Zdzisław Czaplicki[1], Zbigniew Mikołajczyk[2], Aleksandra Prążyńska[2]

[1] **Institute of Natural Fibres and Medicinal Plants,** Poland,
E-mail: zczaplicki@wp.pl

[2] **Lodz University of Technology, Department of Knitting Technology and Textile Machinery**

Analysis of Functional Properties of Knitted Fabrics Made of Alpaca Wool and Other Fibres

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Abstract

The article presents research results on selected properties of knitted products made of alpaca wool and other raw materials. Special attention was paid to properties defining thermal comfort. The material studied were weft-knitted fabrics made of four different yarns: cotton, PAN, sheep wool and alpaca wool. All knitted fabrics were made with different stitches in five variants on a computer controlled knitting machine – Stoll CHS 530 HP. Warmth retention was evaluated using an Alambeta device. The properties tested were as follows: thermal conductivity, thermal diffusivity, thermal absorption, thermal resistance and air permeability. Results concerning the functional properties of the knitted fabrics made of alpaca wool were compared with those obtained for other materials. Generally knitted fabrics made of alpaca wool were positively evaluated.

Key words: *yarns, knitted fabrics, functional properties, thermal protection, thermal conductivity, thermal absorption.*

Introduction

The main scientific goal of the article is the analysis of user's comfort in the aspect of thermal protection provided by outer garments made of alpaca wool and other raw materials frequently used in knitting technologies in the production of knitwear. Other yarns which can be compared with alpaca wool are cotton yarns, sheep wool and polyacrylonitrile.

An important element of research on the analysed knitted structures made of alpaca wool from the point of view of ensuring thermal comfort for the user is the assessment of warmth retention [1, 2]. Thermal comfort is defined as a state in which the human body is in a condition of thermal balance, which means that it feels neither warm nor cold [3, 14]. As a result of research conducted, Fanger P.O. stated that the parameters affecting thermal comfort are as follows: energy expenditure (the amount of heat generated in the body), resistance to heat conduction through clothing, air temperature, average temperature of radiation, the relative air flow rate, and the partial pressure of water vapour in the ambient air [4]. The feeling of thermal comfort requires obtaining thermal balance in the ambient conditions determined.

For a given energy expenditure, the skin temperature and amount of heat which has to be used to evaporate the excreted sweat are assumed to be variable physiological parameters. The task of the thermoregulatory system of the human body, as Fanger observed, is to maintain an almost constant internal temperature. Therefore it can be assumed that with the constant course of metabolic processes and at constant environmental conditions, the body is supposed to reach a state of thermal equilibrium. The equation of thermal balance under these conditions takes the form:

$$Q - Q_d - Q_w - Q_{ou} - Q_{oj} = Q_p = Q_r + Q_k$$

where:
Q – amount of internal heat generated in the body,
Q_d – heat loss by diffusion of water vapour through the skin,
Q_w – heat loss by evaporation of sweat from the skin,
Q_{ou} – loss of latent heat during breathing,
Q_{oj} – loss of sensible heat during breathing,
Q_p – amount of heat penetrating from the skin to the outer surface of clothing covering the body,
Q_r – heat loss by radiation from the outer surface of clothing covering the body,
Q_k – heat loss by convection of the outer surface of clothing covering the body.

The equation above shows that heat transfer from the skin to the outer surface of clothing covering the body is a complex process and occurs through convection, radiation and heat conduction through the clothing product.

The issue presented in the publication is also important from the point of view of alpaca breeding, which is developing in Poland, and the production of wool, characterised by good thermal properties [5, 6], which can be successfully used for knitwear. Currently the population of alpacas in Poland is 5000 and is increasing [7]. The estimated wool production is 10 tons per year.

The world population of alpacas is estimated at 5 million [7], about 3.5 million of which live in Peru, 500 thousand in Bolivia, and 100 thousand in Chile. At the beginning of the 1980s, alpacas started to be bred in other continents. Currently the largest number of alpacas outside South America can be found in Australia (over 200 thousand), USA, Canada, New Zealand and Europe [7]. In Europe, alpacas are bred in such countries as Great Britain (40 thousand), Germany (30 thousand) Switzerland, Austria, France, Spain, Poland, as well as Scandinavian countries.

In the world literature [8-11], some information can be found concerning the history of alpacas, their living conditions and the benefits resulting from using wool in clothing products. So far, most information about alpaca fibres and their future textile applications was presented by Villarroel [8] at the world conference in Bradford. The author drew attention to numerous problems connected with processing alpaca wool into yarns due to, among others, huge variations in fibre thickness, depending on the body part of the animal. Rainsford [9, 10] points out that in Peru clothes made of alpaca wool are a tradition from very old times. In Peru, alpaca wool is called "the wool of gods" because of its high functional properties and comfort.

In Poland, the problem of alpaca breeding as well as its wool, properties and processing is still new. Czaplicki's research works [5-7] initiated a comprehensive study of alpaca wool "from fibre to the final product". Czaplicki and Ruszkowski in their research [12] solved the problem of washing alpaca wool with the use of ultrasound technology. The Works currently conducted concern the improvement of the technology for processing alpaca wool for yarns and textile products.

