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Investigation on Thermal Comfort Characteristics of Newly Engineered Yarn Umorfil® Knitted Fabrics

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ABSTRACT

This study investigated the thermal comfort properties of knitted fabrics produced from newly engineered Umorfil® yarns and their blends with Tencel®, wool, acrylic and polyester yarns. Single jersey-knitted fabrics were produced with 50/50% blended yarns (Umorfil®/Tencel®, Umorfil®/wool, Umorfil®/acrylic, and Umorfil®/polyester) and with 100% Umorfil® yarn for comparison. In this regard, the thermal comfort properties (thermal conductivity, thermal resistance, thermal absorptivity), air permeability, relative water vapour permeability, water absorbency, and wicking characteristics of these fabrics were measured and evaluated statistically. The results revealed that, 100% Umorfil® and 50/50% Umorfil®/Tencel® fabrics provided better characteristics in terms of thermal conductivity, air permeability, water absorbency, wicking behaviours, and colder feelings for the use of fabrics in hot climate products. It is also suggested that owing to the synergistic effect of these two materials, the blend of Umorfil® with Tencel® enhanced the thermal comfort and liquid moisture transmission capacities of the fabrics.

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KEYWORDS

Thermal comfort, Wicking behaviour, Single jersey fabric, Umorfil® yarn, Collagen peptide fibre

1. INTRODUCTION

Natural fibres, especially wool, linen, cotton and silk have served people's textile needs throughout history. However, they cannot meet the demand due to limited resources and increasing world population. This has triggered the development of man-made fibres. Due to the increase in the performance properties expected from the garments in recent years, development of engineering products made from natural resources is increasing worldwide. Along with the increasing environmental problems, the awareness of sustainability has raised the issue of utilizing waste materials in fibre production. The mostly focused sustainability issues were about water, product, energy and waste. Textile manufacturers have many responsibilities such as providing a healthy and safe working environment, reducing water usage, recycling, minimizing environmental footprint via using less-better and again. Among these responsibilities, waste evaluation and use of natural raw materials are among the important topics they focus on.

Waste fish scales are used in the production of Umorfil® bionic fibre. The use of waste as raw material provides an advantage in terms of sustainability and effective use of limited resources. In addition, the waste used also contributes to the performance characteristics of the final product according to its structure. For example waste fish scales, improves moisture management properties of textiles. The Umorfil word comes from the words “moisture” and” yarn”. Umorfil® technology integrates ocean collagen peptide amino acid, obtained from waste fish scales, with different fibres, by supramolecular technology. If the fibre, in which the Umorfil® is integrated, is viscose based, it is called a Umorfil® Beauty Fibre®, if polyester based, Umorfil®T and if nylon based Umorfil® N6UTM fibre. It is stated by the fibre manufacturer that these fibres have softness, high moisture management, natural deodorizing properties, similar to silk

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and wool fibres. With skin-friendly Umorfil® Beauty Fibre®, it is possible to provide UV-cut and protect from skin aging [1]. The chemical structure of the fibre is given in the Figure 1.

In order to enhance the heat and moisture transfer capabilities of textile materials for increasing thermal comfort, textile technologists select the suitable textile materials and position them appropriately within the clothing system. Several characteristics of textile materials, including fiber type, yarn type, yarn smoothness, fabric structure, fabric thickness, etc., are related to thermal comfort. The type and characteristics of fibre is a main factor that influence the thermal comfort characteristic of clothing. The ability of a fiber to absorb moisture and then release it again is closely correlated with the moisture regain of the fiber or fabric. The better the fiber in absorbing perspiration or moisture from the wearer's skin, the longer it will keep the wearer's skin dry [3-5].

