# EXPLORING THE PROPERTIES OF THE NEW BIO-BASED AND CIRCULATED TEXTILE MATERIALS

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ABSTRACT: Textile industry consumes huge amount of natural resources and produces waste enormously. The industry needs to move towards circularity. Therefore, there is a need to have better understanding of the physio-mechanical properties of circular textile materials. The article describes the properties of 20 different bio-based and circular textile materials and compares these results in the properties of non-circular materials, thus identifies the differences and similarities in the physio-mechanical characteristics. The publication consists the results of the testing of 20 different innovative and reformed bio-based and circular materials. The results are compared to the non-circular similar materials, so called control samples. The testing pattern covers several material property tests: tensile properties (breaking strength, ultimate elongation, tensile breaking force), folding, creasing and dimensional changes due to washing and drying as well as resistance to surface wetting, drying properties and burning behavior.
Keywords: biomaterial; bio-based; circular economy; recycling

## 1 AIM AND APPROACH USED

Textile industry consumes huge amount of natural resources and produces waste enormously. The industry needs to move towards circularity. Therefore, there is a need to have better understanding of the physio-mechanical properties of circular textile materials. [1],[2]

This article consists testing results of 20 different innovative and reformed bio-based and circular materials and compares to the results of previous studies. The tested materials are following: bio-based textiles, textiles from circulated materials as well as novel artificial leathers, such as padding and felt based on circulated textile fibres, organic cotton tricot and fleece, circulated cotton flannel, bamboo tricot, ramie, hemp and nettle fabrics, cork fabrics, peat based textiles, Lyocell and cellulose based artificial leather.

The testing was carried out of following properties:

- Tensile properties (breaking strength, ultimate elongation and breaking force) according to SFS ISO 13934-1 (Textiles — Tensile properties of fabrics — Part 1: Determination of maximum force and elongation at maximum force using the strip method)
- Folding based on visual assessment and comparison with control sample (carried out only for rigid materials)
- Wrinkling based on visual assessment and comparison with control sample
- Reversibility based on visual assessment and comparison with control sample
- Dimensional changes due to washing and drying according to SFS EN ISO 5077 (Textiles — Determination of dimensional change in washing and drying)
- Resistance to surface wetting according to SFS EN ISO 4920 (Textile fabrics — Determination of resistance to surface wetting (spray test))
- Drying properties (0, 2, 4 and 24 hours)
- Burning behavior according to SFS 5464 (Textiles. Burning properties. Inflammation and flame spreading)

For test protocols the standard is not defined, the tests were planned bases on the Irma Boncamper´s book published in 2011 about textiles (Tekstiilioppi: Kuituraaka-aineet) as well as testing methods of business entities offering testing services.[3],[4]

The results are compared to the hemp and banana fiber properties introduced in Handbook of Tensile Properties of Textile and Technical Fibres of Bunsell in 2018. [5]

In this article two materials made out of hemp (100 % hemp fabric, 376 g/m$^2$) and banana (100 % banana fabric, 426 g/m$^2$) were compared to the properties of hemp fibers and banana fibers.

**Table I.** Physical properties of Hemp and banana fibers [5]. In the original material the force is expressed as tensile strength, elongation at rupture is expressed as elongation at break, elongation at rupture is expressed as Maximum.

| Physical property | Hemp (fibers) | Banana (fibers) |
|---|---|---|
| Density, g/cm$^3$ | 1,2 | 1-1,5 |
| Maximum force (tensile strength), kN/mm | 270-900 | 500 |
| Elongation at rupture (break), % | 1-3,5 | 4,5-6,5 |
| Maximum elongation, mm | 5-7 | 9 |
| Moisture absorption, % | 10-14 | 10-11 |

## 2 TESTING METHODS AND RESULTS

### 2.1 Tensile properties

The tensile properties (maximum force, force at rupture and elongation at rupture) were determinated to 20 different bio-based and circular textile materials (table 4, 5 and 6) and were performed with the tensile testing machine (S-Series Bench-top Test Machine H5KS) according to the European standard EN ISO 13934-1. The measurements of maximum force (table 1), force at rupture (table 2) and elongation at rupture (table 3) were recorded during the determination. The principle of the determination is that a fabric test specimen of specified dimensions is extended at a constant rate until it ruptures. The maximum force and the elongation at maximum force and, if required, the force at rupture and the elongation at rupture are recorded. Two sets of test specimens are cut from each laboratory sample, one set in the warp direction and the other in the weft direction. Each set consist at least five test specimens.

