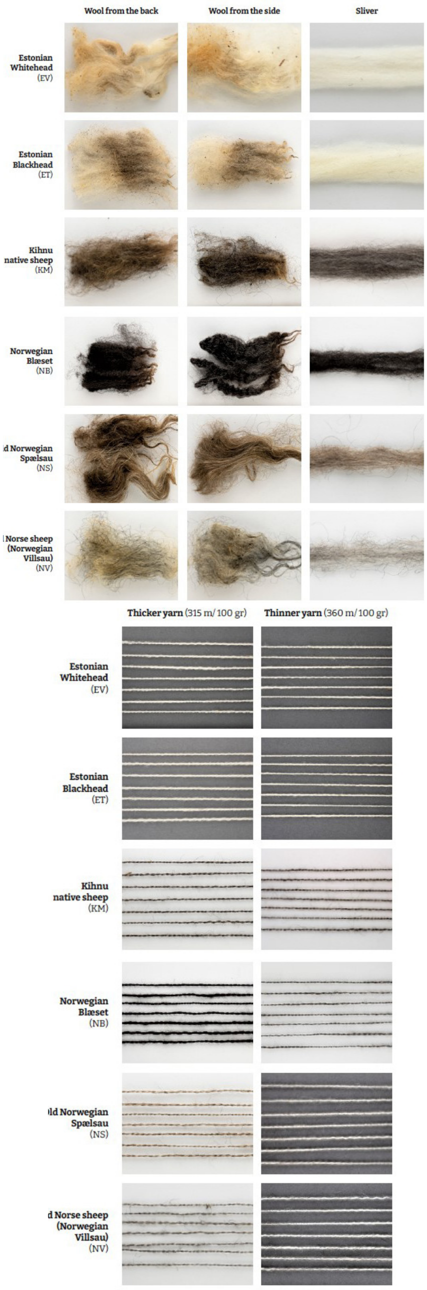


**Figure 7:** Samples of wool, sliver and yarn of six sheep breeds. Order from left: wool from the back, wool from the side, sliver, thicker yarn (315 m/ 100 gr), thinner yarn (360 m/ 100 gr). Photos by Maritta Anton.

Producing the yarn, it was important that the wool of different sheep from one breed was mixed as much as possible. Beginning at the picking stage, fibers of different shades of Kihnu native sheep were mixed together, with the majority mixed during combing. In the Vilma wool mill, the wool went through the following processing steps: picking, carding, pin-drafting (4 times), spinning, plying and cone winding. In Norway, the wool was sent through the picker, a fiber separator, the carder, a draw frame, to the ring spinner and then the plyer. After plying, the yarn was conditioned and left to dry for at least one week.

The carding machine worked very well on mixed sheep wool from Estonian Whitehead Sheep and Estonian Blackhead Sheep. The carding tape ran evenly, which enabled even combing and finally, an even yarn. Kihnu native sheep roving came out more uneven due to the different wool fiber lengths. In Norway, the carding and the stretching/combing went well for all the sheep breeds.

If all the preliminary work has been successful (carding, pin-drafting) and the slivers are even (there are no thicker or thinner places), then the yarn will be even and nice when spun.

The yarn spun in Estonia was measured to spin at the correct coarseness. 63m or 72m of yarn had to weigh 10g. 10 different spun yarns were measured, and each weighed between 9.6-10.4 g. Several such tests were done previously as well. The variation in the thickness of the yarn may be due to the small amount of wool that was tested.

Some of the yarns were of different thicknesses. Even if the yarn number is the same, the thickness of the yarn can differ because of the different weight/density, thickness of the fibers, and because some sheep breeds have more compact wool. This is mainly because the guard hairs are heavier and more compact than the thinner under wool.

To determine how yarns with different strength and elongation affect the fabric's strength and elongation properties the fabrics were made. During the project, fabrics were produced on looms and knitting machines and finishing was carried out.


**Figure 8:** Samples of unfinished and finished woven fabrics. Photos by Maritta Anton.

The woven fabrics (Figure 8) were handwoven in University of South-Eastern Norway (USN) and UT VCA. All fabrics were cut in half, one half of which was tested without finishing and the other with finishing. The density of the fabrics was 8 threads/cm in warp and weft, and they were woven at 2/2 twill weave. The width of the fabric without finishing was 54 cm in the reed, and total length 500 cm.