Currently a wider and more diversified range of innovative textile products, including thermoactive clothing, is available on the market [16]. Dynamic development has been primarily observed in knitting technology. The development of new yarns and fibres, including alpaca

Figure 1. Computer controlled flat knitting machine CMS Stoll.

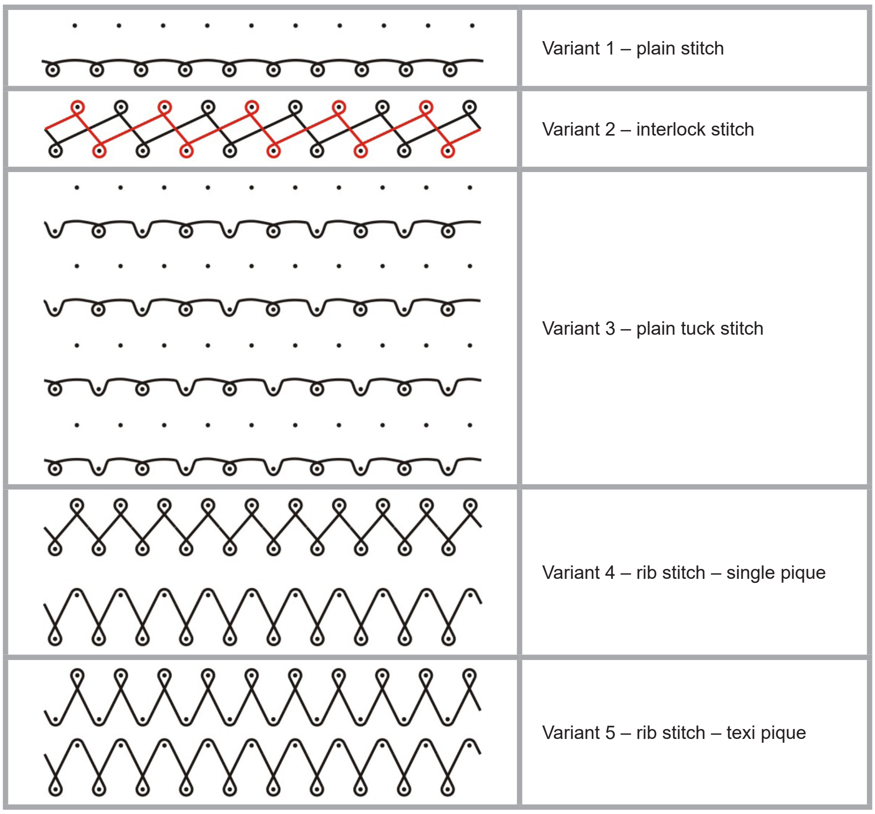


Figure 2. Stitch variants of weft-knitted fabrics produced.

Table 1. Test object and its characteristics.

No	Fabric type	Fibre type	Yarn linear density (tex)
1	Cotton (CO)	Cotton (31/32 mm/1.6 dtex)	(29x10) tex = 290 tex
2	Acryl (PAN)	Acryl (75 mm/1.6 dtex)	(110x3) tex = 330 tex
3	Alpaca wool (WA)	Alpaca wool (80 mm/24.6 μm)	(165x2) tex = 330 tex
4	Sheep wool (WO)	Sheep wool (75 mm/24.4 μm)	[(82x2) tex]×2 = 328 tex
Stitch variants – parameters of the knitting process 1 – plain stitch: NP = 14.0 2 – interlock stitch: NP = 12.8 3 – plain tuck stitch: NP = 14.3 4 – rib stitch – single pique: NP = 13.2; tucking NP = 12.9 5 – rib stitch – texi pique: NP = 13.2; tucking NP = 12.5 Movement speed of the head with locks: 0.80 m/s			