The research of bio-based materials is made mostly with fibers and not textiles/fabrics and the results found from the literature are not comparable. However, it is possible to find out similar tendency of properties between fibers and textiles made of same material.

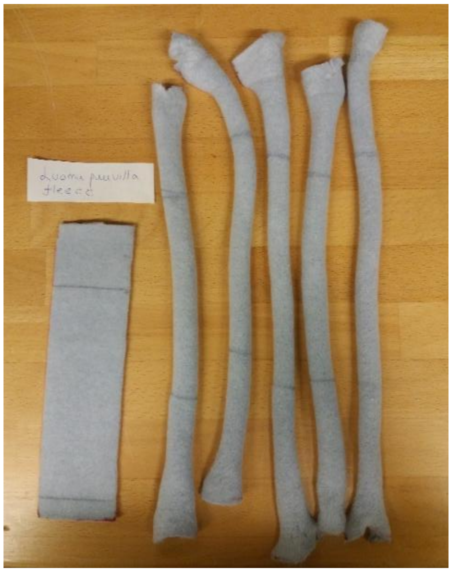


**Figure 1**: On the left the sample before testing maximum elongation according to SFS ISO 13934-1. On the right, five samples of the same material after testing elongation property. (Tuija Manerus)

Maximum force. When the tensile properties are examinated maximum force of hemp fabric is 14,6 N/mm the warp direction and 8,6 N/mm the weft direction and banana fabric 4,3 N/mm (warp) and 2,3 N/mm (weft). The force at rupture and elongation at rupture of hemp fabric is 14,5 N/mm and 11,5 % (warp) and 8,6 N/mm and 10,0 % (weft). The force at rupture and elongation at rupture of banana fabric is 4,3 N/mm and 13,0 % (warp) and 2,2 N/mm and 22,0 % (weft). The test results show that the strenght of hemp fabric is 3,4 – 3,7 times sturdier than banana fabric and the elongation of banana fabric is 1,1 – 2,2 times more than hemp fabric. The elongation rate of banana fabric doubles from warp to weft direction and even the banana fabric is not very stretchy it is much stretchier than hemp fabric.[3]

The results are comparable with the research of physical properties of the tensile strength of hemp fiber which is 270 – 900 kN/mm$^2$ and the elongation at break is 1 – 3,5 %. The same properties to banana fiber are 500 kN/mm$^2$ and 4,5 – 6,5 % [5].

In addition to normal conditions tensile properties of the fabrics were tested after washing and cold treatment to see how fibers respond to the treatment. Washing of the test specimens was made in the washing machine at 40 °C. The specimens were tested after they had dried. The cold treatment of the test specimens was made in a freezer at - 55 °C where the specimens were placed for a week. The results are surprising. The washing or cold treatment impact on tensile properties much with many bio-based and circular materials. It is possible to group materials into three categories:

- No washing nor cold treatment had impact on the tensile properties.
- Washing or cold treatment increased the tensile properties.
- Washing decreased the tensile properties of the tested materials.

Washing and cold treatment have only slight impact on the tensile properties of the hemp fabric. In the warp direction washing decreases slightly strength of the fabric and the cold treatment increases strength about 16 %. In the weft direction impact was vice versa to the strength of the fabric. Washing increases it slightly and the cold treatment decreases strength about 6 %.

Cold treatment doesn´t have any impact on the elongation at rupture but washing cause 17 % increasing in the warp direction and 10 % decreasing in the weft direction.