Literature survey revealed that, there are few studies on the recently improved collagen peptide added regenerated cellulosic fibres. In a research, the dyeing and performance properties of Umorfil® N6U fibre were investigated. Due to having more amine groups in molecular structure, Umorfil® fibre exhibited better colour fastness characteristic than polyamides. It was also concluded that, products made with Umorfil® N6U have better softness and cooler feeling, according to wearing tests [6]. Çeven and Günaydın (2021) conducted a research for evaluating the thermal comfort properties, vapour permeability, water vapour resistance, air permeability and bursting strength properties of single jersey knitted fabrics produced with 100% cotton, Cupro, Lyocell®, Modal and Umorfil® yarns. Within the study, the effect of dyeing process (greige and dyed) on the investigated properties was also investigated. It was found that, knitted fabrics produced with Umorfil® yarns revealed the lowest thermal conductivity, bursting strength, and lowest thermal resistance (for greige fabrics) whereas highest thermal absorptivity (for greige fabrics) and highest air permeability values. It was concluded by the authors that the presence of collagen peptide in the cellulosic fibres may enhance thermo-physiological comfort and may be promising for sustainability [7]. In another study, thermal conductivity, air permeability, relative water vapour permeability and water vapour resistance and physical properties (bursting strength, pilling and dimensional stability) of the single jersey fabrics knitted with cotton, viscose, polyester, Umorfil®, Umorfil®/cotton blended yarns were determined. The results revealed that, fabrics knitted with 100% Umorfil® yarns exhibited higher air permeability and water vapour permeability, better pilling characteristic and lower thermal conductivity [2]. Şen and Gürel (2021) presented detailed information on sustainable fibers such as S.Café®, Umorfil®, Seacell™ and examined the structural and performance properties of the fabrics developed with these fibres [8]. Umorfil containing fabrics showed average results regarding wetting and drying properties. Hou et al. (2022) presented a novel method for converting discarded fish scales into collagen-modified polyester. The suggested bionic silk polyester fiber is known by the brand name "UMORFIL T," and due to its excellent moisture regain activity and skin-friendly structure, it may be used in a variety of items including base fabrics, socks, tops, denim textiles, outerwear, bedding, and more. This fiber maintains the properties of conventional polyethylene terephthalate fibers, such as strength, durability, and resistance to wrinkles and shrinkage [9]. They also approached fibers from a different perspective and evaluated in terms of circular economy; converts the synthetic fiber into a sustainable product [10]. In a different study, Hou et al. (2022) aimed on the development of reusable masks using recycled fish-scale waste to deduce the detrimental effects on the marine ecosystem [11]. Kirci et al (2021) used biodegradable Umorfil nylon 6 (Umorfil® N6U) fiber for improving comfort characteristics of compression stockings. Their findings demonstrated that it is feasible to produce comfortable travel stockings with adequate pressure performance [12]. Soydan et al (2021) studied moisture management, antimicrobial and air permeability properties of plain knitted fabrics produced with 100% collagen peptide added regenerated cellulosic yarn and polyamide yarns. According to their findings, collagen peptide-added fiber had a significant antimicrobial impact [13].

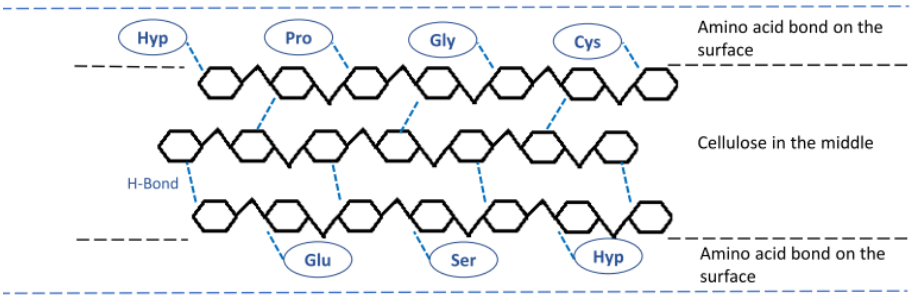


Figure 1. The chemical structure of the Umorfil® fibre [2]

Many researches were carried out on the thermal comfort properties of knitted fabrics produced with different materials. However, the thermal comfort, water absorbency and wicking characteristics of the fabrics produced from Umorfil® yarn and its blends with wool, acrylic, polyester and Tencel® fibres were not investigated in a scientific manner. In this study, it is aimed to investigate thermal comfort properties such as thermal conductivity, thermal resistance, thermal absorptivity, air permeability, relative water vapour permeability, water absorbency and wicking characteristics of single jersey knitted fabrics containing Umorfil® yarn. These fabrics were produced with 50/50% blended yarns (Umorfil®/Tencel®, Umorfil®/wool, Umorfil®/acrylic, Umorfil®/polyester) and with 100% Umorfil® yarn for a comparison.