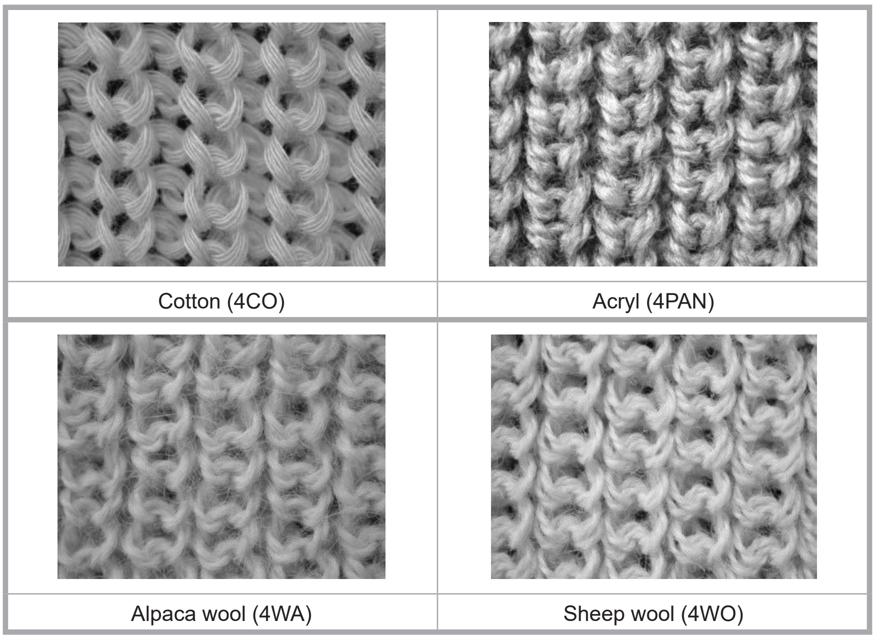


Figure 3. *Photographs of the right side of the rib stitch – single pique.*

wool, broadens the possibilities of providing physiological comfort to users. Innovative clothing can also fulfill new, additional functions such as discharging sweat and water vapour into the environment or protecting against heat loss (products made of alpaca wool). One of the important parameters affecting thermal comfort is the thermal insulation of clothing. This parameter is responsible for clothing ability to conduct heat exchange between the human body and the environment. This exchange depends mainly on the properties of fibres and textiles the clothing is made of [13, 15].

The thermal insulation of clothing is dependent on the clothing construction, fitting degree, climatic conditions outside, as well as the properties of the material from which the clothing was made. In recent years, many works have appeared concerning the issue of the physiological comfort and functional properties of clothing products. Prakash C. et al [17-21] investigated the thermal properties of knitted products made from bamboo fibres and bamboo-cotton blends. The authors discovered, among others, that the thermal properties of knitted products depend on the type of fibre blend, the yarn length in the loop, and on the linear density of the yarn [18]. Kothari [22] investigated the influence of fibre properties on the comfort characteristics of textile products. Kadapalayam Chinnasamy K. and Prakash C. [23] studied the influence of the fibre mixing ratio and linear density of component yarns on the thermal comfort of bamboo-cotton fabrics. Thermal comfort was tested for knitted fabrics made of 100% cotton, 100% regenerated bamboo and mixed bamboo/cotton fabrics. It was found that bamboo fabrics are characterised by the highest air permeability and moderate water vapour permeability. The lowest values were observed for cotton fabrics. Bamboo fabrics, on the other hand, have lower thermal conductivity than fabrics made from cotton.

Results obtained concerning the structure and properties of alpaca wool [6] create premises for a wider use of alpaca in the broadly understood knitted garments, including socks and hosiery, as well as woven products (warm blankets, etc.).

During the tests, the influence was investigated of the yarn type and stitch variant on the functional properties of knitted fabrics characterising physiological comfort.

Table 2. *Basic structural and physical parameters of the knitted fabrics.*

Stitch variant	Fabric type	Warp density P_r, Numer of courses /100 mm	WEft density P_k, Numer of wales /100 mm	Loop shape coefficient $C = P_k/P_r$	Fabric thickness g, mm	Surface density M_p, g/m²
1	1CO	27	26	0.96	2.9	358
	1PAN	34	27	0.79	3.2	442
	1WA	34	24	0.71	3.3	363
	1WO	34	27	0.79	3.4	464
2	2CO	26	29	1.14	6.1	782
	2PAN	32	27	0.84	6.2	881
	2WA	30	28	0.93	6.4	852
	2WO	32	32	1.00	6.2	1029
3	3CO	20	20	1.00	3.9	402
	3PAN	27	21	0.78	6.2	528
	3WA	28	18	0.64	6.4	544
	3WO	29	20	0.69	6.2	588
4	4CO	17	12	0.71	5.7	532
	4PAN	25	14	0.56	7.5	695
	4WA	26	13	0.50	7.4	684
	4WO	26	14	0.52	7.7	793
5	5CO	22	12	0.55	5.9	540
	5PAN	26	15	0.58	8.0	674
	5WA	26	12	0.46	8.1	574
	5WO	30	13	0.43	7.4	725

Test material

The test material were knitted fabrics made in 5 variants of stitches using a CAD program called M1 plus. The fabrics were made on a numerically controlled knitting machine – Stoll CMS 530 HP (Germany) with an E 5 needle gauge. An image of the knitting machine is shown in ***Figure 1***. The research object and its characteristics are presented in ***Table 1***. The stitch variants of the weft-knitted fabrics are shown in ***Figure 2***.

Some photographs of the right side of the rib stitch – single pique are shown in ***Figure 3***.

Tests of fabric parameters

Fabrics parameters were tested according to Polish Standards at the Department of Knitting Technology and Textile Machinery of Lodz University of Technology.

- Pilling – PN-EN ISO 12945-2 Textiles. Determination of fabric propensity to surface fuzzing and pilling Part 2: modified Martindale method.
- Air permeability – PN-89/P-04618 Flat textile products. Determination of air permeability.
- Thickness of fabrics – PN-EN ISO 5084: 1999 Textiles. Determination of thickness of textile products.
- Surface density – PN-P-04613: 1997 Textiles. Knitwear and non-wovens. Determination of linear and surface density.
- Warmth retention of clothing materials – Alambeta device (Czech Republic).