**Table II:** Hemp fabric: tensile properties and elongation at rupture in the basic conditions, after washing and after cold treatment. [3]

| the warp direction | basic | washing | cold treatment |
|---|---|---|---|
| Maximum force N/mm | 14,6 | 14,0 | 16,9 |
| Force at rupture N/mm | 14,5 | 14,0 | 16,8 |
| Elongation at rupture, % | 11,5 | 13,5 | 11,5 |

| the weft direction | basic | washing | cold treatment |
|---|---|---|---|
| Maximum force, N/mm | 8,6 | 8,6 | 8,6 |
| Force at rupture, N/mm | 8,6 | 8,6 | 8,6 |
| Elongation at rupture, % | 10,0 | 10,0 | 10,0 |

Impact of washing and cold treatment on tensile properties is much bigger with banana fabric. In the warp direction washing increases slightly strength of the fabric and the cold treatment increases strength about 21 - 23 %. In the weft direction washing increases strength of banana fabric 122 – 132 % and the cold treatment increases strength 152 - 159 %.

Washing increases the elongation at rupture 11 - 27 %, but cold treatment decreases it 4 - 9 %.

**Table III:** Banana fabric: tensile properties and elongation at rupture in the basic conditions, after washing and after cold treatment. [3]

| the warp direction | basic | washing | cold treatment |
|---|---|---|---|
| Maximum force N/mm | 4,3 | 4,5 | 5,3 |
| Force at rupture N/mm | 4,3 | 4,5 | 5,2 |
| Maximum force N/mm | 13,0 | 16,5 | 12,5 |

| the weft direction | basic | washing | cold treatment |
|---|---|---|---|
| Maximum force N/mm | 2,3 | 5,1 | 5,8 |
| Force at rupture N/mm | 2,2 | 5,1 | 5,7 |
| Maximum force N/mm | 22,0 | 24,5 | 20,0 |

2.2 Water absorption

Water absorption of materials were tested also in the study. Test specimens were weighed as dry and soon after dipped into water. It was possible to see how much water had been adsorbed into the specimen. The test continued by investigating the drying properties. The drying was made at the normal room temperature and humidity while specimens of fabrics hanged on a loundry stand. The specimens were weighed after 2, 4 and 24 hours from the dipping into water and hanging out to dry. [3].

Hemp fabric adsorbed water 115 percentages of weight and banana fabric about 3 times more 373 percentages of weight. Hemp fabric dried quicker than banana fabric. Hemp fabric was totally dry after 4 hours when banana fabric was still wet 126 percentages of weight and it was totally dry after 24 hours of drying. The results differ from the moisture absorption of fibers, which is 10 – 14 % for hemp and 10 – 11 % for banana. [3] There is not significant difference between hemp and banana fibers to adsorb moisture [5].

2.3 Dimensional changes of fabrics

Test of dimensional changes due to washing and drying was performed according to SFS EN ISO 5077 (Textiles — Determination of dimensional change in washing and drying). The test specimens were marked 10 cm times 10 cm area were washed in a washing machine without any detergents at two different temperatures: 40 °C and 60 °C. After washing test specimens were hung to dry on a loundry stand. [3]

The dimensional changes of hemp fabric are small. It shrinks in the warp direction 1,0 % at 40 °C and 2,5 % at 60 °C and stretches in the weft direction 2,0 % at 40 °C and 0,5 % at 60 °C. Banana fabric has more dimensional changes. It shrinks in the warp direction 9,5 % at 40 °C and 8,0 % at 60 °C and shrinks in the weft direction 6,5 % at 40 °C but stretches 2,0 % at 60 °C [3].

2.4 Water resistance

Determination of resistance to surface wetting so called spray test was investigated as well. The test was determined according to the standard SFS EN ISO 4920 with little modifications of test apparatus. In the test a specified volume of water is sprayed on a test specimen that has been mounted on a ring and placed at an angle of 45° so that the center of the specimen is at a specified distance below the spray nozzle. The spray rating is determined by comparing the appearance of the specimen with descriptive standards and photographs.[3]

Banana fabric wets completely of the entire specimen face beyond the spray points. Water penetrates through the fabric when it is totally wet and there are no water drops on the specimen face. Also banana fiber of fabric gets thicker as wet. There is only slight random sticking or wetting of the specimen face of hemp fabric. Water drops fall off the specimen face when tapped. Water doesn´t penetrate easily through the hemp fabric.[3].