2. MATERIAL AND METHOD

2.1 Material

Umorfil® as well as wool, acrylic, Tencel® and polyester fibres were used in this study. Staple length (38 mm) of all fibres were suitable for short staple spinning system. SEM analyses were conducted to examine the physical structure of the fibres (Figure 2).

2.2 Method

2.2.1. Yarn production

Umorfil® fibres were blended with Tencel®, wool, acrylic and polyester fibres in MDTA (Micro-Dust and Trash Analyser) machine, which is used for foreign material analyses and easy fibre blending. MDTA has advantages over the time consuming and expensive conventional methods used to obtain fibre blends. Individual blend components were presented to the machine, opened to a single fibre, collected to a rotor ring assembly and formed a sliver. Each sample was passed through the system three times in order to obtain a homogeneous blend. Afterwards the final sliver is fed into an open-end rotor-spinning machine. As a result, 50/50% blended yarns (Umorfil®/Tencel®, Umorfil®/wool, Umorfil®/acrylic, Umorfil®/polyester) and for comparison 100% Umorfil® OE rotor spun yarns of 20 tex were produced.

2.2.2. Fabric production

Single jersey fabrics were knitted in the same machine tightness factor by using the experimental circular knitting machine, "Lab Knitter" (Mesdan-Lab) which has 3¾ inches diameter, one knitting system, 294 working needles. After the knitting process, the fabrics were relaxed in dry state and then finished by washing without detergent, according to the EN ISO 6330 standard.

2.2.3. Testing

Five fabric samples (50/50% Umorfil®/Tencel®, 50/50% Umorfil®/wool, 50/50% Umorfil®/acrylic, 50/50% Umorfil®/polyester, 100% Umorfil®) were preconditioned for at least 24 hours in an environment with a relative humidity of 65 ± 4% and a temperature of 20 ± 2ºC. The dimensional (course density (cpc), wale density (wpc), loop length), physical (weight, thickness, fabric density) and thermal comfort (air permeability, thermal conductivity, thermal resistance, thermal absorptivity, relative water vapour permeability, wicking (absorbency and vertical wicking height time)) properties were measured. Course/wale density and loop length values of the fabrics were tested according to CSN EN 14971:2006 and EN 14970:2006 standards, respectively. Loop length values of the fabrics were measured by using H.A.T.R.A device. Ten readings for each fabric were recorded. Mass per unit area values were tested according to TS EN 12127:1997 by using GSM (grams per square meter) round cutter. Three readings for each fabric were recorded. The Equation (1) was used to determine the fabric density (ρ) of the samples:

$$\rho = \frac{M}{t}(kg / m^3) \qquad (1)$$

where M is mass per unit area of the fabrics (kg/m^2) and t is fabric thickness (m).