All knitted fabrics (Figure 9) were produced at the UT VCA. All samples were knitted on a Brother hand knitting machine (Model 323), density 6. Two fabrics were knitted from each yarn, the shorter (1000 rows) went into testing without finishing and the longer one (1200 rows) was felted before testing. The width of the textile was 198 loops.

All woven textiles were treated in exactly 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 of the knitted textiles were finished together at the UT VCA. The fabrics were felted with a semi-industrial washing machine, Electrolux S556 model, which has a capacity of 10 kg. In total, the fabrics weighed 4.1 kg. Approximately 2/3 of the machine was filled with this weight. Normal wash was selected for the washing machine program: Normal Colour 40°C, which lasts 42 minutes. ProFit Wool detergent was used in 0.25 ml amounts.


**Figure 9:** Samples of unfinished and finished knitted fabrics. Photos by Maritta Anton.

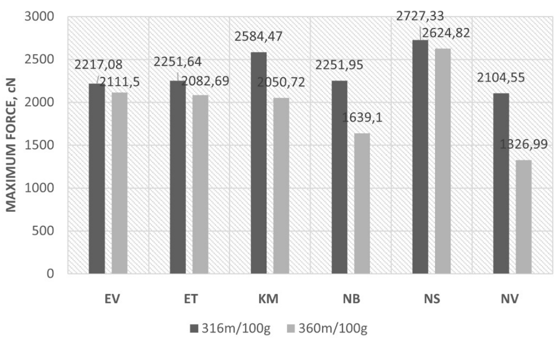


**Figure 10:** Tensile strength of yarns, cN.

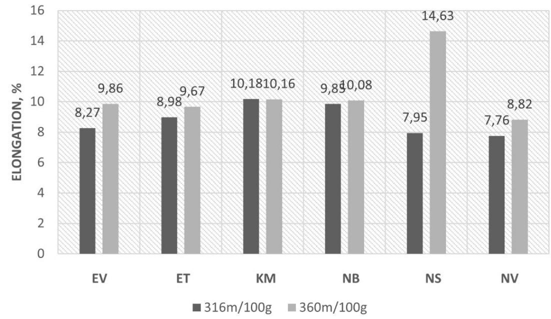


**Figure 11:** Elongation at break of the yarns, %.

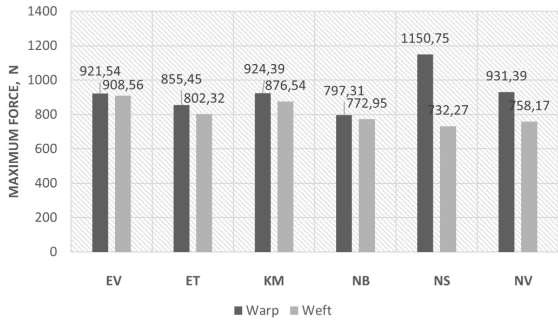


**Figure 12:** Tensile strength of woven fabrics, N.

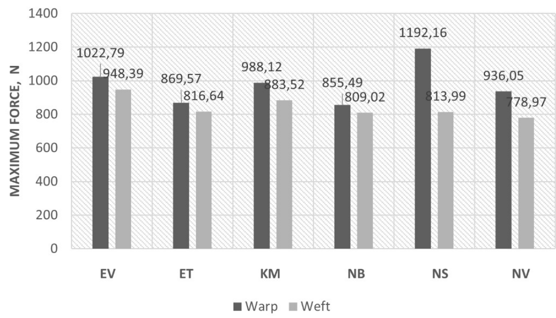


**Figure 13:** Tensile strength of finished woven fabrics, N.

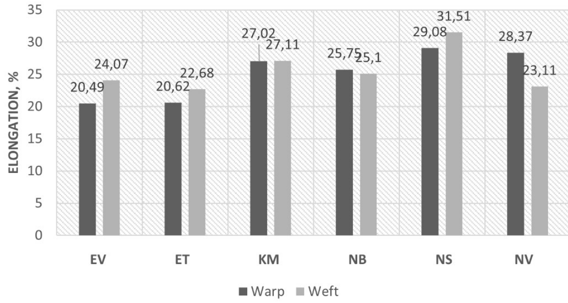


**Figure 14:** Elongation of woven fabrics, %.

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 colors of wool were used for the same breed, to be better able to keep the yarns apart, but the colours might have slightly different properties, so the conclusions drawn for one yarn cannot be exactly generalized for the whole breed. On the other hand, choosing only one colour would not be representative, and the mixing of colours to get a more general result would also be difficult. There are significant differences in wool quality between sheep of different colours, due to the different colour genes [10].