2.5 Burning behavior

Burning behavior of materials were realized according to SFS 5464 with modifications. There are differences between the two fabrics. Banana fabric is more inflammable than hemp fabric, but in comparation to results of tested fabrics there are much more inflammable materials. The inflammability and flame spreading of hemp fabric are weak. Minimum inflammation rate of banana fabric is 0,5 seconds and hemp fabric about a second. Both fabrics burn; hemp fabric doesn´t create smoke but banana fabric creates grey smoke [3].

There were some tests based on visual assessment as wrinkling and reversibility which were made also to hemp and banana fabrics. The results were compared with control samples. Hemp fabric is hard and it wrinkles easily. After wrinkling hemp fabric don´t reverse well and visual wrinkles can be seen on the fabric. Banana fabric is much softer than hemp fabric. It wrinkles slightly and reverses almost to the original form. The behavior of control fabric samples is identical with the tested ones [3].

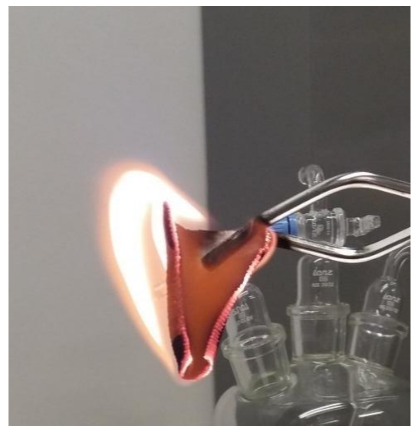

**Figure 2**: The fast burning of the fleece produced out of organic cotton. (Tuija Manerus)

## 3 FINDINGS

The tensile properties (breaking strength, ultimate elongation and breaking force) were determinated with the tensile testing machine (S-Series Bench-top Test Machine H5KS. The detailed results are introduced in Tables IV, V and VI.

In terms of tensile properties, the tested materials can be devided in three groups depending on response to washing and cold treatment.

- No washing nor cold treatment had impact on the tensile properties.
- Washing or cold treatment increased the tensile properties.
- Washing decreased the tensile properties of the tested materials. [3]

NO IMPACT: Washing and cold treatment didn´t cause significant impact on the tensile properties of materials as leather paper cellulose, cork fabric, recycled leather (ReLeda), Felt, recycled textiles (Green Craft), hemp fabric and Ramie fabric, China grass, soft.

INCREASED IMPACT: Washing or cold treatment increased the tensile properties at least 1,5 times, generally 2 –3 times on many materials. The most significant impact was on bamboo tricot, 2 – 6 times. Normally impacts were in both directions (the warp and the weft). In addition to bamboo tricot washing or cold treatment increased the tensile properties on organic cotton tricot, recycled cotton flannel, organic cotton fleece fabric. Materials as nettle fabric and nettle cotton union the tensile properties increased only in the warp direction, but with banana fabric and recycled cotton fabric the influence was opposite in the welf direction. On some materials washing impacted on the tensile properties but there was no impact with cold treatment. This kind of materials were Lyocell - modal cellulosic fibres and padding fibre.

DECREASED IMPACT: Washing decreased the tensile properties of peat wool and ramie fabric, China grass in the warp direction.

Most of circular materials had better water absorbance properties than the non-circular control samples. However, there are some exceptions on that. [3]

In general, the tested materials were shrinking due the washing more in warp direction than in weft direction. Some materials were lengthening in warp direction and shrinking in weft direction. The tensile properties were not tested in bias direction. As expected, there occurred more shrinking in the higher washing temperatures. [3]

Dimensional changes with shrinking material were considerably more in the warp direction than in the weft direction. The shrinkage of the tested materials was strongest with organic cotton fleece fabric, padding fibre, peat wool, recycled cotton flannel, banana fabric and ramie fabric. Some materials which shrank in the warp direction stretched in the weft direction e.g. organic cotton fleece fabric, peat wool, hemp and Lyocell - modal cellulosic fibres. [3]