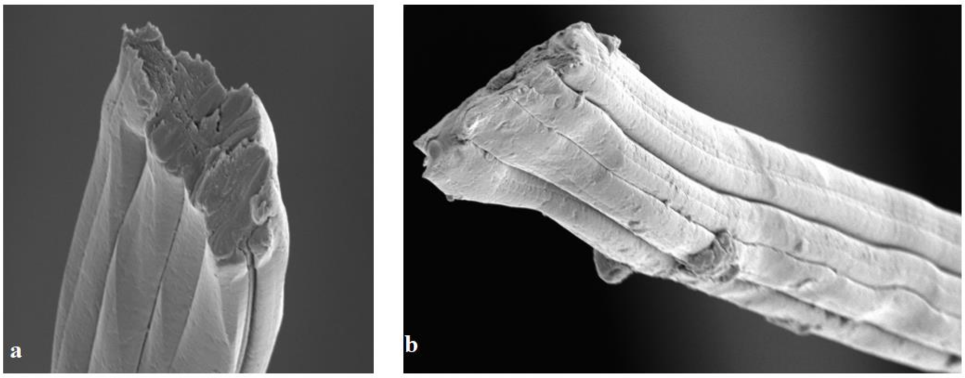


Figure 2. Cross-sectional (a) and longitudinal (b) view of the Umorfil® fibres

Air permeability was measured using Textest FX 3300 instrument with a pressure of 100 Pa on the sample area 5 cm^2 according to TS 391 EN ISO 9237:1995. For air permeability properties, ten measurements for each fabric were done. Air permeability refers to the rate at which air flows through a fabric and Fabric thickness, thermal conductivity, thermal resistance and thermal absorptivity values were tested using Alambeta instrument according to ISO 8301. Relative water vapour permeability was tested on Permetest instrument according to ISO 11092. For thermal comfort and water vapour permeability characteristics, three measurements for each fabric were recorded.The fabric's capability to conduct heat is defined by its thermal conductivity. Thermal resistance (R) is defined as the ratio of the temperature difference between the two faces of fabric to the rate of heat flow per unit area normal to the faces [3] and can be calculated as shown in Equation (2).

$$R = \frac{h}{\lambda}(m^2K/W) \tag{2}$$

where h is fabric thickness (m) and λ is thermal conductivity of the fabrics (W/mK).

When a human skin contacts a material, there is a heat exchange between them. This initial perception, which is described as a warm-cool sensation, may be measured objectively in terms of thermal absorptivity (b) [14], which is determined by Equation (3).

$$b = (\lambda \rho c)^{1/2}(Ws^{1/2}/m^2K) \tag{3}$$

where λ is thermal conductivity (W/mK), ρ is fabric density (kg/m^3) and c is specific heat of the fabric (J/kgK).

The relative water vapour permeability (q; %) can be calculated by using Equation (4):

$$q = 100 \times \frac{q_s}{q_0}(\%) \tag{4}$$

where q_s is the heat flow rate measured with a sample (W/m^2) and q_o is the heat flow rate measured without sample (W/m^2).

Absorbency tester according to AATCC 79:2014 tested the water absorbency attribute of the samples. The samples were placed below the burette, dripped a droplet with 0.1 ml in volume on them, and started the stopwatch simultaneously. When the mirror reflection of the droplet diminished, the elapsed time was recorded as the absorbency time. Vertical wicking performance of the samples were measured by vertical wicking tester according to DIN 53924:1978. A strip of samples 3cm x 4cm were suspended vertically with its lower end (10mm) immersed and 3 parallel 1 cm lines were drawn on the sample through its long side. The capillary action started with immersing the fabric sample vertically in potassium dichromate coloured water and wicking height time was measured for each lines by a stopwatch. These values were recorded as wicking performances of the fabrics. Both absorbency and vertical wicking height time measurements were repeated three times for each sample. The fabric surface appearances were captured by Leica projection microscope.

2.2.4. Statistical evaluation

Variance analysis utilizing the Duncan multiple comparison approach was used to ascertain how the Umorfil® yarn in the fabric structure affected the dependent variables. If the p-value was 0.05 or less for each dependent variable, any differences are considered significant. In Table 3, the subsets (the means of test results) which are in the same column refers to the values are not significantly different from one another.

3. RESULTS AND DISCUSSION

Tables 1 and 2 illustrate the characteristics of the samples and p-values of the tested parameters, respectively. Additionally, the results of variance analysis by using Duncan multiple comparison are given in Table 3.

When course and wale densities of the fabrics are examined, it is seen that the course and wale density of the fabrics are in the range of 13-15 courses/cm and 11-12 wales/cm, respectively. Since the fabrics were manufactured with the same tightness factor, the loop length values are very similar. As it is seen from the Table 1, Umorfil®/wool fabric is the heaviest fabric among the samples. The thickness values of the fabrics are minimum for Umorfil®/Tencel® following by Umorfil® fabric and maximum for Umorfil®/wool fabric. Additionally, the fabric densities of Umorfil®/wool and Umorfil®/Tencel® fabrics have the lowest and highest values, respectively.

