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LINA ČEPUKONĖ

DEVELOPMENT OF PEAT FIBRE KNITS AND INVESTIGATION OF THEIR PROPERTIES

Summary of Doctoral Dissertation
Technological Sciences, Materials Engineering (08T)

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INTRODUCTION

Research Problem Justification and Relevance of the Work. During the last decade, special attention in the field of textile engineering has been paid to the functional exceptionality and origin of textile products. In order to obtain novel functional (specifically; protective, medicinal, enhanced comfort, etc.) properties of textile materials or to boost the already available ones, innovative textile structures and types of finishings, as well as new types of fibres, have been created.

When designing quality knitted structures, it is essential to be highly competent in the field of weaving knitted fabric. The type of weaving depends on the type of structural elements and the method of formation of the knitted structure. This determines not only the visual appearance of the knitted fabrics but also the properties of the obtained product. The loops of the knitted products may contain threads made of different fibres or be denoted by different structures, when one of the elements is formed from threads of one particular type or several different types of threads that contribute to determining the properties of the final material. The present thesis compares knitted products of plain transverse weavings obtained by folding within a single loop, either the yarn of a single type of yarn or a variety of yarns, containing only natural fibres.

The growing awareness of users and the increasing demand for organic materials demands the dedication of special interest to natural fibres of organic origin in the production of functional textiles.

The issue of global organic manufacturing has been raised for more than a decade. Sustainable consumption and the need to deal with environmental issues prompts interest in the cyclic economic model, which is highly relevant and employed in numerous European countries. The urgent challenge is not merely the production of an organic item but also the discovery of the most environmentally-friendly way of manufacturing and obtaining the required fibre. Therefore, the present doctoral thesis chooses the peat fibre as the main object of research. This fibre is a by-product of peat harvesting. Annually, enormous amounts of peat are mined for use in many fields, including but not limited to fuel production, agriculture – yet the above listed products use only the deeper layers of peatlands; whereas the surface layer is essentially industrial waste. The surface layer consists of cottongrass (Eriophorum vaginatum) stems that complete the vegetative cycle and partially degraded upon undergoing the impact of the specific environmental conditions of a marshy ecosystem. Therefore, the production of peat fibre does not require lots of arable land, which are heavily exhausted when growing fibre cultures (e.g., linen). In addition, no pesticides and/or herbicides need to be used (differently from the process of growing various cultures) and additional use of water is not required, for example, in the process of growing cotton. The peat fibre is environmentally friendly because its source is renewable, due to the harvested peatlands natural recovery.

A shortage of investigations grounded with scholarly research data on the application of the peat fibre for the production of textile fabrics, the feasibility of its processing and its impact on the manufactured product's consumption and functional properties has been observed. Evidently, further scholarly research in this field is not only highly relevant but also urgent, due to the real life needs of the industry.

The aim of the dissertation; The aim of the present thesis is to determine the peat fibre morphology and the chemical structure, as well as the establishment of the impact of the peat fibre on the structural, mechanical and physical properties of knitted fabrics.

The objectives of the thesis are the following:

1. To investigate the morphology and the chemical structure of peat fibre.
2. To find the influence of fibrous composition on structural parameters of knits with peat fiber.
3. To determine the influence of fibrous composition on wear and abrasion resistance, friction and dimensional stability of knits with peat fibre.
4. To explore the influence of peat fibrous composition of knittings on air permeability, absorbtion properties and thermal conductivity.
5. To research and identify the impact of peat fibre on the flammability and the effect of special finishing on knitted non-combustible materials.

Scientific novelty. The application of peat fibre for the knitting industry and the manufacturing of household and functional knitted fabrics is denoted by the excellent future prospects, even though it is a totally new field of production. Although the beginning of the 20th century witnessed attempts of manufacturing peat fibre yarn and textile materials of peat fibre, so far, virtually no data based on scholarly research pertaining to the knitted articles made of this fibre and its properties are available. Essentially, peat fibre and its properties were only discussed in 19th century sources, as well as some scant scholarly works focusing on the peat applicability in the energy production industry and/or botanic science (pertaining to the investigation of the plants involved in the peat production). No academic investigation data covering the morphology, the chemical composition, the mechanical properties of the yarn and their impact on the structure of the produced textiles or the mechanical and physical properties of such textiles has been found (Wegman, 1929).

The conducted research and the obtained results demonstrated that threads containing peat fibre are suitable for knitting and that the mechanical and real life use qualities of such articles are not inferior if compared with the most commonly used cellulose textile fabrics made of cotton fibre – or they may be even denoted by superior qualities, for instance, better thermal and non-flammability qualities. The research established an exceptional quality of peat fibre, notably that the timespan of its burn through (which is a characteristic of supreme importance) is prominently longer than that of knitted cotton fabrics.

Having considered the fact that the peat fibre is exceptionally of organic origin, its use instead of similar lignocellulose fibres (whose growth is resource-demanding) should be highly promoted, due to excellent future prospects. The thesis research results expands the knowledge about the properties of peat fibre, the feasibility of its application in the knitting industry and the scope of the usage benefits stemming from the mechanical, consumption and functional properties of knitted structures containing peat fibre. The obtained results may be practically employed and used for further research, promotion of environmentally-friendly production and the enhancement of environment protection.

Approbation of the research results. The results of this research were presented in 9 scientific publications and 9 conferences.

Structure of the dissertation. The dissertation consists of an introduction, 3 chapters, conclusions, a list of references (positions) and a list of scientific publications.

CONTENT OF THE DISSERTATION

The Introduction identifies the main problem and the possible/necessary solutions for the problem of this dissertation. The aim and the tasks are provided in detail, with the defense propositions presented at the end of the Introduction.

The first chapter provides a short literature review of information and publications related to the topic of the dissertation, mainly about natural cellulosic fibers and functional fabrics from previous research papers. It was estimated that the morphology, chemical composition of fiber or blend from the fiber can be advanced to predict the properties of yarns from their blends or knitted fabric properties. Many studies have been done to investigate the mechanical and physical properties of fibers, yarns and weft knitted fabrics, but very little on peat fibre. It is also important to assess the durability of textile materials when worn or in use. However, there is no such scientific information or publications on peat fiber or textile products. Therefore, considering the possibilities and perspectives of sustainable production of textile products from peat fiber, the aim and tasks of this dissertation were raised.

The second Research methodic chapter describes the object of research and the methodology of experimental investigations.

Experimental materials:

Highly sustainable biodegradable cellulose-based peat fibre yarns have been used for newly developed knits, whereas cotton, woolen yarns and their combinations with peat yarns have been chosen for comparative analysis. Experimental knits have been produced in the textile company ‘JSC Vegateksa’ (Kaunas, Lithuania). Fabrics have been knitted in a single jersey knitting pattern on a circular 14E gauge, 3“-cylinder diameter, one needle-bed knitting machine Matec Techno New (Italy). The fabrics were knitted of peat, cotton and woolen yarns, peat and woolen yarns combination, three variants of peat and cotton yarns combination, as well as of the mentioned yarns in combination with elastomeric Lycra® yarns, which have been developed for this experimental work (see Table 1). All combinations of natural yarns were made by multiple winding, whereas Lycra® yarn was used as a ground yarn in a single plated structure. The content of Lycra® yarn used is less than 5 %. One part of the knitted samples, used for comparative analysis, has been designed with elastomeric Lycra® yarns; as at present, most knitted products are manufactured with a small amount of elastomeric yarns in order to improve the tensility and elasticity of knitted garments. The newly developed fabrics are provided for use in socks, therefore pull on/off comfort, provided by elastomeric yarn’s elastic extensibility, and is very important for such knits.

Table 1. Composition of knitted materials

Code	Yarn fibrous composition and linear density
4P	Peat, 60 tex ×1×4
8C	Cotton, 29.4 tex ×1×8
2W	Wool, 111 tex ×1×2
1P + 6C	Peat, 60 tex + Cotton, 29.4 tex ×1×6
2P + 4C	Peat, 60 tex ×1×2 + Cotton, 29.4 tex ×1×4
3P + 2C	Peat, 60 tex ×1×3 + Cotton 29.4 tex ×1×2
4P + L	Peat, 60 tex ×1×4 + Lycra®, 8.6 tex
2P + 1W	Peat, 60 tex ×1×2 + Wool, 111 tex
2P +1W + L	Peat, 60 tex ×1×2 +Wool, 111 tex + Lycra®, 8,6 tex
1P + 6C + L	Peat, 60 tex + Cotton, 29.4 tex ×1×6 + Lycra®, 8.6 tex
2P + 4C + L	Peat, 60 tex ×1×2 + Cotton, 29.4 tex ×1×4 + Lycra®, 8.6 tex
3P + 2C + L	Peat, 60 tex ×1×3 + Cotton, 29.4 tex ×1×2 + Lycra®, 8.6 tex

In Table 1, the used notation “60×1×4” means the yarn is folded of four single yarns, each with 60 tex linear density. The same system was used for all yarns and their compositions. P is peat yarn (40% peat fibre and 60% cotton fibre), C is cotton yarn, W is woolen yarn. The twist amount of single cotton, as well as peat yarn, is 35 m^{-1}, while of single woolen yarn it is 36 m^{-1}.