The burning properties varied very much between the tested materials. For example, the fleece produced out organic cotton flamed easily around the sample, while bamboo tricot burned out shortly after flaming and burned only from the sample sides. [3]

The folding, wrinkling and reversibility testing were based on visual assessment after folding the material. The results varied from the permanent change in the structure of the sample to no indication of folding. [3]

The water resistance of the material surface (Spray test) varied between the samples as well as drying properties. Some of the tested materials resisted the water well or the surface was saturared only from water dropping areas while some materials were absorbing and retaining the moisture. [3] The fabric production process of the tested fabric did not have influence in the water absorbance of the hemp fiberbased fabric but increased remarkable the water absorbance qualities of the banana fibre based fabric.

**Table IV:** Tensile strength and Maximum force of untreated material (basic), after washing (washed at temperature of 40°C) and cold treatment (frozen a week at – 55°C), the tensile tests were performed when materials were dry and at room temperature. [3]

| Tensile strength, N/mm | Maximum force, warp direction | | | Maximum force, weft direction | | |
|---|---|---|---|---|---|---|
| Material | Basic | Washed | Frozen | Basic | Washed | Frozen |
| Cellulose pulp sheet, 957 g/m² | 23,9 | ** | 28,5 | 27,8 | ** | 23,9 |
| Leather paper cellulose 60% and latex 40 %, 316 g/m² | 8,2 | 7,3 | 8,0 | *** | *** | *** |
| Cork fabric R100, cork 50 %, background cotton 25 % and polyester 25 %, 376 g/m² | 12,7 | 12,0 | 12,9 | 12,2 | 11,6 | 11,6 |
| Recycled leather (ReLeda) | 11,6 | 10,2 | 10,6 | 9,9 | *** | 10,2 |
| Organic cotton fleece fabric, 100 %, 375 g/m² | 2,7 | 3,9 | 4,2 | 1,7 | 2,3 | 2,3 |
| Padding fibre, blended fibres from waste textiles 70 % and wool 30 %, 218 g/m² | 0,4 | 1,4 | 0,4 | 0,7 | 1,9 | 0,8 |
| Peat wool, sheep wool 50 % and peat wool 50 %, 318 g/m² | 6,5 | 3,3 | 8,1 | 7,8 | 6,1 | 8,7 |
| Felt, recycled textiles (Green Craft), 385 g/m² | 2,2 | 2,6 | 2,4 | 4,6 | 4,6 | 4,6 |
| Recycled cotton flannel, cotton 75 % and polyester 25 %, 365 g/m² | 4,7 | 8,6 | 7,9 | 3,8 | 10,4 | 8,5 |
| Organic cotton tricot (Lydia), 100 %, 205 g/m² | 3,0 | 7,2 | 7,9 | 2,7 | 3,6 | 3,8 |
| Bamboo tricot, bamboo 95 % and lycra 5 %, 255 g/m² | 1,7 | 3,4 | 3,5 | 0,5 | 3,0 | 3,3 |
| Recycled plastic lycra, nylon 90 % and elastane 10 % (Sportwear lycra), 160 g/m² | 7,4 | 7,8 | 9,2 | 4,4 | 5,1 | 5,3 |
| Recycled cotton, cotton 75 % and polyester 25 % (Veikko), 246 g/m² | 6,3 | 5,9 | 6,5 | 6,3 | 8,0 | 7,9 |
| Nettle fabric, 100 %, 483 g/m² | 7,4 | 9,5 | 8,3 | 6,0 | 6,2 | 5,9 |
| Nettle cotton union, nettle 80 % and cotton 20 %, 391 g/m² | 2,9 | 4,4 | 5,0 | 3,9 | 9,8 | 7,2 |
| Banana viscose, 100 %, 426 g/m² | 4,3 | 4,5 | 5,3 | 2,3 | 5,1 | 5,8 |
| Hemp fabric, 100 %, 376 g/m² | 14,6 | 14,0 | 16,9 | 8,6 | 8,8 | 8,1 |
| Ramie fabric, China grass, 100 %, 192g/m² | 10,3 | 8,4 | 10,9 | 8,6 | 9,9 | 11,5 |
| Ramie fabric, China grass, soft, 100 % (LILY), 245 g/m² | 8,6 | 8,7 | 9,5 | 3,3 | 3,1 | 3,9 |
| Lyocell - modal cellulosic fibres (Ella-Tencel), 184 g/m² | 7,3 | 14,2 | 8,6 | 7,3 | 10,0 | 8,8 |