The basic structural parameters of the knitted fabrics are shown in ***Table 2***. The pilling tendencies of the fabric variants were evaluated using a Weartester device (Hungary). The abrasion head subjected to a load of 15 N (150 g) moved over the surface of the knitted fabric along the Lissajous curve. A plain stitch fabric made of sheep's wool, with a surface density of 270 g/m^2 and 875 loops/dm^2, was used as the abrasion medium. The tests were continued until pilling appeared and/or fuzzing significantly affected the appearance (aesthetics) of the samples. Pilling and fuzzing were assessed visually in the subsequent stages of the study for individual fabric variants. The results of the tests are presented in ***Table 3***.

Air permeability was determined using an FF12 instrument (Hungary). The test was carried out at a pressure difference of 10 daPa on a nominal measuring surface of 15 cm^2. The results of the tests are shown in ***Table 4***. Assessment of the warmth retention of the fabrics tested was carried out with the Alambeta device. The properties measured were the thermal conductivity, diffusivity and heat absorption coefficient.

One of the most important properties of textiles which affects the warmth retention of clothing is the thermal insulation R, which determines the amount of heat flowing through 1m^2 of material per time unit, with the temperature difference on both sides of the clothing equal to 1 °K. Thermal resistance, expressed in m^{2}KW^{-1}, is the measure of thermal insulation.

Thermal conductivity λ is the value which characterises fabric ability to conduct heat. It is defined as the amount of heat per unit of the surface area perpendicular to the direction of the heat flux,

Table 3. *Degree of pilling resistance of fabrics tested.*

No.	Fabric type	Evaluation according to the comparison scale of photographic standards (1-5)				
		Stitch variant				
		1	2	3	4	5
1	Cotton (CO)	2	2	2	4	4
2	Acryl (PAN)	3	3	4	3	3
3	Sheep wool (WO)	5	4	5	3	5
4	Alpaca wool (WA)	1	1	1	1	1

Table 4. *Evaluation parameters of warmth retention and air permeability.*

Stitch variant	Fabric type	Thermal conduction $\lambda \cdot 10^{-3}$, Wm^{-1}K^{-1}	Thermal diffusivity $a \cdot 10^{-6}$, m^{2}s^{-1}	Thermal absorption b, Wm^{-2}s^{½}K^{-1}	Thermal resistance $R \cdot 10^{-3}$, W^{-1}Km^2	Air permeability P, dm^3/m^{2}s
1	1CO	50.7	0.314	90.9	57.4	5480
	1PAN	44.5	0.366	75.4	72.0	2530
	1WA	39.5	0.206	87.2	83.1	5350
	1WO	42.8	0.205	94.6	78.6	6270
2	2CO	72.4	0.343	124.0	84.0	3070
	2PAN	55.6	0.324	99.0	112.5	1240
	2WA	56.3	0.326	98.7	114.0	2860
	2WO	60.4	0.293	111.5	103.0	4020
3	3CO	49.7	0.449	74.6	79.2	6240
	3PAN	50.8	0.778	57.8	122.5	3440
	3WA	57.5	0.650	72.0	111.0	4760
	3WO	56.6	0.491	82.1	110.3	6640
4	4CO	60.1	0.814	66.6	94.7	6340
	4PAN	54.4	0.777	55.2	139.0	3030
	4WA	58.8	0.799	62.0	126.0	4570
	4WO	62.1	0.726	72.9	124.5	5720
5	5CO	61.3	0.551	83.3	96.2	5380
	5PAN	57.6	0.625	73.5	139.3	3150
	5WA	64.3	0.773	73.4	126.7	5110
	5WO	65.4	0.495	93.4	114.0	6862

Table 5. *Test results of fabric density and relative thermal resistance.*

Stitch variant	Fabric type	Apparent density d_p, kg/m^3	Relative thermal resistance related to thickness unit w_1, m·°K/W	Relative thermal resistance related to unit of surface density w_2, m^{4}·°K/Wkg
1	1CO	123.0	19.7	0.16
	1PAN	138.2	22.5	0.16
	1WA	110.5	25.3	0.23
	1WO	138.0	23.4	0.17
2	2CO	128.9	13.9	0.11
	2PAN	141.2	18.0	0.13
	2WA	132.5	17.7	0.13
	2WO	165.9	16.6	0.10
3	3CO	102.2	20.1	0.20
	3PAN	84.8	19.7	0.23
	3WA	85.1	17.4	0.20
	3WO	94.2	17.7	0.19
4	4CO	93.6	16.7	0.18
	4PAN	92.2	18.4	0.20
	4WA	92.3	17.0	0.18
	4WO	102.8	16.1	0.16
5	5CO	91.6	16.3	0.18
	5PAN	84.4	17.4	0.21
	5WA	70.5	15.6	0.22
	5WO	97.4	15.3	0.16

per unit of the temperature gradient and time unit.

In the SI system of units, thermal conductivity is expressed in $Wm^{-1}K^{-1}$.