Experimental methodics:

All experiments were carried out in the standard atmosphere for testing according to standard LST EN ISO 139:2005.

Analysis of fiber surface and cross section was performed using an optical microscope, Nikon Eclipse E200 and digital camera Lumenera Infinity 1 (using ×40 (for yarns) and ×100 (for fibres) magnification with 0.001 mm accuracy) as well as by SEM microscopy. The fibre surface was scanned and analyzed by SEM (Scanning Electron Microscopy) Quanta 200 FEG (10 kV, magnification ranges of the specimens: 1000x and 5000x).

The peat and peat cotton grass fibres diameter and length were measured using an optical microscope Askania RML5, using ×40 magnification, digital camera Nikon Coolpix 4500, and software Metric. 100 measurements were performed in each of two directions of cotton grass fibre cross section (as those fibres have an elliptical form of cross section) to evaluate diameter of this fibre. 1000 measurements were performed to evaluate the diameter of the cotton grass bast fibres and 100 measurements were made to determine the length of fibre. A large amount of measurements were performed, as the diameter of those fibres is very irregular.

Chemical constituents of the peat fibre was carried out by the Latvian State Institute of Wood Chemistry (Riga, Latvia), according to the Klason method. Wood meal (or pulp) is treated with 72% H_2SO_4 for 2 hours. The material is then diluted to 3% H_2SO_4 and then boiled for 4 hours. The lignin is filtered, washed and weighed.

A tensile strength and, especially, elasticity of a yarn is an important parameter in the assessment of quality of the knitted structure. In knitting, yarn strength is not such an important parameter, because in this process the yarn is not subjected to very high loads, approximately 0.5-1.5 cN/tex. Tensile characteristics of the peat fibres were determined using Zwick/Roell (Germany) tensile testing machine. The distance between clamps was 20 mm; tensile speed – 50 mm/min. The average values of tensile force and elongation were calculated from 50 elementary tests. Stress-strain characteristics of the studied yarns have been obtained according to standard LST EN ISO 2062:2010. The distance between clamps was 100 mm and tensile speed 100 mm/min. The breaking force F (N) and elongation ε (%) were determined, their average values were calculated from 50 elementary tests, coefficient of variation did not exceed 11 %.

Structure parameters of newly developed knits, such as actual loop length, wale and course density, and area density, have been analyzed in this work. The actual loop length was measured by the unknitting method according to standard LST EN 14970:2006. A length of yarn taken from the sample over 10 stitch loops is measured under pretension of 0.02 cN/tex. Stitch length is determined by calculation, dividing the length measured by the number of loops. 10 yarns from each course where taken for the length measurement. The course and wale density of knitted fabrics were counted in the length (wale) and crosswise (course) directions of the knits over a 10 cm distance and evaluated per 1 cm (according to standard LST EN ISO 14971:2006). Measurements where repeated 5 times in 5 different places.

The mass per unit area M was calculated according to the formula presented below:

$$M = P_w \cdot P_c \cdot l \cdot T \cdot 10^{-2}; \tag{2.1}$$

where P_w is the wale density in cm^{-1}, P_c is the course density in cm^{-1}, l is the loop length in mm, T is the yarn linear density in tex.

In order to investigate the main comfort and functional properties of fabrics, dimensional stability, permeability to air, static water absorption, friction properties, heat transfer, abrasion resistance and the flammability of the knits were all measured in this work.

Dimensional stability of knitted fabrics, i.e. shrinkage value after washing and drying was investigated according to Standard ISO 26330:1993. After washing in (10±0.5) min in (40±2)° C temperature and 3 g/l washing powder concentration washing solution, the samples where rinsed three times in (20±2)° C temperature. Duration of each rinse was (1±0.1) min. The rinsed samples were spun (frequency of revolution 1000 min^{-1}) during (1±0.1) min and dried for 24 h on a smooth surface. The shrinkage value λ was determined by the following equation:

$$\lambda = \frac{L - L_0}{A} \cdot 100; \tag{2.2}$$

where λ is shrinkage in %; L_0 is the dimension of sample before washing and drying in mm; L is the dimension of sample after washing and drying.

Air permeability tests of the investigated knitted fabrics were provided according to Standard EN ISO 9237:1997 by equipment L14DR (Karl Schroder KG, Germany) using the head area of 5 cm^2 and pressure difference of 100 Pa. 20 tests per sample were performed. The air permeability R was determined according to the following equation:

$$R = \frac{D}{A}.167; \tag{2.3}$$

where R is the air permeability in $\text{dm}^3/(\text{m}^2\text{s})$, D is the average of the air flow rate in dm^3/min, A is the sample operative area in 5 cm^2, 167 - coefficient.

The static water absorption was measured according to the BV S1008 “Bureau Veritas Consumer Products Service” internal test method. The samples were conditioned in laboratory conditions, cut into pieces (10×10cm) and weighed. After this, the samples were kept for 1 min in distilled water. After being removed from the water, they were hung for 3 min to remove excess water, and the weight of the wet samples were measured. The static water adsorption S_w was calculated using the following formula:

$$S_w = \frac{m_w - m_d}{m_d}.100\ ; \tag{2.4}$$

where S_w is the static water absorption in %; m_w is the weight of the wet sample in g; m_d is the weight of the dry sample in g.

Heat transfer dependence on the raw material of knitted fabrics was investigated using an IG/ISOC (Giuliani Technologies, Italy) attachment designed for establishing heat insulation. The knitted sample was laid down on the heated plate and a thermosensor was superimposed on the outward side of the fabric. The plate was heated up to 36°C. Temperature on the fabric surface was measured by a digital thermometer HD9214 with platinum sensor PT100 (DELTA OHM SRL, Italy). The changes of temperature were observed every 30 minutes until the results began to range in the margins of error;24 experimental points for each variant of the knits where obtained. A coefficient of variation did not exceed 6%. Five tests for each experimental point were performed.

A friction test was carried out according to standard LST EN ISO 53375 by a tensile machine Zwick/Z005, using a leather tray and laying the samples back side on the tray. During the experiment, the samples were clamped to a grip with 1.96 N force. 6 tests for each variant of the knits were carried out in both the lengthwise and transverse directions. A coefficient of variation did not exceed 7%.

A comparative investigation of abrasion resistance of pure peat, cotton, and woolen knits were performed. The abrasion resistances of the fabrics were tested by Martindale equipment according to standard ISO 12947-4:1998 (Determination of the abrasion resistance of fabrics by the Martindale method. Part 4: Assessment of appearance change) and LST EN ISO 12947-3: 2001 (Part 3: Determination of mass loss). The number of revolutions required for knitted fabrics used for clothing is 14400. In this study, 100000 revolutions were used to reach an apparent difference in surface appearance. Determination of Mass loss the number of revolutions: 10 000, 15000, 25 000, 75 000, 100 000.

The flammability of the knits were investigated using the horizontal test method according to standard DIN 50050-1:1989, which is applicable to all textile materials. In accordance with the procedure, a fabric specimen was clamped wrinkle free between two plates in a horizontal position. The horizontal flammability test was used, and the burning time from the start until the flame arises on the surface of the knit was measured. The height of the flame was 4 cm and the distance between the flame source and materials investigated was 2 cm. Average values of the tests were calculated from 5 measurements.