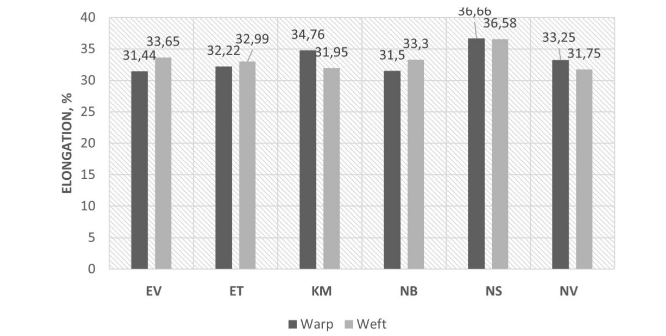


**Figure 15:** Elongation of finished woven fabrics, %.

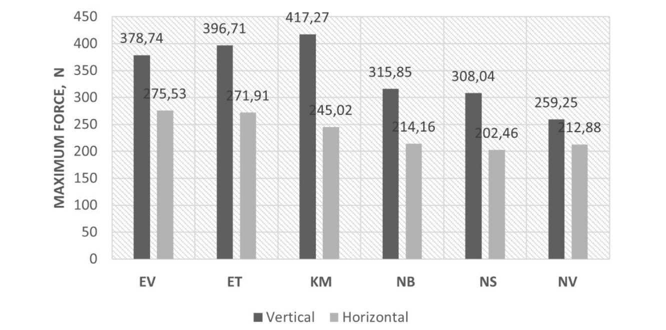


**Figure 16:** Tensile strength of knitted fabrics, N.

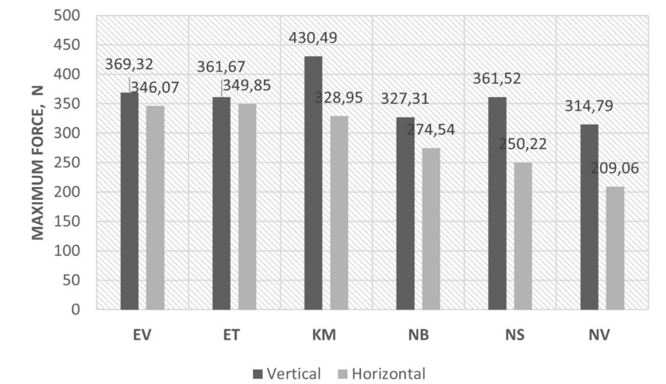


**Figure 17:** Tensile strength of finished knitted fabrics, N.

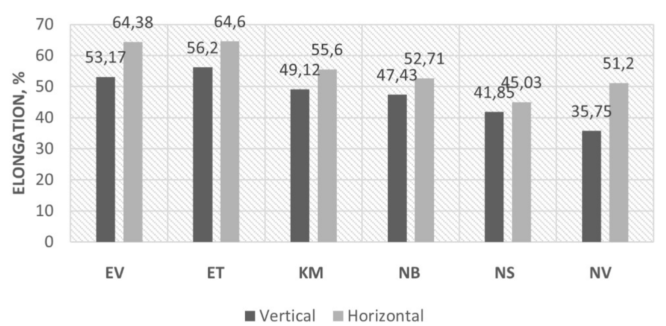


**Figure 18:** Elongation knitted fabrics, %.

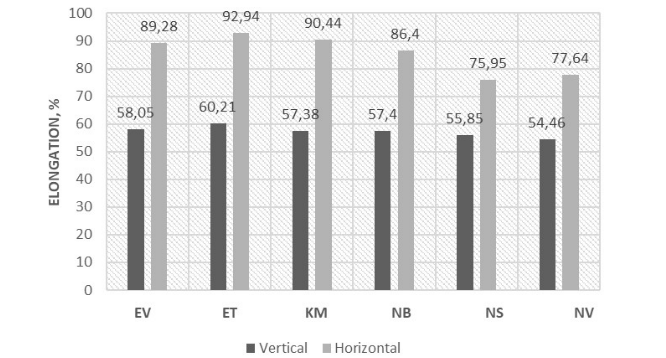


**Figure 19:** Elongation of finished knitted fabrics, %.

There were also several differences in the yarn processing procedure. Although both wool factories use a similar semi-worsted technique, UT VCA Vilma wool mill does not use a fiber separator to remove coarse outer wool hairs nor finishes the yarn with a conditioner (water vapor 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 breed of one country with others.