Table 1. Characteristics of the fabric samples

Parameter	100% Umorfil®	50/50% Umorfil®/ Tencel®	50/50% Umorfil®/ wool	50/50% Umorfil®/ acrylic	50/50% Umorfil®/ polyester
Courses/cm	15.00	14.70	14.00	14.80	13.10
Wales/cm	11.67	11.00	11.33	12.00	11.50
Loop length (mm)	0.448	0.436	0.457	0.454	0.440
Mass per unit area (g/m^2)	154.70	165.50	213.30	172.50	152.40
Thickness (mm)	0.900	0.833	1.519	0.935	0.928
Fabric density (kg/m^3)	171.89	198.68	140.42	184.49	164.22

Table 2. p values of the tested parameters

	F	Sig.
Mass per unit area	28.547	.000*
Thickness	1096.819	.000*
Air permeability	100.864	.000*
Thermal conductivity	49.198	.000*
Thermal resistance	616.718	.000*
Thermal absorptivity	41.503	.000*
Relative water vapor permeability	122.378	.000*
*Significant at 0.05 level		

Table 3. Variance analysis of results

(a) Air permeability

Code	N	Subset for alpha = 0.05		
		1	2	3
50/50% Umorfil®/acrylic	10	902.90		
50/50% Umorfil®/wool	10	949.90		
50/50% Umorfil®/polyester	10		1174.00	
50/50% Umorfil®/Tencel®	10			1319.00
100% Umorfil®	10			1332.00
Sig.		.195	1.000	.718

(b) Thermal conductivity

Code	N	Subset for alpha = 0.05				
		1	2	3	4	5
50/50% Umorfil®/wool	3	.0413				
50/50% Umorfil®/polyester	3		.0433			
50/50% Umorfil®/acrylic	3			.0458		
100% Umorfil®	3				.0473	
50/50% Umorfil®/Tencel®	3					.0494
Sig.		1.000	1.000	1.000	1.000	1.000

(c) Thermal resistance

Code	N	Subset for alpha = 0.05			
		1	2	3	4
50/50% Umorfil®/Tencel®	3	.0169			
100% Umorfil®	3		.0190		
50/50% Umorfil®/acrylic	3			.0204	
50/50% Umorfil®/polyester	3			.0214	
50/50% Umorfil®/wool	3				.0368
Sig.		1.000	1.000	.051	1.000

(d) Thermal absorptivity

Code	N	Subset for alpha = 0.05		
		1	2	3
50/50% Umorfil®/polyester	3	108.10		
50/50% Umorfil®/acrylic	3	111.33		
50/50% Umorfil®/wool	3	112.20		
100% Umorfil®	3		125.80	
50/50% Umorfil®/Tencel®	3			139.40
Sig.		.203	1.000	1.000

(e) Relative water vapour permeability

Code	N	Subset for alpha = 0.05	
		1	2
50/50% Umorfil®/wool	3	44.43	
50/50% Umorfil®/acrylic	3		57.67
50/50% Umorfil®/Tencel®	3		57.83
100% Umorfil®	3		57.97
50/50% Umorfil®/polyester	3		58.10
Sig.		1.000	.610

3.1. Air Permeability

One of the most crucial factors for assessing and comparing a fabric's ability to breath is considered to be its air permeability. It is influenced by the yarn used, fabric constructional aspects, and bulk characteristics, particularly thickness, mass per unit area, and porosity [15]. The air permeability results (Figure 3) and statistical evaluation (Table 2 and 3 (a)) indicate that, Umorfil®/Tencel®

and Umorfil® fabrics have the highest air permeability values followed by Umorfil®/polyester fabric. In addition, Umorfil®/acrylic and Umorfil®/wool fabrics have lower air permeability characteristics. These results can be explained by fabric thickness and especially by fabric porosity. As it can be seen from Figure 4, Umorfil®/ Tencel®, 100% Umorfil® and compared to other fabrics, Umorfil®/polyester fabrics have a more porous structure, and as the porosity increases, the air permeability values rise as expected. Besides porosity, thickness values of the fabrics contributed to air permeability results. Due to lower thickness and higher porosity characteristics, Umorfil®/ Tencel® and 100% Umorfil® exhibited higher air permeability properties.