Flammability test were performed for untreated knitted fabrics as well as for 4P (peat fibre) and 8C (cotton fibre) fabrics treated with phosphorus-based flame retardant Aflammit®KWB (in various concentration). Formulation of the treatment solution was: 250 g/l of AFLAMMIT®KWB (flame retardant) diluted in cold water, 20 g/l of melamine formaldehyde cross linking agent QUECODUR DM 70 and 1 g/l of non-ionic wetting agent KYOLOX BAT also diluted and added to the bath. Finally, the catalyst 15 g/l of 85% phosphorus acid (as well diluted with water) was added to the bath. As received peat yarns were hydrophobic (natural fat from the fibres), knitted fabrics were washed at 90 °C for 30 min with a 2% standard detergent before the flame-retardant treatment. This pre-treatment was performed to remove hydrophobic impurities from the fibres and ensure its uniform flame-retardant treatment. After treatment with Aflammit®KWB, knitted fabrics were padded, dried at 100 °C (to residual moisture of 6-8%), and, immediately after the drying, curing for 2 min at 170°C was carried out. After this treatment, knitted fabrics were washed out to prevent acid damage. Flammability tests were performed for fabrics treated by the above described flame retardancy treatment, as well as for fabrics treated by consistently decreased concentrations of the flame retardant: 1:2, 1:4, 1:8, 1:16 and 1:32.

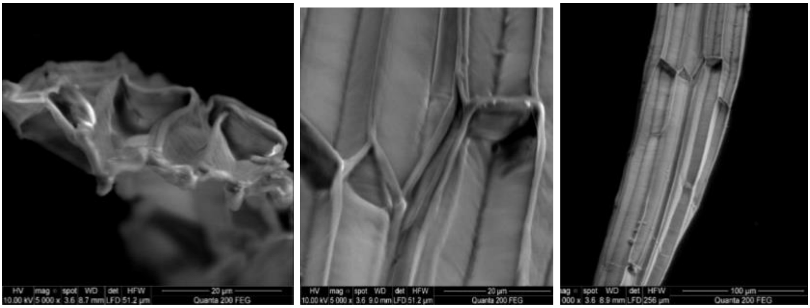
The statistical characteristics were calculated on the grounds of the known standard equations.

The third chapter presents the results of experimental and theoretical investigations.

Peat fibres morphology and chemical composition

Fibres of cotton grass head (Fig. 1) are not used for textiles because of their weak mechanical characteristics. SEM images of cotton grass head fiber surface and cross section are presented (Fig. 2).

Figure 1. The head of cotton grass

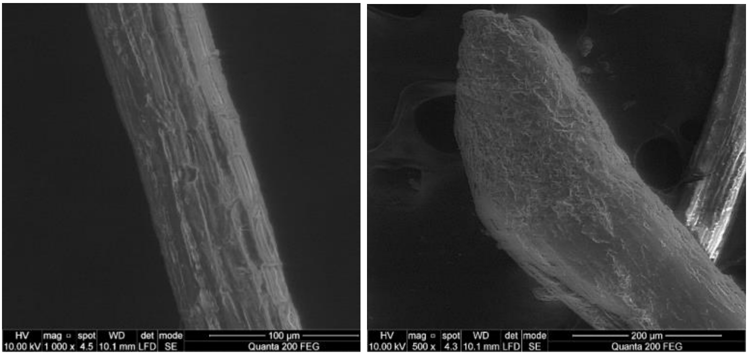


a) b) c)

Figure 2. Cotton grass head fibre (a) cross section, (b) and (c) longitudinal surface view

As can be seen in Figure 2 (a), the cross-section of the cotton grass fibre has an elliptical shape (the average major diameter cotton grass head fibre obtained is 81.96 µm, and the average minor diameter is 18.57 µm) as well as a segmented and hollow structure. This segmentation is well visible in Figure 2 (b) and (c). Due to the segmented structure, breaking force of this fibre is only 1.08 cN. In addition, it was also noticed that this fibre is very fragile, thus, cotton grass head fibres are not suitable for spinning.

Surface and cross section view of cotton grass bast (peat) fibre that is used in peat yarns manufacturing is presented in Figure 3. Peat yarn, used in the study's knitted fabrics, is produced of two types of fibres – cotton and cotton grass bast fibres. The proportion of these fibres in the yarn is 40% of cotton grass bast and 60% of cotton (cross section view of the peat yarn is presented in Fig. 4). Breaking force of this fibre is 12.41 cN, breaking elongation 8.63%, the average of linear density is 5.4 tex.



a) b)

Figure 3. Cotton grass bast fibre (a) longitudinal surface view, (b) cross section

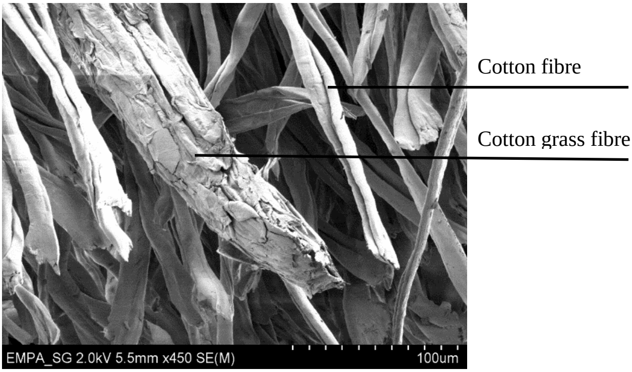


Figure 4. Cross section of the peat yarn

The structure of the cotton grass bast fibre is quite compact, however the diameters vary in range – from 25 µm up to 150 µm. Due to such irregularity, the average fibre diameter was calculated based on 1000 elementary measurements.

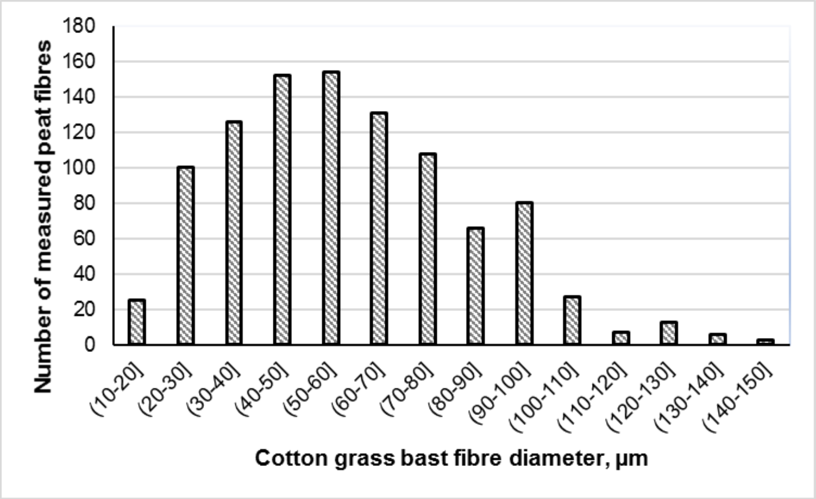


Figure 5. Distribution of cotton grass bast fibre diameter, µm

In Figure 5, presents the cotton grass bast fibre diameters and distribution, which has the character of a normal (Gaussian) distribution. The average fibre diameter was found to be 59.8 µm (in comparison, average diameter of cotton fibres, used in the study knitted fabrics, was 18.5 µm). Number of the thicker fibres, with a diameter more than 100 µm, is relatively low, only 2%. This is caused by the thicker fibres dropping out during the spinning process. Due to higher rigidity and higher diameter, cotton grass fibres are also lost during the knitting process. After knitting, the proportional composition of the peat yarn changes, i.e. proportion of the fibres in the yarn is 25% of cotton grass bast fibres and 75% of cotton fibres. In addition, some more cotton grass fibres can be lost during the washing process. There were 20 % of cotton grass bast fibres and 80 % of cotton fibres found in the machine washed and dried fabric. The cotton grass bast fibre length was also measured, with the average fibre length identified as 19.27 mm.

The chemical composition of the peat yarn used in this work are presented in Table 2. A raw cotton cellulose fibre is composed primarily of cellulose and impurities, such as wax (0.4%–1.7%), ash (inorganic salts) (0.7%–1.8%), pectin (0.4%–1.9%), and others (resins, pigments, hemi-cellulose) (1.5%–2.5%) (Degani, Dosoretz and Gepstein, 2004). The majority of these impurities are removed during scouring and bleaching.

Table 2. Chemical composition of peat yarn

Fibre	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Other (%)
Cotton	97.06	2.0	0.54	0.4
Cotton grass	78.08	4.44	10.2	7.28
Peat yarn (cotton grass 40 % + cotton 60 %)	87.57	3.22	5.37	3.84

It is known that lignin can influence the burning behavior of cellulose-based textile. Lignin is the most difficult to decompose, as it has a low decomposition rate, whereas the high content of cellulose can result in an increased flammability (Ramamoorthy et al., 2015). The evident difference of lignin content in the cotton and the peat yarns creates a presumption that burning of the textile made of these yarns can behave in a different way.