## Methods

For analysis of yarn and fabric properties several tests were done. All tests were performed in the textile testing laboratory of TTK University of Applied Sciences, Estonia.

For the results of the tests to be comparable, the conditions for performing the tests are very important. During the testing conditions were on average the following: temperature 26±2°C and relative humidity 44±4%. It should be temperature 20±2°C and relative humidity 65±2% [11]. The conditions are different from standard conditions, but the probability that this would affect 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 in this study, and thus the test results of different fabrics are comparable.

The method of sampling is done according to Standard EVS-EN 12751:2000 [12]. The accuracy of recording the test results is also determined according to the testing standards used.

In this paper we performed following tests, because tensile property is one of the important factor that determines the quality of the yarn and the fabric [13]:

Tensile strength and elongation at break of yarns according to Standard EN ISO 2062:2009 (500mm 500mm/min) [14].

Tensile strength and elongation at break of fabrics according to Standard EN ISO 13934-1:2013 [15].

Yarn and fabric elongation and strength analyses were performed with the James Heal Tensile Tester device Titan 5. The T15 Pneumatic Yarn Grips were used to test the yarn and T27 Universal Pneumatic Fabric Grips were used for fabric testing. All the samples were subjected to a controlled tension until failure.

20 tests were performed with all yarn samples, the length of the test object was ~60 cm and the results were automatically saved in the program. Yarn tensile strength was measured in cN. 10 tests were performed with all fabric samples, 5 pieces in horizontal and 5 pieces in vertical direction. The length of the test body was 30cm for woven fabrics and 20cm for knitted fabrics. The tensile strength of the fabric was measured in N.

As mentioned, this paper focuses on yarn properties – tensile strength and elongation at break, also whether and how the properties of yarns can affect the equivalent properties of fabrics made from the same yarns.

## Results and Discussions

Yarns of two different thicknesses spun from the wool of each sheep breed have been tested: for weaving (two-ply 316m/100g) and for knitting (two-ply 360m/100g) - a total of 12 yarns.

All yarns were tested for tensile strength according to the standard EN ISO 2062:2009. Figure 10 shows the average result of yarns (thicker and thinner) spun from wool fibers of each sheep breed. The maximum force (cN) was measured at the moment of breaking.

As can be seen in Figure 10, the strongest yarns for both weaving and knitting were the Old Norwegian Spælsau (NS) sheep breed.

The strengths of yarns made from the wool of Estonian sheep breeds are relatively similar, the strengths of yarns made from the wool of Norwegian sheep breeds vary more, especially when comparing the strength properties of coarser and finer yarns.

The biggest difference in tensile strength was found in yarns made from the wool of the Norwegian Old Norse sheep (NV) breed. The yarn for knitting was almost twice as weak as the yarn for weaving. This may be caused by the different properties of wool fibers of different colors, but this still needs further research. There is a very big difference in the tensile strength of the finer yarn in the Old Norse sheep (NV) and Old Norwegian Spælsau (NS) sheep breed, where yarn of same number spun from the wool of the Old Norse sheep breed is twice as weak as the yarn spun from the wool of the Spælsau sheep breed. Both yarns of the Estonian Whitehead and Blackhead sheep breeds were relatively uniform in strength.

While measuring the tensile strength, the maximum elongation (%) of the yarns before breaking was also tested (Figure 11) at the same time.  Elongation is the change in length of a material when stretched.

The elongation of the yarns before breaking was relatively similar for all yarns: stretching 8-10%, with one exception: the finer yarn for knitted products spun from the wool of the Old Norwegian Spælsau Sheep (NS) breed was completely different, stretching over 14% before breaking. Based on the experience of wool sorters, Old Norse sheep (NV) fleeces have many kemp fibers. Kemp fibers are short, without shine, white in color and brittle [16].  The high proportion of kemp fibers in the yarn may affect the tensile strength and elongation of the yarn, but this statement also needs further investigation. Thinner yarns generally stretch more before breaking. Stretchability increases the strength of yarns.

The tensile strength of fabrics testing is based on the standard EVS-EN ISO 13934-1:2013. The tensile strength test is performed separately in the warp and weft direction of the fabric. When taking samples, it had to be done in a way where each sample contains as many different yarns as possible. The properties of finished fabrics were tested because these fabrics are usually used in finished form.