** Cellulose pulp sheet degrades in washing and test wasn´t performed
*** Tensile properties were tested only to one direction

**Table V:** Force at rupture of untreated material (basic), after washing (washed at temperature of 40°C) and cold treatment (frozen a week at – 55°C), the tensile tests were performed when materials were dry and at room temperature. [3]

| Force at rupture, N/mm | Force at rupture, warp direction | | | Force at rupture, weft direction | | |
|---|---|---|---|---|---|---|
| Material | Basic | Washed | Frozen | Basic | Washed | Frozen |
| Cellulose pulp sheet, 957 g/m² | 23,9 | ** | 28,5 | 27,8 | ** | 23,9 |
| Leather paper, cellulose 60% and latex 40 %, 316 g/m² | 8,1 | 7,2 | 7,9 | *** | *** | *** |
| Cork fabric R100, cork 50 %, background cotton 25 % and polyester 25 %, 376 g/m² | 12,7 | 12,0 | 12,9 | 12,2 | 11,5 | 11,6 |
| Recycled leather (ReLeda) | 11,6 | 10,2 | 10,6 | 9,9 | *** | 10,2 |
| Organic cotton fleece fabric, 100 %, 375 g/m² | 2,7 | 3,8 | 4,1 | 1,6 | 2,2 | 2,2 |
| Padding fibre, blended fibres from waste textiles 70 % and wool 30 %, 218 g/m² | 0,4 | 1,3 | 0,4 | 0,7 | 1,8 | 0,8 |
| Peat wool, sheep wool 50 % and peat wool 50 %, 318 g/m² | 6,4 | 3,2 | 8,1 | 7,5 | 5,8 | 8,4 |
| Felt, recycled textiles (Green Craft), 385 g/m² | 2,1 | 2,5 | 2,3 | 4,4 | 4,4 | 4,3 |
| Recycled cotton flannel, cotton 75 % and polyester 25 %, 365 g/m² | 4,4 | 8,5 | 7,8 | 3,7 | 10,0 | 8,1 |
| Organic cotton tricot (Lydia), 100 %, 205 g/m² | 2,9 | 7,1 | 7,9 | 2,7 | 3,6 | 3,7 |
| Bamboo tricot, bamboo 95 % and lycra 5 %, 255 g/m² | 1,6 | 3,4 | 3,4 | 0,5 | 2,9 | 3,1 |
| Recycled plastic lycra, nylon 90 % and elastane 10 % (Sportwear lycra), 160 g/m² | 7,4 | 7,8 | 9,2 | 4,4 | 5,0 | 5,3 |
| Recycled cotton, cotton 75 % and polyester 25 % (Veikko), 246 g/m² | 6,1 | 5,8 | 6,4 | 6,2 | 7,7 | 7,7 |
| Nettle fabric, 100 %, 483 g/m² | 7,3 | 9,5 | 8,1 | 5,9 | 6,2 | 5,8 |
| Nettle cotton union, nettle 80 % and cotton 20 %, 391 g/m² | 2,8 | 4,4 | 5,0 | 3,7 | 9,7 | 6,9 |
| Banana viscose, 100 %, 426 g/m² | 4,3 | 4,5 | 5,2 | 2,2 | 5,1 | 5,7 |
| Hemp fabric, 100 %, 376 g/m² | 14,5 | 14,0 | 16,8 | 8,6 | 8,8 | 8,1 |
| Ramie fabric, China grass, hard, 100 %, 192g/m² | 10,2 | 8,4 | 10,9 | 8,5 | 9,8 | 11,5 |
| Ramie fabric, China grass, soft, 100 % (LILY), 245 g/m² | 8,5 | 8,7 | 9,5 | 3,2 | 3,0 | 3,8 |
| Lyocell - modal cellulosic fibres (Ella-Tencel), 184 g/m² | 7,2 | 14,2 | 8,4 | 7,2 | 9,8 | 8,6 |