With the help of an Alambeta device, it is possible to measure not only the static thermal properties of knitted fabrics, such as thermal resistance and thermal conductivity, but also the dynamic ones: thermal diffusivity and thermal absorption.

Thermal diffusivity a, also referred to as the temperature equalisation coefficient, is the physical quantity characterising transient heat conduction.

Thermal absorption b is also called the heat absorption coefficient.

The thermal absorption unit is $Wm^{-2} s^{½}K^{-1}$.

Thermal absorption is a property which characterises the material tested from the point of view of a warm or cold sensation when touched. The results of warmth retention measurements for the fabrics tested are shown in ***Table 4***.

The apparent density of the knitted fabric was determined from the formula:

$$d_p = \frac{M_p}{g}, kg/m^3 \quad (1)$$

where: M_p – surface density, g – thickness

The relative heat resistance related to the thickness unit w_1 was also determined (this parameter indicates the heat resistance of the thickness unit of a given fabric) as well as the relative heat resistance related to the unit of surface density w_2 (heat resistance per unit of surface density).

$$w_1 = \frac{heat\,resistance}{thickness}, \frac{m \cdot K}{W} \quad (2)$$

$$w_2 = \frac{heat\,resistance}{surface\,density}, \frac{m^4 \cdot K}{W \cdot kg} \quad (3)$$

The calculation results obtained from ***Equations (1)***, ***(2)*** and ***(3)*** are presented in ***Table 5.***

Research results and discussion

The test results are presented in ***Tables 3, 4*** and ***5***. Graphical representation of the test results is shown in ***Figures 4-13***.

Pilling

The degree of pilling resistance was evaluated according to a five-point scale for all the variants of knitted fabrics tested. After the abrasion process was completed, the samples were compared with the corresponding photographs. The results are shown in ***Table 3***.

Cotton knitted fabrics

In case of cotton fabrics, the process of pilling occurs earlier than fuzzing. The ourse of the abrasion process of the cotton samples was similar for all the stitches produced, resulting in the formation of the first single pills not connected to the surface after 90 to 210 strokes. After some time, pilling progresses (540 strokes) and small pills are formed which are permanently connected with the surface of the knitted fabric (960 strokes). The completion of the abrasion process after the maximum number of 3600 strokes for variant 1 leads to an appearance change for all the variants. Significant fuzzing is observed and small pills are evenly distributed over the surface of the samples.

Acrylic fabrics

Knitted fabrics made of acrylic yarns, as a result of the abrasion process, show strong surface fuzzing and significant pilling. In the initial phase, individual fibres are combed out, which leads to slight fuzzing after 150 strokes in the case of variants 1, 2 and 3. For variants 4 and 5, this effect is noticeable after 510 strokes, and in the case of variant 5 the first loose pills are visible on the knitted surface. Visual evaluation of the samples undergoing further abrasion showed increasing fuzzing and the formation of pills permanently connected with the surface.

In case of a rib stitch – single pique and rib stitch – texi pique, the execution of 1200 strokes significantly affected the appearance of the knitted surface, thus the abrasion process was discontinued. An undesirable change in the appearance of the sample made with a plain tuck stitch was observed after 1530 strokes. The abrasion process for the plain and interlock stitch was finished after 2550 strokes.

Sheep's wool knitted fabrics

As a result of the research, it was demonstrated that knitted fabrics made of sheep's wool show the lowest tendency to fuzz and pill. In the case of samples with plain and plain tuck stitches (variants 1 and 3), after 5400 strokes the only noticeable change was the increase in hairiness on the surface, caused by the combing out of individual fibres. In the case of variants 2 and 4, the change in appearance of the samples due to the combing out of individual fibres and the creation of single pills not permanently connected to the product surface could be noticed after 900 strokes. Variant 2 after 3720 strokes was characterised by an increased number of fibres protruding from the surface and the formation of small pills permanently connected to the fabric surface. The abrasion process, completed after 5400 strokes, caused the combing out of a considerable number of fibres and the creation of small pills, with no noticeable fuzzing affecting the aesthetics of the product. In the case of variant 4, over time, the process of combing out individual fibres and the formation of pills deteriorated, resulting in a clearly fuzzy surface and significant pilling after the completion of 5400 strokes. The pills observed were quite large. Subjecting the rib stitch – texi pique (variant 5) to the abrasion process resulted in the combing out of individual fibres and the creation of pills not permanently connected with the surface of the sample after 630 strokes. After completion of the test (5400 strokes), a change in the appearance of the knitted fabric was noticeable in the form of pills not permanently connected to the surface and increased hairiness resulting from the combing out of individual fibres.

Alpaca wool knitted fabrics

All variants made from alpaca wool showed a high tendency to fuzz and pill. The abrasion process, completed after 2400 strokes, in the case of variants 2 and 3 and the execution of 1230 strokes caused strong surface fuzzing and intense pilling. Pills of large dimensions were observed, both loose and permanently connected to the fabric. The first changes in the appearance of the samples tested were observed after the execution of 150 strokes except for the plain stitch (variant 1), where the first undesirable changes could be noticed after 600 strokes. The small pills in the course of the abrasion process change into one large pill carried by the abrasion element over the entire surface of the fabric. The abrasion process negatively influenced the aesthetics of the samples tested.