The tensile strength was relatively equal for all fabrics (Figure 12 & 13), with a slightly higher strength in the warp direction than in the weft direction. The exception was fabrics from the Old Norwegian Spælsau sheep breed (NS), which were significantly stronger in the direction of the warp than other fabrics. Yarn made from wool of the same breed was also the strongest of the yarns. But in the weft direction, the strength of the fabrics is significantly more uniform and does not correlate with the strength of the yarns as much as in the warp direction. Finishing did not significantly affect the tensile strength of woven fabrics, they remained proportionally the same.

While the elongation of thicker yarns varied between 8-10%, the elongation of woven fabrics (unfinished) from the same yarn in the direction of the warp varies between 20-30% (Figure 14), proportionally matching the tensile strength results. The fabrics that stretched a little more than the others were also slightly stronger.

Finishing made the elongation of the woven fabrics more uniform (Figure 15), increasing the elongation at breakage for all fabrics, ranging from 31-36%. Thus, the increase in elongation with finishing was uneven– the elongation of fabrics from the Estonian Whitehead (EV) and Blackhead sheep (ET) breeds increased the most, and the elongation of fabrics from the Norwegian Spælsau (NS) breed increased the least.

It is significant that, compared to other yarns, yarns made from the wool of Norwegian sheep breeds - Old Norwegian Spælsau Sheep (NS) and Old Norse Sheep (NV) - showed weaker results in elongation, but fabrics from the same yarn are the stretchiest in the direction of the warp compared to other fabrics, although they are woven and finished in exactly the same way.

The tensile strength of the knitted fabrics in the vertical direction was higher than in the horizontal direction for all fabrics (Figure 16-17). The tensile strength of knitted fabrics of Estonian sheep breeds was higher than that of Norwegian sheep breeds. The tensile strength varies more in the vertical direction than in the horizontal direction.

Felting made the tensile strength of the knitted fabrics more uniform (Figure 17). The tensile strength of all fabrics increased more in the horizontal direction and remained relatively the same in the vertical direction compared to unfelted fabrics, with the exception - tensile strength of knitted fabrics of two Estonian sheep breeds wool, Estonian Whitehead (EV) and Estonian Blackhead (ET), decreased somewhat in the vertical direction after finishing. The strength of thinner yarns of the wool of Estonian sheep breeds was relatively uniform, and the strength of knitted fabrics is also relatively uniform in both horizontal and vertical directions. At the same time, the strength of thinner yarns made from the wool of Norwegian sheep breeds was very uneven, for example, the strength of Old Norwegian Spælsau (NS) yarn was twice as high as that of Norwegian Old Norse (NV) breed. The strength of knitted fabrics made of the same yarn is relatively equivalent in both vertical and horizontal directions. At the same time, for the woven fabric, the correlation between yarn strength and fabric strength remained the same for the same breeds.

In the case of knitted and woven fabrics, the finished fabrics were in general stronger, elongated more at the moment of breaking, and elongated more in the horizontal direction than in the vertical direction (Figure 18).

Felting made the knitted fabrics more uniformly stretchable in the vertical direction, with all being close to 60% elongation at breakage (Figure 19). In the horizontal direction, the elongation became significantly higher, although the tensile strength became only slightly higher in these fabrics.

Comparing the stretchability of knitted fabrics and the yarns used to make them, it can be said that there is a correlation. The exception is Old Norwegian Spælsau sheep (NS) breed yarn, which elongated a lot, but in terms of knitted fabric, it is no different from other fabrics.

## Conclusion

The limited volume of the article does not allow us to highlight and analyze all the results of the tests. A choice has been made here, considering that it is possible to produce yarn with different properties and use them as wisely as possible to make different textiles with expected properties.

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

According to the specific characteristics of the yarn properties, there can be also recommendations for possible 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 the value is good or bad depends on the intended use of the product and the expected properties.

As a result of the tests, it can be concluded that the properties of the fabric are affected by the sheep breed, wool quality, and the structure of the fibers, the yarn, and the fabric making technique. The influence of the technique used in the production of fabric may even be the biggest. For example, the yarn made from the wool of the Old Norwegian Spælsau (NS) sheep breed for knitwear was the strongest compared to other yarns, but the knitwear fabric made from the same yarn had almost the lowest tensile strength compared to other fabrics. Therefore, it cannot be concluded that a strong yarn can always be made into a strong fabric. And more, the finishing processes of woolen fabrics make them more uniform in properties, with regard to tensile strength and elongation in the case of this study.

In terms of these studies, it is not possible to say that the strength and elongation of the yarns significantly depends on whether the sheep breeds have single or double coated wool. Comparing single- and double-coated sheep breeds, there are no big differences in properties for knitted fabrics, but there were some differences for woven fabrics. Elongation of the woven fabrics of double-layered sheep breeds was significantly lower, especially after finishing.