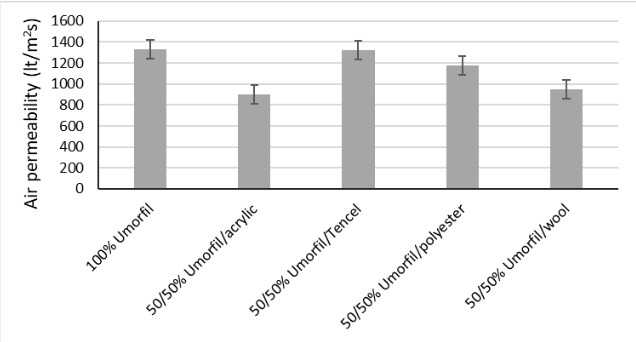


Figure 3. Air permeability results

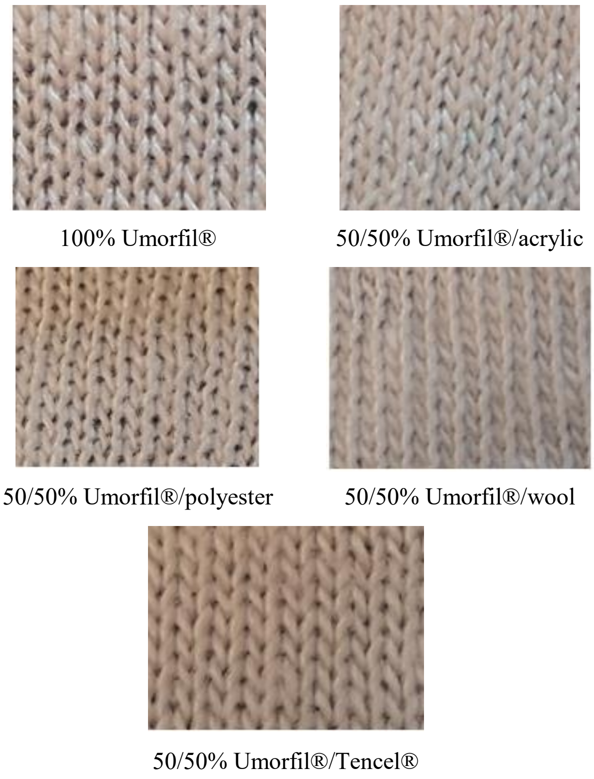


Figure 4. Surface views of fabrics

3.2. Thermal Conductivity and Thermal Resistance

According to the Table 3(b), material type has statistically significant effect on this value. The highest and lowest thermal conductivity values are obtained from Umorfil®/ Tencel® and Umorfil®/wool fabrics, respectively (Figure 5). Umorfil®/Tencel® fabric has highest fabric density, which means that the amount of fibre in a specific area of this fabric is higher [16, 17]. The combination of air and fiber conductivity is known as thermal conductivity. Higher fabric density leads to an increase in thermal conductivity, because the thermal conductivity of fibre is higher than the thermal conductivity of the entrapped air [18, 19]. Contraversely, Umorfil® wool fabric has the lowest thermal conductivity, because due to higher crimpness and lower fiber density (1.30 g/cm^3), wool fabric has highest thickness values resulting in lowest fabric density.

Thermal resistance characteristic is influenced by the fabric's thickness, porosity, and amount of trapped air. According to the researches, when describing the materials' thermal insulation properties, thermal resistance mostly depends on the thickness of the fabric [20 - 24]. Due to the higher thickness and lower thermal conductivity, Umorfil®/wool fabric exhibit highest thermal resistance properties within entire fabrics, respectively (Table 3(c)). Given that air has superior insulating properties than fiber, thicker fabrics offer greater resistance to heat passage across them. This is because thicker fabrics contain more air than thinner ones do, which increases their thermal resistance. Additionally, smoothness has a significant role on the determination of the thermal resistance. Hairy fibre and/or fabrics also offer greater surface area of still air than smooth ones, acting as an insulator against heat and moisture [3]. The hairy structure of Umorfil®/wool fabric (Figure 4) also contributed to the thermal resistance value to be high.