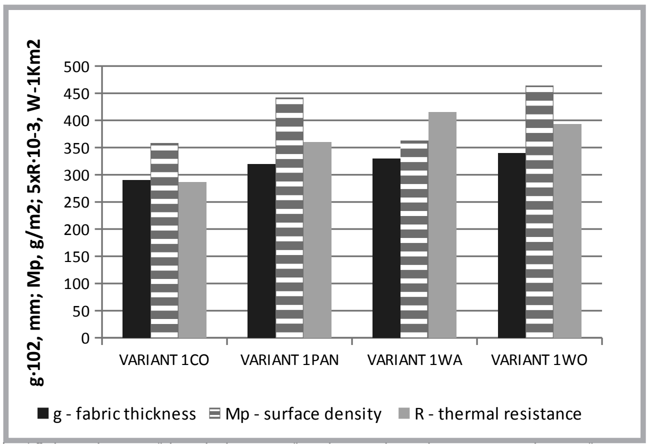


Figure 4. Relation between fabric thickness, surface density, thermal resistance, and type of yarn for plain stitch (1).

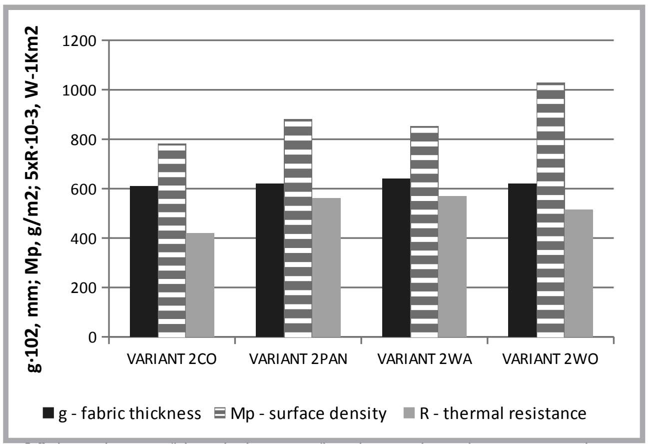


Figure 5. Relation between fabric thickness, surface density, thermal resistance, and type of yarn for interlock stitch (2).

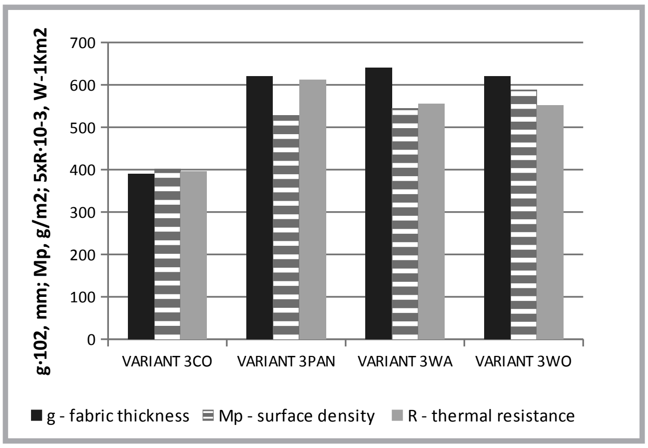


Figure 6. Relation between fabric thickness, surface density, thermal resistance, and type of yarn for plain tuck stitch (3).

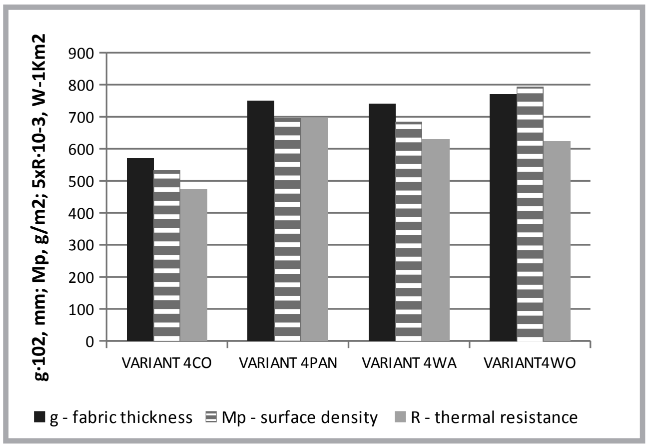


Figure 7. Relation between fabric thickness, surface density, thermal resistance, and the type of yarn for rib stitch – single pique (4).

Air permeability

The results obtained (***Table 4***) indicate that knitted fabrics made of sheep's wool and cotton are characterised by the highest air permeability, while the smallest was observed in the case of knitted fabrics made of polyacrylonitrile. The situation above repeats itself for each stitch variant. The values of air permeability for all knitted structures made of alpaca wool are lower than for sheep's wool and cotton.