Knowing how the strength and stretch properties change in the textile manufacturing process and what they depend on, allows us to consciously choose suitable technological production methods and produce textile materials with the necessary properties.

In order to find the maximum use for wool, it is important that all parts of the complete wool processing chain work, cooperate and have equal throughput. The advent of small-scale wool processing brings producer and consumer closer together, as the farmers can sell yarn made from their own wool spun at a local spinning mill.

One of the aims of large-scale processing is to get very big amounts of wool with similar properties. It helps to keep costs lower and allows the use of the material in big industries. On the other hand, big quantities lower the richness of the assortment and do not allow using all different wool qualities in the best way. The question about similar quality also pushes aside the wool from different smaller local sheep breeds either with different color or different properties as it has happened with wool from different native breeds. As seen from the test results, in some areas the double-coated fleeces can widen the properties and quality of the 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.

During the project wool from three sheep breeds from Estonia and three sheep breeds from Norway was tested as yarn, woven, and knitted fabric with and without finishing. At first glance, the simple task of finding out the properties of the wool of different sheep breeds turned out to be a much more complex and multifaceted research question. The results show that the wool from these breeds is indeed strong and can have many different 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 would be important to proceed with product development that takes into account the results of this research, which would help to provide connections between the types of wool and their processing and the desired properties of the products. The local small-scale wool industry supports the idea of a big variety of different yarn sorts and helps to develop innovative products.

## References


1. Haugrønning V, Broda J, Espelien IS, Klepp IG, Kobiela-Mendrek K, Rom M, et al. Correction to: upping the WOOLUME: waste prevention based on optimal use of materials. In: Cham: Springer International Publishing. p. C1-; 2022. Local, slow and sustainable fashion: wool as a fabric for change [internet] Klepp IG, Tobiasson TS, editors. 2022.
2. Løvbak Berg L, Klepp IG, Sigaard AS, Broda J, Rom M, Kobiela-Mendrek K. Reducing plastic in consumer goods: opportunities for coarser wool. Fibers. 2023; 11: 15.
3. Vet anim Sci TJ. Behrem S, Gül S. Turkish Journal of Veterinary and Animal Sciences Effects of age and body region on wool characteristics of Merino sheep crossbreds in Turkey.
4. McNeil SJ, Sunderland MR, Leighs SJ. The utilisation of wool as a catalyst and as a support for catalysts. Appl Catal A. 2017; 541: 120-40.
5. Johnson NAG, Wood EJ, Ingham PE, McNeil SJ, McFarlane ID. Wool as a technical fibre. J Text Inst. 2003; 94: 26-41.
6. Broda J, Przybyło S, Kobiela-Mendrek K, Biniaś D, Rom M, Grzybowska-Pietras J, et al. Biodegradation of sheep wool geotextiles. Int Biodeterior Biodegrad. 2016; 115: 31-8.
7. Republic of Estonia Agricultural Registers and Information Board. PRIA.
8. Matsin A, Tali K, Kabun K, Kool L. Ülevaade eesti villamajandusest 2022. Stud Vernacula. 2022; 14: 206-23.
9. The Norwegian Association of Sheep and Goat Farmers. NSG.
10. Atav R, Ergünay U, Gürkan Ünal P. Determining the effect of pigmentation on some physical and mechanical properties of yak and cashmere down fibers. J Nat Fibers. 2023; 20.
11. EVS-EN ISO 139:2005. Text-Stand Atmos Cond Test. 2005.

12. EVS_EN_12751; 2000_en_preview.

13. Ahmad S, Rasheed A, Afzal A, Ahmad F. Advanced textile testing techniques. 2017; 134-60.

14. Eesti K; 2010. EVS-EN ISO 2062:2010 Textiles - Yarns from packages - Determination of single-end breaking force and elongation at break using constant rate of extension (CRE) tester [Internet]. Available from: http://www.evs.ee.

15. Eesti S. part 1: Determination of maximum force and elongation at maximum force using the strip method [Internet]; 2013. EVS-EN ISO 13934-1:2013 Textiles - Tensile properties of fabrics -. Available from: http://www.evs.ee.

16. Kabun K. Arhailiselt high-tech. Lambavilla teadmistepõhine rakendamine. Tallinn: Eesti Kunstiakadeemia tekstiiliosakond. 2022; 38.