** Cellulose pulp sheet degrades in washing and test wasn´t performed
*** Tensile properties were tested only to one direction

**Table VI:** Elongation at rupture of untreated material (basic), after washing (washed at temperature of 40°C) and cold treatment (frozen a week at – 55°C), the tensile tests were performed when materials were dry and at room temperature. [3]

| Elongation at rupture, % | Elongation at rupture, warp direction | | | Elongation at rupture, weft direction | | |
|---|---|---|---|---|---|---|
| Material | Basic | Washed | Frozen | Basic | Washed | Frozen |
| Cellulose pulp sheet, 957 g/m² | 2,3 | ** | 1,7 | 1,4 | ** | 2,5 |
| Leather paper, cellulose 60% and latex 40 %, 316 g/m² | 12,0 | 15,0 | 12,5 | *** | *** | *** |
| Cork fabric R100, cork 50 %, background cotton 25 % and polyester 25 %, 376 g/m² | 9,0 | 9,0 | 9,0 | 21,0 | 22,0 | 21,0 |
| Recycled leather (ReLeda) | 25,5 | 25,5 | 24,5 | 30,5 | *** | 33,0 |
| Organic cotton fleece fabric, 100 %, 375 g/m² | 35,5 | 46,0 | 36,5 | 134 | 119 | 130 |
| Padding fibre, blended fibres from waste textiles 70 % and wool 30 %, 218 g/m² | 46,5 | 55,5 | 47,0 | 52,5 | 62,5 | 60,5 |
| Peat wool, sheep wool 50 % and peat wool 50 %, 318 g/m² | 18,0 | 27,5 | 18,0 | 7,3 | 8,0 | 7,6 |
| Felt, recycled textiles (Green Craft), 385 g/m² | 57,0 | 64,0 | 64,0 | 19,5 | 22,5 | 20,0 |
| Recycled cotton flannel, cotton 75 % and polyester 25 %, 365 g/m² | 15,0 | 21,5 | 17,0 | 10,5 | 17,0 | 15,5 |
| Organic cotton tricot (Lydia), 100 %, 205 g/m² | 55,5 | 80 | 68,5 | 186 | 183 | 187 |
| Bamboo tricot, bamboo 95 % and lycra 5 %, 255 g/m² | 117 | 142 | 141 | 166 | 226 | 224 |
| Recycled plastic lycra, nylon 90 % and elastane 10 % (Sportwear lycra), 160 g/m² | 161 | 182 | 169 | 232 | 268 | 231 |
| Recycled cotton, cotton 75 % and polyester 25 % (Veikko), 246 g/m² | 19,0 | 21,5 | 21,0 | 9,5 | 13,0 | 13,0 |
| Nettle fabric, 100 %, 483 g/m² | 12,5 | 17,5 | 18,5 | 7,5 | 9,0 | 6,5 |
| Nettle cotton union, nettle 80 % and cotton 20 %, 391 g/m² | 23,0 | 24,5 | 25,5 | 3,6 | 4,7 | 4,1 |
| Banana viscose, 100 %, 426 g/m² | 13,0 | 16,5 | 12,5 | 22,0 | 24,5 | 20,0 |
| Hemp fabric, 100 %, 376 g/m² | 11,5 | 13,5 | 11,5 | 10,0 | 9,0 | 10,0 |
| Ramie fabric, China grass, hard, 100 %, 192g/m² | 3,5 | 10,5 | 3,5 | 7,5 | 7,5 | 8,0 |
| Ramie fabric, China grass, soft, 100 % (LILY), 245 g/m² | 5,8 | 7,1 | 5,7 | 18,0 | 20,5 | 16,5 |
| Lyocell - modal cellulosic fibres (Ella-Tencel), 184 g/m² | 17,5 | 21,0 | 16,0 | 10,0 | 10,5 | 10,5 |

** Cellulose pulp sheet degrades in washing and test wasn´t performed
*** Tensile properties were tested only to one direction

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