Comparative results of various cellulose (peat, cotton and flax) fibre yarns tensile properties at break are presented in Table 3. All the yarns, used for tensile properties investigation, were with the same linear density of 60 tex, was 50 elementary experiments, koeficient of variation less than 11%

Table 3. Comparison of tensile characteristics of cellulose fibre yarns

	Breaking force, cN/tex	**Elongation at break, %**
Peat yarn	11.47	5.3
Cotton yarn	9.46	7.4
Flax yarn	17.46	1.8

As the results presented in Table 3 show, peat yarn has an intermediate strength and elongation values between those of the cotton and flax yarns, i.e. breaking force of the peat yarn is 20% higher and elongation at break is 28% lower compared to the cotton yarn. However, elongation of the peat yarn is almost three times higher than that of the flax yarn, thus the peat yarns fit for knitting because of its elongation and elasticity property of a yarn is very important in the knitting process. However, due to the very low elongation and high rigidity of flax yarns, they are usually not used for knitting.

An analysis of structural parameters, physical and mechanical properties of knitted fabric. Structural parameters of new developed fabrics knitted in a single jersey pattern from peat fibre and its combinations with cotton, woollen and Lycra® yarns were calculated and compared. The new knitted fabrics with peat fibre have an optimal structure for use. This is confirmed by the tightness factor *TF* values: 1.26÷1.41 $tex^{1/2}/cm$ (according to the Munden, Knapton and Konopasek investigations where the optimal *TF* value is in the ranges 1.10÷1.90 $tex^{1/2}/cm$). Loop length of the knits with different fibrous compositions is very similar (11.1÷11.5 mm) in all variants. However, geometry of the loop (defined by wale *A* and course *B* spacing) in different variants of knits vary in more wide margins. The course *B* and wale *A* spacing are important structural factors, as they are directly related to the loop geometry and course and wale densities, which represent the changes of stitch shape using various yarns. On the other hand, the structural parameters, such as course and wale spacing and density, are one of the main factors that influence the majority of physical properties of a knit. Comparing knits with Lycra® elastomeric yarn to knits without the Lycra® yarn, the course spacing is up to 12% lower, the wale spacing is up to 8% lower and the loop length is only up to 2.5% lower than in the fabrics without the Lycra® yarn.

Shrinkage is one of the most serious problems of fabrics from natural fibres, especially as it is obtained in single jersey knitted fabrics because of the lowest number of interdependent relations between the yarns bent into the loops. Thus, single jersey structure is flexible and allowing changes of a loop form and width-height dimensions (Çoruh, 2015).

Results of experimental fabrics shrinkage after washing and drying are presented in Fig.6. As was expected, all knitted samples shrunk in the lengthwise direction to a high percentage because it was the first wet treatment after knitting. The lowest shrinkage value in the lengthwise direction was obtained for the woollen knitted sample, however knits from a woollen and peat yarns combination reached the shrinkage values closer t other cellulosic knits, made from peat, cotton yarns and their combinations. In the transverse direction, the investigated fabrics changed their dimensions noticeably less (up to 3-5%), with only the pure peat fibre knit and the peat/cotton knit with the highest amount of peat fibre yarns shrinking in the transverse direction. Dimensions of all other investigated samples elongated in the transverse direction, which is typical for single jersey weft knitted fabrics with high (more than 10%) shrinkage in the lengthwise direction.

The wale and course density, as well as the wale and course spacing, are changed according to the dimensions change in, respectively, the lengthwise and transverse direction. However, the loop length shortened after washing and drying by only up to 3%, and differences in loop length between all investigated knits decreased. This indicates that dimensional changes occurred not only because of relaxation of tensile stresses but also because of relaxation of other deformations, such as bending or torsion deformations.

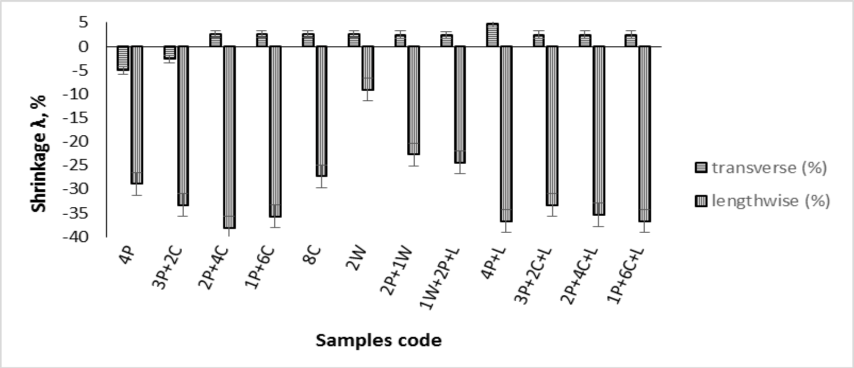


Figure 6. Shrinkage of investigated knitted fabrics after washing and drying cycle

Air permeability of knitted fabrics depends on the loop length and loop density in the knit and is strongly related with the yarn characteristics, such as yarn type, twist level and linear density of the yarn, number of yarns in the loop.

Results of the air permeability of investigated knitted fabrics before and after washing and drying are presented in Table 4. Air permeability of pure cotton fibre knit is 5% higher than of pure peat fibre knit, mainly because of the smoother, less hairy surface of the cotton yarn. However, this difference in permeability to air is not significant. Air permeability of pure woollen knit has the highest value (14% higher than of pure cotton fibre knit and 18% higher than of pure peat fibre knit) though the linear density of woollen yarns in this knit is the same as in cotton and peat fibre knits, additionally the loop length in all knits are similar. One more interesting point was observed, in that the air permeability of knits made from a peat and cotton yarns combination is lower than of pure cotton or peat fibre knits. This leads to the conclusion that different behaviour of the peat and cotton yarns during the loop formation (due to the reason of different friction, rigidity, etc.) determines a slightly different geometry of the combined peat and cotton yarns in the loop, and this influences a higher surface covering by the combined yarn as well as the lower porosity of such knits.

The results obtained confirm the statement, also made by other researchers that air permeability of knits significantly decreases by using elastomeric yarns in a plated structure, even when the amount of the elastomeric yarn in the knit is very low, i.e. less than 3-5% (Çoruh, 2015; Abramavičiūtė, Čiukas and Mikučionienė, 2011). In the study case, air permeability of knits plated with Lycra® yarn decreased in 43-48% comparing with the knits without the Lycra® yarn. Due to the elastomeric yarn, the knitted structure becomes tighter, the geometry of a knitted loop changes and the wale and course spacing, as well as porosity, of the knit decreases.

Table 4. Air permeability of investigated knitted fabrics before and after washing and drying

Sample code	Air permeability *R*, dm^3/(m^{2}s)		Coefficient of variation, %	
	Before washing	After washing	Before washing	After washing
4P	915.2	314.0	1.83	5.35
2W	1118.9	679.7	1.53	3.66
8C	961.9	252.2	3.49	8.10
1P + 6C	734.8	220.4	3.61	7.62
2P + 4C	820.0	275.6	3.10	5.38
3P + 2C	893.5	319.0	2.68	3.76
1W + 2P	1067.1	472.6	2.38	2.59
4P + L	624.6	138.6	4.62	5.67
1W + 2P + L	587.8	215.4	3.40	7.91
1P + 6C + L	384.1	95.9	4.46	7.73
2P + 4C + L	457.6	100.2	3.43	0.90
3P + 2C + L	512.7	108.6	3.19	7.89

Whereas the shrinkage after washing and drying cycle was very high, especially in the lengthwise direction, the air permeability of washed knitted samples crucially decreased and this decrease obviously correlates with the shrinkage level. Shrinkage of woollen knit has the lowest value (less than -10%), accordingly the decrease in air permeability of this fabric is the lowest – 1.6 times lower than that of the knit before washing. Shrinkage of knits of pure peat, cotton fibre yarns and their combinations was more than -25%, accordingly air permeability of these fabrics decreased 2.8-3.8 times. As shrinkage values of peat/cotton/ Lycra® blended knits were more than -30%, air permeability of these fabrics decreased even more – 4.0-4.7 times. Such a crucial drop in permeability to air arises not only for the reason of the structure's tightening through shrinkage but also because of the felting of elementary fibres on the surface of the yarns, as well as on the surface of the knit. This fact is proved by the air permeability dependence on the tightness factor (presented in Fig.7).