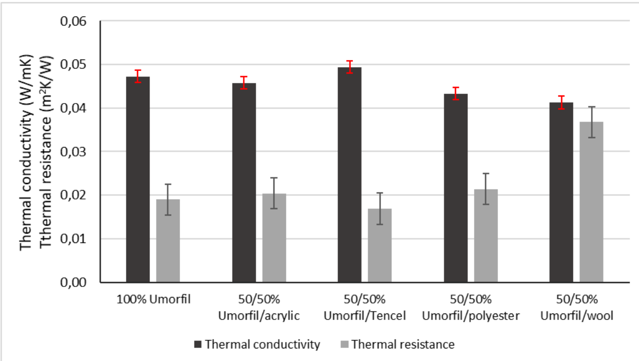


Figure 5. Thermal conductivity and thermal resistance results

3.3. Thermal Absorptivity

According to Table 3 (d), Umorfil®/Tencel® following by Umorfil® fabric with higher thermal absorptivity values give cooler feeling at initial touch (Figure 6). This situation can be explained by thermal conductivity and density of the fabric. Thermal absorptivity of the fabric increases with the thermal conductivity of the fabric and density. Having lower thermal absorptivity values, Umorfil®/-polyester, -acrylic and -wool fabrics have warmer feelings and there are not any significant differences between the absorptivity values of these fabrics.

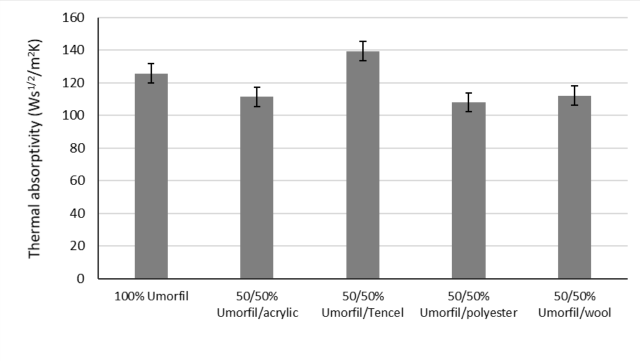


Figure 6. Thermal absorptivity results

3.4. Relative Water Vapour Permeability

Effective clothing should be able to transport sweat vapour by having good water vapour permeability. The pores of a fabric won't get blocked by water that has evaporated from the skin surface and passed through it as vapour, allowing for continuous airflow and heat transfer [3]. The relative water vapour permeability results reveal that, Umorfil®/ wool fabric has the lowest water vapour permeability characteristics within the entire fabric samples. The statistical evaluations indicate that, there are not any significant differences between relative water vapour permeability values of the other fabric samples (Figure 7, Table 3(e)). The moisture regain/hygroscopic property, capillarity, thickness, weight, porosity and other parameters all determine how permeable fabrics are to water vapour [25]. Previous researches [26, 27] presented that higher square mass, thickness and lower porosity of wool fabrics led to a decrease in the relative water vapour permeability and increase in the water vapour resistance of wool fabrics. Additionally, wool can quickly absorb moisture up to 30% of its weight without feeling wet or clammy [28-30]. Therefore, textiles' ability to transport water vapour could be greatly worsened by an increase in their moisture content.

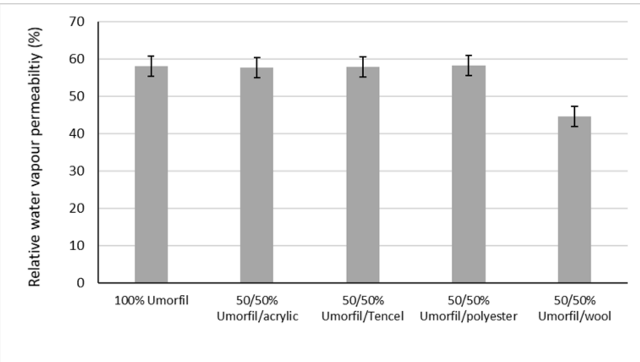


Figure 7. Relative water vapour permeability results

3.5. Water Absorbency and Wicking Characteristics

Comfort is also affected by liquid water transmission properties of fabrics. If sweat builds up on the skin's surface, the wearer will feel uncomfortable. The lack of perspiration to be transferred to the outer surface for evaporation, which is required for the release of body heat, is a result of fabrics' low water absorption and wicking qualities [3, 5]. Two-stage processes are actualized during liquid transfer: wetting and wicking. The first stage in spreading a fluid is wetting. The spreading of water along the surface becomes faster with an increase in surface roughness. As the spreading area of water on the fabric surface increase, the water absorption behaviour of the fabric can get worse which lead to be experienced discomfort by the wearer [31].