The average values of air permeability for the knitted structures produced show that the highest air permeability is characteristic for knitted fabrics with a plain tuck stitch and the lowest for those with an interlock stitch. Analysing the absolute value of air permeability, it is found that the lowest value occurs for the interlock stitch and knitted fabric made of polyacrylonitrile, and the highest for the knitted fabric with a rib stitch – texi pique fabric made from sheep's wool. Lower values of air permeability obtained for alpaca wool compared to fabrics made from sheep's wool probably result from different arrangements of single yarns (twist, linear density) forming the folded yarn used in the knitting process (***Table 1***).

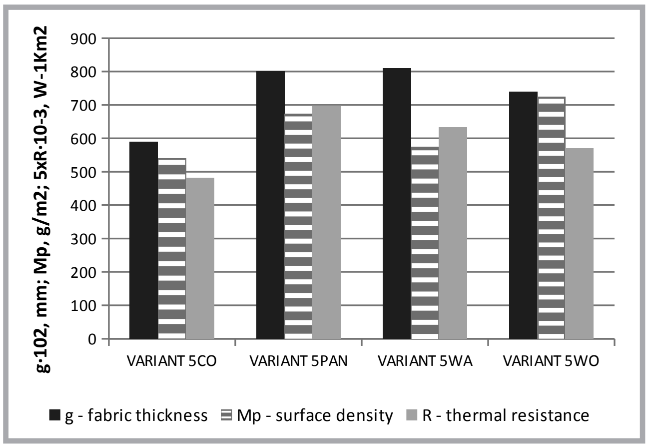
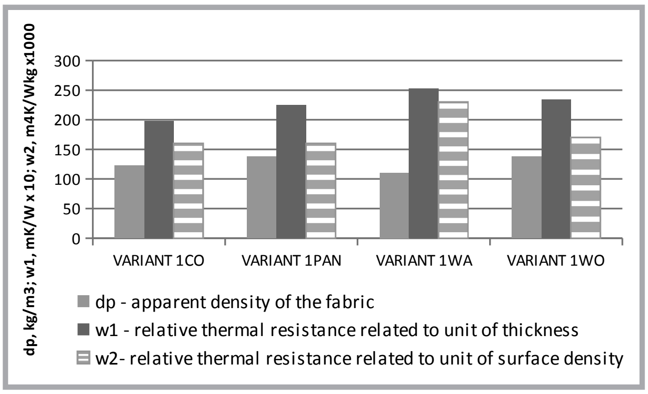


Figure 8. Relation between fabric thickness, surface density, thermal resistance, and type of yarn for rib stitch – texi pique (5).

Warmth retention

Analysis of the test results for the knitted fabric variants (***Table 5***) showed that the best warmth retention properties are observed for two types of weft stitches, plain stitch and plain tuck stitch. In the case of the first one, the fabrics tested are characterised by good relative resistance related to the unit of thickness. In the second case, both the thermal resistance related to the thickness unit and the surface density show comparatively high values.



***Rysunek 9.** Relation between the apparent density of the knitted fabric, the relative thermal resistance related to the unit of thickness and that of surface density and the type of yarn for plain stitch (1).*

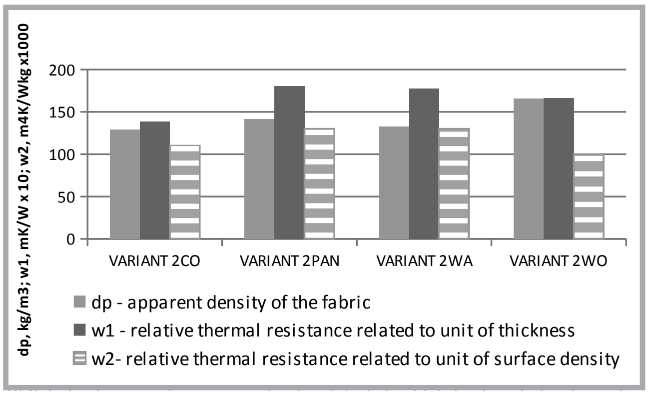


***Figure 10.** Relation between the apparent density of the knitted fabric, the relative thermal resistance related to the unit of thickness and that of surface density and the type of yarn for interlock stitch (2).*

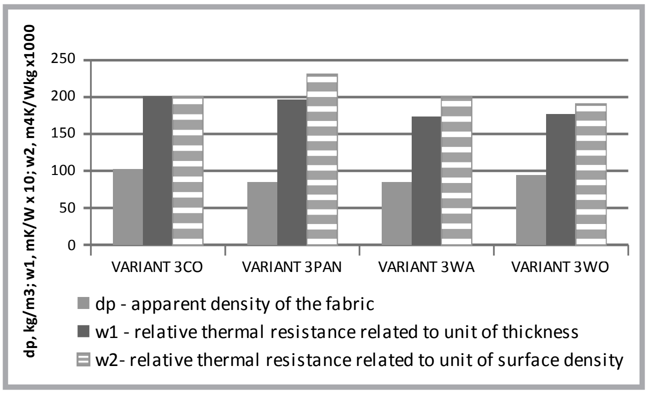


***Figure 11.** Relation between the apparent density of the knitted fabric, the relative thermal resistance related to the unit of thickness and that of surface density and the type of yarn for plain tuck stitch (3).*