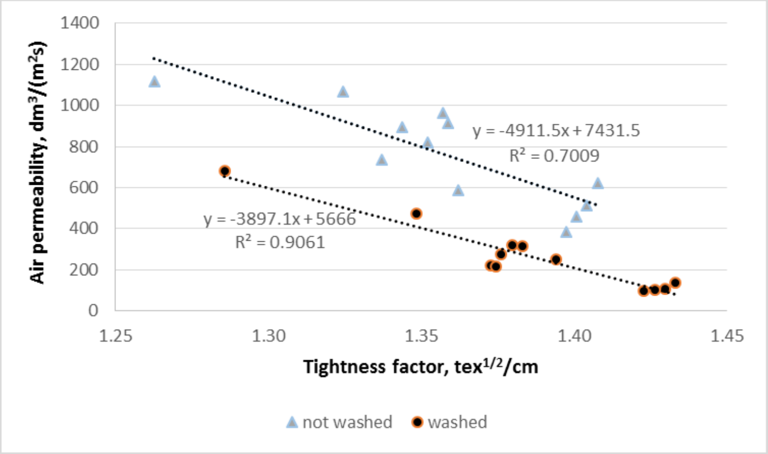


Figure 7. Dependence of permeability to air of knits on tightness factor

As presented in Fig.7, knits with the same tightness factor have up to 2 or even more times higher air permeability. The tightness factor indicates the surface covering by the yarn bent into the loop and is correlative only with the loop length (not evaluating a different geometry of the loop) and linear density of the yarn (not evaluating a surface's smoothness/roughness). Due to felting of the knit's surface during the washing process, coefficient of determination of dependency presented of washed knits is higher than of the unwashed knits. Felting of elementary fibres on the surface of the yarn decreases porosity of the knit's surface, as well as air permeability.

The thermal property of knitted fabric is very important, not only for its thermal comfort but also for protection against cross weather conditions.

Results showed that heat transfer through the woollen knitted fabric is slower than through the cellulose based knitted fabrics (as was expected) but this difference starts to be obvious after approx. 3 minutes. In the first 3 minutes, the heat transfer dynamic through the peat fibre fabric is similar to the woollen fabric, however later its behavior becomes similar to the cotton fibre fabric. However, the heat transfer dynamic through the peat fibre knit is slower than through the cotton one, because the peat fibre yarn has a higher hairiness and larger differences between the diameter of peat and cotton fibres (Van Amber, 2015).

There were very similar heat exchanges when comparing the pure cotton knit and knits from the cotton yarns combination with peat yarns in various percentages. Although the heat exchange dynamic through the pure cotton knits is faster than through the knits made from the combined cotton and peat yarns. It is because the geometry of cotton and peat yarns segments bent into a stitch is slightly different and therefore the porosity of such knitted fabric is lower than of that of one knitted from one kind of yarn. The difference in heat the transfer dynamic is most obvious in the period of 3-10 min observation. A similar situation is the same in the knit variants with elastomeric Lycra® yarn in the structure, as elastomeric yarn, even with small linear density, have an influence on the loop geometry. The new developed knits with elastomeric yarn in the structure have up to 12% higher course spacing and up to 8% higher wale spacing comparing to the same knits without the elastomeric yarn, and the higher loop density influences lower heat transfer through the fabric at the initial time of observation

The ability to absorb water is an important physical property that can have a significant impact on comfortability and functionality of clothing. All natural fibres are more or less hydrophilic and peat fibre is not the exception (Nosbi, 2011). Results of the water adsorption of the knitted investigated fabrics are presented in Fig.8. As can be seen from the results presented, pure peat fibre knits and combined peat/cotton fibre knits of variants 3P + 2C and 3P + 2C + L (with the highest amount of peat fibre) demonstrate the lowest values of static water adsorption. In the main cases, the difference in static water adsorption values before and after washing vary in the ranges of errors, though adsorption values of unwashed pure peat fibre knit or knit plated with Lycra® yarn and their combination with the lowest amount of cotton yarns are significant lower than of the same knits after the washing cycle. This could be because of the additional chemicals used in peat yarns production that reduce hydrophilicity of the yarns and can be removed during washing (Roy et al., 2016). After washing, static water adsorption of peat fibre knits remains the lowest, however this difference is not as high as before the washing.

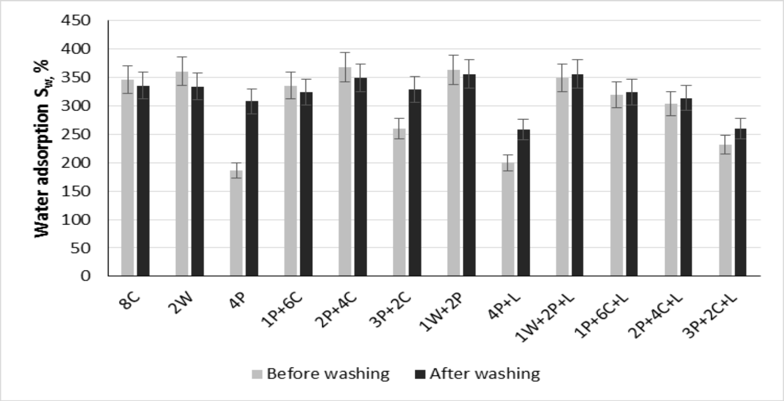


Figure 8. Static water adsorption of investigated knitted fabrics

Friction can be characterized as static and dynamic friction. Static friction is related to the resistance force, which must be overcome at the beginning of sliding when the solid body's state changes from a still to a movement state. Dynamic friction starts with the solid body's movement and is expressed as the force of the solid body's resistance to continuous movement (Čiukas and Svetnickienė, 2016). Friction is important, both for mechanical and comfort properties. High friction between the fabric and human skin can cause skin damage or an allergy reaction (Kirk and Ibrahim, 1966; Anthony and LI, 2010).

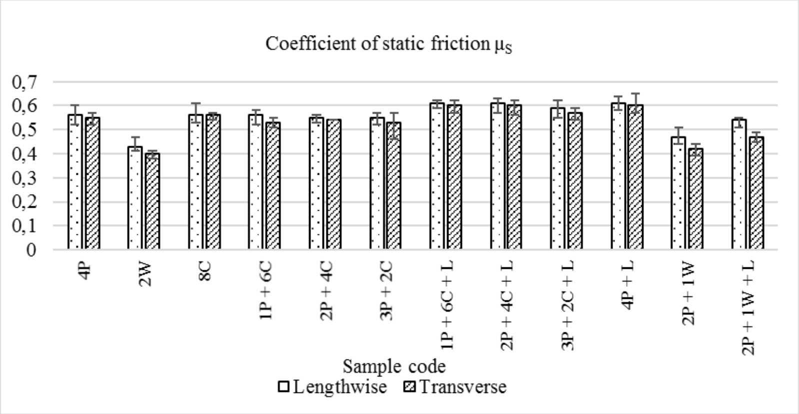


Figure 9. Influence of raw composition and movement direction on coefficients of static and dynamic friction

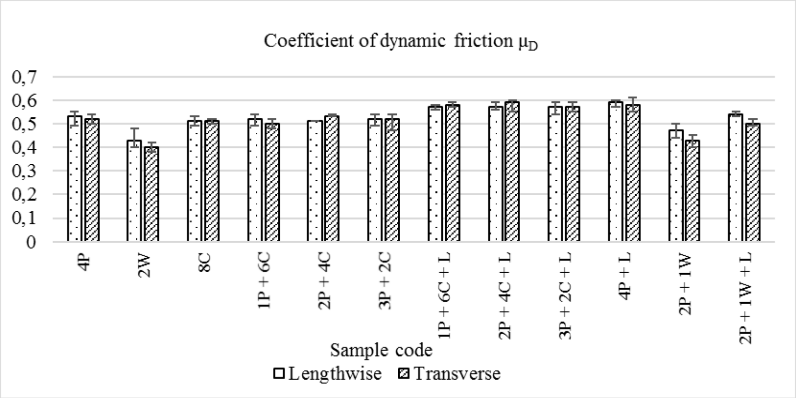


Figure 9. Influence of raw composition and movement direction on coefficients of static and dynamic friction

As can be seen from the results presented in Figure 9, values of static as well as of dynamic friction coefficient of knits with different fibres compositions differ to a high level depending on the raw composition rather than on the direction of knit's movement. Values of frictional resistance to the movement of knits in a lengthwise (wale way) and transverse (course way) directions vary in the margins of error, however only for knits from woollen yarns this difference is more evident. Whereas the fibres raw composition in the knit has a higher influence on frictional properties. Presence of woollen fibres in a knit decreases frictional resistance when comparing with cellulose fabrics. Whereas knits with Lycra® yarn in the structure are distinguished for higher (in 8-17%) coefficient of static and dynamic friction than the corresponding knits without the Lycra® yarn. This is because the elastomeric Lycra® yarn makes the surface of a knit tighter, which leads to a larger contact area between the knit and surface against which the knit is moving.

The abrasion resistance test was performed by Martindale equipment for three variants of knits – pure peat, cotton and woollen knits. After 14,400 revolutions (recommended in the standard) any evidence of changes appeared on the samples surface, the changes of surface were evaluated after 50,000, 75,000 and 90,000 revolutions. The surface view of the investigated knits after the mentioned number of revolutions are presented in Figure 10. If a knitted fabric, designed to use for clothing, withstands 50,000 revolutions of abrasion testing before the surface of the knit starts to crack, such fabric is characterized as high abrasion resistant fabric.

Figure 10. Surface view of pure peat, cotton and woollen knits after 5×10^4, 7.5×10^4, and 9×10^4 revolutions during the abrasion resistance test

Till 50,000 revolutions, knitted textile from peat fibre has lost up to 30 % weight, after 50,000 revolutions, there are pills visible on the surface of all three variants of knit. However, the surface of all the knits is unbroken. Comparing the results obtained after 75,000 revolutions, it can be seen that the surface of all the knits is still unbroken but the pills start to felt, especially on the surface of peat fibre fabric. After 90,000 revolutions, the surface of peat fibre knit is damaged to a level, where not only fibres are broken and there is felt on the surface, but also yarns are moved from the loops and some gaps appear in the structure. After 100,000 revolutions, cotton textile loss the weight about 20% higher than textile from peat fibre. Pure wool fabric after 100,000 revolutions, has lost 3 times more mass than knits from peat or cotton fibre. With different fibrous yarns in the loop, desrease two times higher mass loss than fabrics from pure fibres in the structure. Thus, it can be stated that all the new designed knitted fabrics, including fabric knitted from peat yarns, have high abrasion resistance and can be used for clothing manufacturing.

An analysis of flammability properties of knitted textile from peat fibre

Lignin is responsible for char formation on a textile's surface. Lignin, which is primarily composed of phenolic polymers, burns slowly and during the burning process could produce aromatic chars. Char formation during the burning process is a good indication of flame retardancy. This char layer acts as a fire insulation.

In order to investigate the behavior of knits during burning, the horizontal burning test was carried out for fabrics knitted of cotton and peat yarns, as well as all of their various combinations. Results of the burning test are presented in Table 5, burning behavior of knits with different fibre composition are illustrated in Figure 11.

Table 5. Burning time

Sample code	Burning time, sec
P	65
C	45
1P + 6C	48
2P + 4C	55
3P + 2C	58
W	5
2P + 1W	36

As the results presented in Table 5 show, burning time of the peat yarn knits are ~30 % higher than of the cotton knits. As discussed earlier, peat knit contains 10 times a higher amount of lignin than the cotton knit, and lignin is responsible for char formation during burning, as well as for fire insulation for a definite period (Salmeia et al., 2016). Flame arises on the surface of the cotton knit after 45 sec, whereas on the surface of the peat knit, only an area covered by char is visible after 45 secs (see Figure 11) and the flame arises on the surface of the peat knit after 65 sec, i.e. 20 secs later than on the cotton knit. Cotton knit burns completely over 85 sec, while peat knit stops burning after 80 sec and for another few seconds smulders until what remains is a charred knitted structure. Presence of peat yarns in the knitted structure increases burning time and this increase correlates to the percentage of peat yarns, i.e. cotton grass fibres. 25% of peat yarns in the combined cotton / peat knitted structure (1P + 6C variant) increases burning time ~7%, respectively 50% of peat yarns (2P + 4C variant) increases burning time ~22%, and 75% of peat yarns (3P + 2C variant) increases burning time ~29%. The influence of the peat yarns presence in the knitted structure on the burning time can be very well illustrated by comparing the burning behaviour of the woollen knit (W variant), which is very flammable, and the combined peat (52%) / wool (48%) knit (2P + 1W variant). Burning time of the pure woollen knit is 5 sec, whereas combined 2P + 1W knit only starts to smoulder after 5 secs.

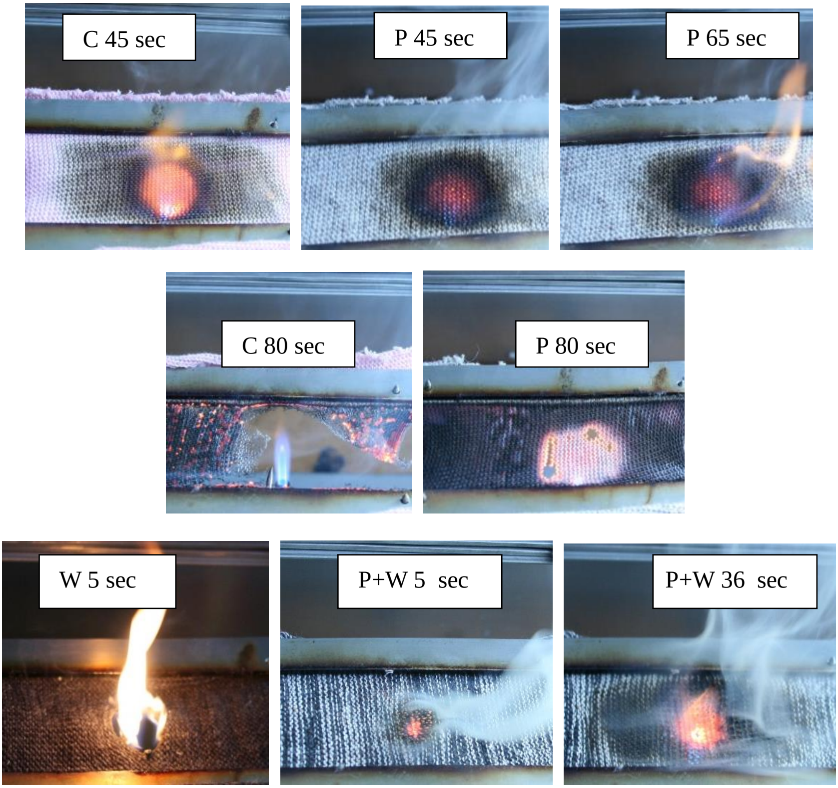


Figure 11. Burning behaviour depending on fibre composition of knits: *C* – cotton yarns, *P* – peat yarns, *W* – woollen yarns, *P+W* – combination of 52% peat and 48% woollen yarns

Presence of 52% of peat yarn in the knitted structure increases burning time by more than 7 times (Fig. 11). Thus, peat yarns, containing cotton grass fibres with relatively high amount of lignin, can be used in the knitted structure to significantly reduce the flammability rates.

However, the burning time of 1 minute or less is insufficient to secure in the case of higher-risk of fire. In order to enhance flame retardancy of cellulose-based textiles, finishing treatment by phosphorus-based flame retardant Aflammit®KWB can be used. As the producer of the flame-retardant guarantee, flame retardancy of the peat and cotton knits, treated according to recommendations given in treatment instruction, is very high – burning time of the peat knit is 17 min 15 sec and of the cotton knit – 19 min 40 sec (see in Table 6). Burning time of the peat knit, treated by the flame retardant, is more than 2 min lower than of the cotton knit, treated in the same conditions. The reason for this is the higher amount of lignin in the peat yarn.