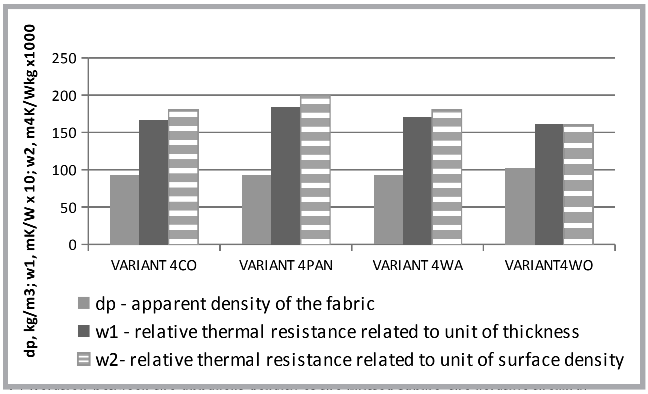


***Figure 12.** Relation between the apparent density of the knitted fabric, the relative thermal resistance related to the unit of thickness and that of surface density and the type of yarn for rib stitch – single pique (4).*

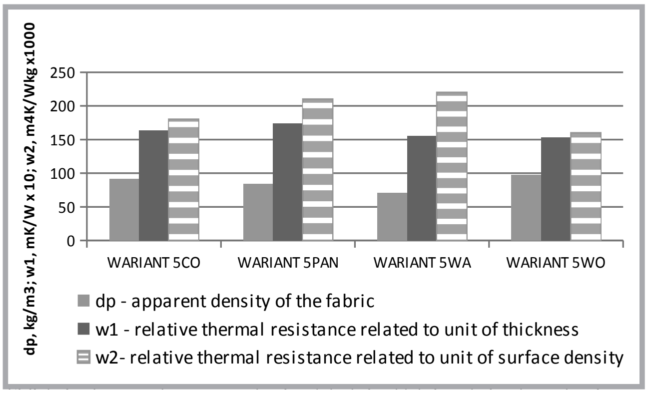


***Figure 13.** Relation between the apparent density of the knitted fabric, relative thermal resistance related to the unit of thickness and that of surface density and the type of yarn for rib stitch – texi pique (5).*

Maximum values of thermal resistance (***Table 4*** and ***Figures 4-8***) occur for the stitches and yarns of alpaca wool and polyacrylonitrile, and in the case of alpaca wool the highest values of thermal resistance were obtained for knitted fabrics with a plain stitch and interlock stitch.

Knitted fabrics with these stitches can be recommended for outer clothing, which must be characterised by high warmth retention. For knitted fabrics with other stitches, the thermal resistance of alpaca wool is also significant, although it does not take the maximum values (***Figures 4-8***). The analysis presented concerns absolute values of thermal resistance, whereas, as proven by research, the thermal resistance of a barrier in the form of a knitted fabric depends on the thickness of the barrier and the surface density (apparent density) of the knitted fabric.

The results of the tests of relative thermal resistance related to the thickness and surface density of the knitted fabric (***Table 5***) indicate what amount of thermal flux is stopped by the unit of thickness and that of surface density. Relative heat resistances correlate with each other, and, as the test results show, the highest values of these parameters are observed for polyacrylonitrile yarns, whereas only for knitted fabrics with a plain stitch made from alpaca wool are these values the maximum. No direct relationship was observed between the apparent density of knitted fabrics d_p (***Table 5***) and the relative thermal resistance (w_1 and w_2). It can be concluded that knitted fabrics from alpaca wool are characterised by average values of relative thermal resistance (***Figures 9-13***). The value of relative thermal resistance related to both the unit of thickness (w1) and that of surface density (w2) is influenced by the type of stitch (***Figures 9-13***). On the basis of the analysis of results of the air permeability and thermal resistance tests, it can be stated that knitted fabrics made from alpaca wool have good functional properties, in particular the possibility of significant air and water vapour penetration (good ventilation features of under-clothing climate) with good thermal insulation (thermal resistance R, ***Table 4***). Knitted products made from this type of yarn will also certainly perform well as sports and leisure clothing in winter conditions.

Summary

The test results obtained indicate that the functional properties of knitted fabrics depend on the type and composition of the yarn and on the type (variant) of stitch. The analysis of the fabric variants showed that the best thermal protection is provided by two types of stitches, the plain stitch and plain tuck stitch. In the first case, the fabrics tested are characterised by good relative thermal resistance in relation to the unit of thickness. In the second case, the thermal resistance related to both the unit of thickness and that of surface density shows comparitively high values. When it comes to the raw material, the best warmth retention for the plain stitch is exhibited by alpaca wool. For the second stitch structure chosen-plain tuck stitch, no advantage was visible of using alpaca wool compared to other raw materials. In the case of other structures, the warmth retention values are at a medium level. Summarising, the overall assessment of knitted fabrics made from alpaca wool was quite favorable compared to other knitted fabrics.

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