Table 6. Burning time of treated by flame retardant knits

Concentration of flame retardant	Burning time, sec	
	4P (peat yarn knit)	8C (cotton yarn knit)
1:1 (max)	1035	1180
1:2	755	860
1:4	525	565
1:8	375	495
1:16	330	455
1:32	90	295

After treatment with the flame retardant Aflammit®KWB, the knitted fabrics become more rigid, therefore it was decided to perform flame retardancy treatment using a lower concentration of the flame retardant. The treatment was performed using 2, 4, 8, 16, and 32 times lower concentrations of Aflammit®KWB and analyzing the burning time after each treatment. Results of burning time investigation, using lower concentration flame retardant, are presented in Table 6. Treatment by flame retardant with two times lower concentration reduced burning time of both peat and cotton knits ~ 28%, still flame retardancy remains high - 12 min 35 sec for the peat knit and 14 min 20 sec for the cotton knit, meanwhile rigidity of the knits change after such treatment is insignificant. Even using very low concentrations of phosphorous based flame retardant (32 times lower concentration than is recommended by the producer) burning time of the cotton knit is ~ 6.5 times higher than of the untreated cotton knit. Burning time of the peat knit, treated by such low concentration flame retardant, is just ~ 1.5 times higher than of the untreated peat knit, however it is important to note that around the burned hole on the peat knit a charred area forms and the knit stops to burn, even if the flame source was not removed. This property is very significant for fire safety, as it is important, not only for the burning time, but also the time during which the flame goes out. If the textile stops burning without removing the flame source, it can be characterized as textile with low flammability.

CONCLUSIONS

1. The morphological and chemical investigations of cottongrass and peat fibres demonstrated that:

- due to its segmented structure, cottongrass fibres are not suitable for spinning as the break force is as low as 1.08 cN;
- peat fibres are suitable for the production of yarn as the obtained medium diameter equalled ~ 60 µm while the length measured 19.27 mm, whereas the medium thread break force equalled 12.41 cN;
- the chemical structure of the investigated peat fibre was as follows: cellulose: 78.08 %, hemicellulose: 4.44 %, as much as 10.2 % of lignin and 3.84 % of other constituents (pectins and various impurities).

2. The break values of the peat yarn consisting of 40 % peat fibre and 60 % cotton fibre, specifically, the break force of 11.47 cN/tex and break elongation of 5.3 %, are intermediate between the widely used cotton and linen yarns. Therefore, such yarn is suitable for knitting.
3. Having explored the structural values of the designed knitted fabrics, it was discovered that:

- all the newly designed knitted fabrics were of the optimal structure, since the values of their twist factor ranged between 1.26 and 1.41 tex$^{1/2}$/cm and the obtained loop length was fairly similar, yet the geometry of the loop differed depending on the fibre structure of the knitted fabric;
- while washing, the break behaviour of the knitted fabrics featuring peat fibre is similar to those of cotton fabrics: in the longitudinal direction, the shrinkage measured up to 35 % whereas in the transverse direction the measurement values altered within the permissible range, i.e., up to ± 5 %. After the washing procedure, the twist factor values remained optimal (1.29 ÷ 1.43 tex$^{1/2}$/cm).

4. Having explored the mechanical properties of knitted fabrics containing peat fibre, it was established that:

- the obtained friction coefficient values show that knitted fabrics containing peat fibre are of medium coarseness, the properties of static and dynamic friction of knitted fabrics made of peat yarn and their combinations with cotton yarn are extremely close to the relevant properties of cotton knitted fabrics;
- the values of static and dynamic friction of knitted fabrics containing elastomeric threads were found to be 8 to 30 % higher, due to the denser structure and the larger contact surface in comparison with knitted fabrics not containing any elastomeric threads;

- the behaviour of peat fabrics undergoing wear is similar to that of cotton fabrics, as the fabrics of both types withstood up to 90,000 turns of fatigue wear without wearing out.

5. Having explored the key physical properties of knitted fabrics containing peat fibre, it was found that:

- the air permeability of a peat fabric is 5 % lower than that of a pure cotton fabric and 18 % lower than that of a wool fabric;
- after a washing cycle, due to the contraction caused by the washing process, the produced structural alterations and the dishevelled threads reduced the air permeability by up to 4.7 times;
- the dynamic of the heat exchange of peat fibre fabrics is medium and close to cotton knitting;

6. The investigation of the flammability of fabrics containing peat fibre and the investigation of the impact of special finishings on the non-flammability of fabrics demonstrated that:

- the resistance against the burn through of peat fabrics is 30 % higher than that of cotton fibres, due to the higher content of lignin in peat fabrics;
- the peat fibre, which is present in a mixed fibre knitted structure containing 52 % peat yarn and 48 % wool yarn, extends the timespan of the burn through sevenfold;
- antipiren of the maximum concentration of Aflammit®KWB increases the timespan of the burn through of a peat fabric, which increases by about 16 times (up to 17 min 15s) due to a higher content of lignin;
- yarns processed by antipiren of 16 times lower concentration still maintain a burn through duration higher than 5 minutes;

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A LIST OF PUBLICATIONS ON THE TOPIC OF THIS DISSERTATION

Articles in journals in the *Thomson Reuters Web of Knowledge* list

1. Mikučionienė, Daiva; Čepukonė, Lina. Comparative analysis of knits from peat fibre and its combinations with other natural fibres // Fibres and textiles in Eastern Europe. Lodz: Institute of Biopolymers and Chemical Fibres. ISSN 1230-3666. 2017, vol. 25, iss. 2, p. 24-29. DOI: 10.5604/12303666.1228161. [Scopus; Science Citation Index Expanded (Web of Science)] [Citav. rod.: 0,626 (2016, InCites JCR SCIE)] [CiteScore: 0,64, SNIP: 0,637, SJR: 0,321 (2016, Scopus JM)] [M.kr.: 08T] [Indėlis: 0,500]
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REZIUMĖ

Tiriamos problemos pagrindimas ir darbo aktualumas. Pastarąjį dešimtmetį ypatingas dėmesys tekstilės inžinerijoje yra kreipiamas į tekstilės gaminių funkcionalų išskirtinumą ir ekologiškumą. Siekiant išgauti naujas funkcines (apsaugines, gydomąsias, geresnio komforto ir pan.) tekstilės gaminio savybes arba sustiprinti esamas, yra kuriamos naujos tekstilinės struktūros, naujos apdailos rūšys ar nauji pluoštai.

Projektuojant kokybiškas megztines struktūras, būtina gerai išmanyti mezginio pynimą. Pynimo tipas priklauso nuo sandaros elementų tipo bei megztos struktūros formavimo būdo. Tai lemia ne tik mezginio išvaizdą, bet ir gaminio savybes. Mezginių kilpos gali būti lankstomos iš įvairios pluoštinės sudėties ir struktūros siūlų, vieną mezginio elementą formuojant iš vienos rūšies arba skirtingų rūšių siūlų, nes tai taip pat lemia gaminio savybes. Šiame darbe tiriami lygiojo skersinio pynimo mezginiai, kurie suprojektuoti vienoje kilpoje lankstant tiek vienos pluoštinės sudėties verpalus, tiek skirtingus natūralios pluoštinės sudėties verpalus.

Dėl didėjančio vartotojų sąmoningumo ir reiklumo ekologiniams gaminiams, funkcionalios tekstilės gamyboje ypatingas dėmesys yra skiriamas ekologiškiems natūraliems pluoštams.

Globalus ekologiškumo klausimas keliamas jau ne vienerius metus. Tvaresnis vartojimas ir būtinybė spręsti gamtosaugos problemas skatina domėtis žiedinės ekonomikos modeliu, kuris yra aktualus ir naudojamas daugelyje Europos valstybių. Siekiama atrasti būdų išspręsti pastaruoju metu aktualią problemą – kaip pagaminti ne tik ekologišką gaminį, bet ir rasti kuo draugiškesnį / tinkamesnį gamtai būdą šiai gamybai vykdyti bei reikalingam pluoštui išgauti. Todėl šiame disertaciniame darbe pagrindiniu tyrimų objektu pasirinktas durpių pluoštas. Šis pluoštas yra durpių kasybos pramonės šalutinis produktas. Kasmet iškasami didžiuliai kiekiai durpių, naudojamų kurui, žemdirbystei ir kitoms reikmėms. Šiems produktams naudojami tik giluminiai durpynų sluoksniai, o paviršinis sluoksnis yra šios pramonės šakos atliekos. Tačiau šią, paviršinę sluoksnio dalį, sudaro vegetacinį ciklą baigusių ir iš dalies degradavusių švylių (lot. *Eriophorum vaginatum*) stiebai, paveikti specifinių pelkėtos vietovės aplinkos sąlygų. Taigi, skirtingai nei kitoms pluoštinėms kultūroms (pvz., linams), durpių pluoštui išgauti nereikia dirbamos žemės plotų, nenualinami laukai, nenaudojama pesticidų ir herbicidų (kas yra būdinga auginant kultūrinius augalus), taip pat nereikia papildomai vandens (pvz., auginant medvilnę). Durpių pluoštas palankus aplinkai, nes gaminamas iš atsinaujinančių žaliavų – iškasti durpynai natūraliai atsistato.

Durpių pluošto pritaikymo galimybių tekstilės gaminiams gaminti, taip pat moksliniais tyrimais pagrįstų duomenų apie šio pluošto savybes, jo perdirbimą bei įtaką baigtų tekstilinių gaminių vartojamosioms ir funkcinėms savybėms, labai trūksta. Todėl moksliniai tyrimai šioje srityje yra labai reikalingi ir aktualūs.

Darbo tikslas – ištyrus durpių pluošto morfologiją bei cheminę sudėtį nustatyti durpių pluošto įtaką mezginių struktūrinėms, mechaninėms ir fizikinėms savybėms.

Darbo uždaviniai:

1. ištirti durpių pluošto morfologiją ir cheminę sudėtį;
2. nustatyti pluoštinės sudėties įtaką mezginių su durpių pluoštu struktūriniams rodikliams;
3. nustatyti pluoštinės sudėties įtaką mezginių su durpių pluoštu atsparumą dėvėjimui ir dilinimui, trinčiai bei matmenų stabilumui;
4. nustatyti pluoštinės sudėties įtaką mezginių su durpių pluoštu laidumą orui, sorbcinėms savybėms ir šilumai;
5. nustatyti mezginių su durpių pluoštu degumą ir specialios apdailos įtaką mezginių nedegumui.

Mokslinis darbo naujumas. Durpių pluošto pritaikymas mezgimo pramonei ir buitinių bei funkcinių mezginių gamybai yra labai perspektyvi ir šiuo metu nauja sritis. Nepaisant to, kad praėjusio šimtmečio pradžioje buvo bandymų gaminti durpių pluošto verpalus ir tekstilės medžiagas iš durpių pluošto, moksliniais tyrimais pagrįstų duomenų apie šį pluoštą, mezginius iš jo bei savybes, beveik nėra. Literatūros apie durpių pluoštą ir jo savybes randama tik senuosiuose XIX a. šaltiniuose arba nedaug moksliniuose straipsniuose, kuriuose dažniausiai nagrinėjamas durpių panaudojimas energetikos pramonėje bei botanikos srityje (tiriant durpių augalų rūšis). Duomenų apie durpių pluošto morfologiją ir cheminę sudėtį, pluošto mechanines savybes ir jų įtaką tekstilės struktūrai, mechaninėms bei fizikinėms savybėms literatūroje nerasta (Wegman, 1929).

Šioje disertacijoje atlikti tyrimai ir gauti rezultatai įrodė, kad siūlai su durpių pluoštu gali būti naudojami mezginiams projektuoti. Tokie mezginiai mechaninėmis ir vartojamosiomis savybėmis nenusileidžia plačiausiai naudojamiems celiulioziniams tekstilės gaminiams iš medvilnės pluošto arba pasižymi geresnėmis savybėmis – šilumos ir degumo. Darbo metu nustatyta išskirtinė durpių pluošto savybė – gerokai ilgesnė degimo trukmė nei medvilninių mezginių, kuri yra labai svarbi funkcinės paskirties gaminiams.

Įvertinus tai, kad durpių pluoštas yra išskirtinai ekologiškas, jo naudojimas vietoje panašių lignoceliuliozinių pluoštų, kuriems auginti išeikvojama daug resursų, yra labai perspektyvus ir skatintinas. Disertacinio darbo tyrimų rezultatai išplėtė žinias apie durpių pluošto savybes, jo taikymo mezgimo pramonėje galimybes, megztų struktūrų su durpių pluoštu mechanines, vartojamąsias ir funkcines savybes, panaudojimo sritis. Šie rezultatai gali būti pritaikomi praktiškai ir naudingi tolimesniems tyrimams siekiant skatinti ekologišką gamybą bei propaguoti gamtos saugojimą.

IŠVADOS

1. Atlikus morfologinius ir cheminius tyrimus nustatyta, kad:

- švylių pluoštas dėl segmentuotos struktūros netinkamas verpimui, nes trūkimo jėga yra tik 1,08 cN;
- durpių karnienos pluoštas tinkamas verpalams gaminti, nes vidutinis skersmuo gautas ~ 60 µm, ilgis 19,27 mm, vidutinė plaukelio trūkimo jėga 12,41 cN;
- cheminė durpių pluošto sudėtis yra 78,08 % celiuliozės, 4,44 % hemiceliuliozės, net 10,2 % lignino ir 3,84 % kitų sudedamųjų dalių (pektinų, įvairių priemaišų).

2. Durpių verpalų, sudarytų iš 40 % durpių pluošto ir 60 % medvilnės pluošto, trūkimo charakteristikos (11,47 cN/tex trūkimo jėga ir 5,3 % trūkimo ištįsa)

yra tarpinės tarp plačiai naudojamų medvilninių ir lininių verpalų, todėl tokie verpalai yra tinkami mezgimui.

3. Išanalizavus suprojektuotų mezginių struktūros rodiklius nustatyta, kad:

- visi naujai suprojektuoti mezginiai yra optimalios struktūros, nes jų dengiamumo koeficiento vertės yra nuo 1,26 iki 1,41 tex$^{1/2}$/cm, jų kilpos ilgis gautas panašus, tačiau kilpos geometrija skyrėsi priklausomai nuo mezginio pluoštinės sudėties;
- mezginių su durpių pluoštu traukumo skalbiant elgsena artima medvilniniams mezginiams - visi mezginiai išilgine kryptimi susitraukė iki 35 %; skersine kryptimi matmenys kito leistinose ribose, t.y. iki ± 5 %. Po skalbimo dengiamumo koeficiento vertės išliko optimalios (nuo 1,29 iki 1,43 tex$^{1/2}$/cm).

4. Ištyrus mezginių su durpių pluoštu mechanines savybes nustatyta, kad:

- gautos trinties koeficientų vertės rodo, kad mezginiai su durpių pluoštu yra vidutinio šiurkštumo, statinės ir dinaminės trinties savybės yra labai artimos medvilninių mezginių savybėms;
- mezginių su elastomeriniu siūlu statinės ir dinaminės trinties vertės dėl tankesnės struktūros ir didesnio kontaktinio paviršiaus ploto gautos nuo 8–30 % didesnės nei mezginių be elastomerinio siūlo;
- mezginių iš durpių verpalų elgsena dilinant yra panaši į medvilninių mezginių, visi jie atlaikė iki 90 000 sūkių dilinimo ciklų.

5. Ištyrus mezginių su durpių pluoštu pagrindines fizikines savybes nustatyta, kad:

- durpių mezginio laidumas orui yra 5 % mažesnis nei grynapluoščio medvilninio mezginio ir 18 % mažesnis nei vilnonio mezginio;
- po skalbimo visų mezginių laidumas orui, dėl santraukos skalbiant atsiradusių struktūros pokyčių ir susivėlusių plaukelių, sumažėjo iki 4,7 kartų;
- šilumos mainų dinamika per durpių pluošto mezginius yra artima medvilniniams mezginiams.

6. Mezginių su durpių pluoštu degumo ir specialios apdailos įtakos mezginių degumui tyrimai parodė, kad:

- durpių mezginių pradegimo trukmė dėl didesnio lignino kiekio yra ~ 30 % ilgesnė nei medvilninių mezginių;
- mišrioje (52 % durpių verpalų/48 % vilnonių verpalų) megztoje struktūroje esantis durpių pluoštas pradegimo trukmę pailgina 7 kartus;
- maksimalios koncentracijos antipirenas Aflammit®KWB durpių mezginio pradegimo trukmę pailgino maždaug 16 kartų (iki 17 min. 15 s);
- apdorojus net ir 16 kartų mažesnės koncentracijos antipirenu šių mezginių pradegimo trukmė išlieka daugiau nei 5 min.

PADĖKA

Darbo vadovei prof. dr. Daivai Mikučionienei už nuoširdžius patarimus ir padrąsinimus, profesionalias pedagogines žinias bei neišblėstančią šypseną veide.

Tekstilės įmonei UAB „Vegateksa” už pagamintus lygiojo skersinio pynimo mezginius, kurie buvo naudojami tyrimams.

Dr. Daivai Milašienei už pagalbą ir atliktus mezginių šiluminių savybių tyrimus.

Studijų kolegei Gintai Laureckienei už draugiškumą ir pagalbą atliekant stipruminius pluošto tyrimus.

Tėvams ir savo šeimai, kurie nuo pat mokslinės veiklos pradžios mane palaikė, buvo supratingi ir vertino tai, ką dariau.

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