The water absorbency attribute of the samples was tested by recording the “absorbency time (s)”. It is well known that fabrics having shorter absorbency time have better water absorbency attributes. The surface energy of the textile substrate, which is significantly correlated with the surface tension and effective capillary pore distribution of the fibers, hygroscopicity of the yarn, tightness, areal density, thickness, and surface roughness of the fabric, determines how a fabric will wet [3, 31–33]. Umorfil®/Tencel® and Umorfil® fabrics with shorter absorbency time exhibit better water absorbency property than the other samples. The smooth surfaces of these two fabrics provide to easily transmit water from the face to the back side of the fabric. As it is seen from the Figure 8, the smooth surface of Umorfil® fibre combined with Tencel® enhance the water absorbency characteristic of the fabrics. This is due to the high absorbency, the nano-structure and the smooth surface of Tencel® resulted in improved physiological functions [34]. On the other hand, Umorfil®/wool fabric absorbed the water more slowly than the entire fabric samples. This situation might be also explained by the surface structure of wool fibre. Surface of wool fibre due to the cuticle cells on it, differs from typical synthetic fibres that have very smooth surfaces. The cuticle cells provide a tough exterior in order to protect the fibre from damage. So, surface roughness lead to an increase in absorbency time.

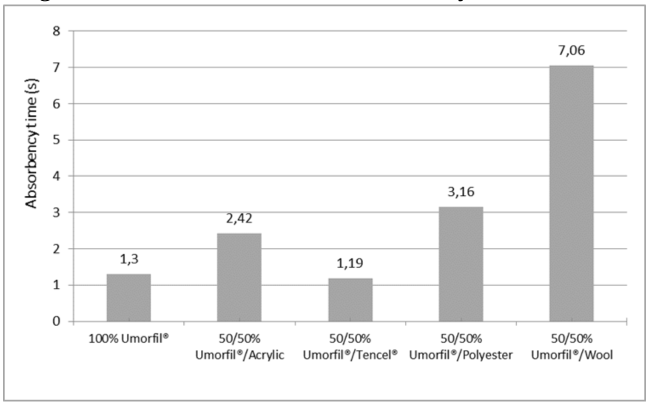
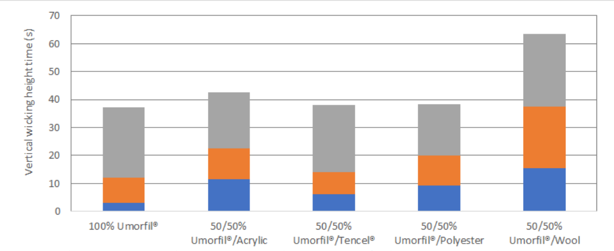


Figure 8. Absorbency time of the fabrics

The spontaneous flow of a liquid by capillary forces is known as wicking, and it is the second stage that occurred during the transfer of water in liquid form [35]. It is the most effective process to provide comfort in sweating conditions. When wearing clothing with a high wickability, skin perspiration distributes throughout the fabric and leaves the wearer feeling dry, and the spreading of the liquid facilitates the rapid evaporation of liquid sweat from larger surface [31]. Wicking behaviour depends mainly on the surface tensions, liquid/solid interfacial tensions, and the type of fibre, type of fabric construction and the finishes applied to the fabrics. Curvature and roughness of contact surfaces are two critical factors for wicking process [31, 35].



	100% Umorfil®	50/50% Umorfil®/Acrylic	50/50% Umorfil®/Tencel®	50/50% Umorfil®/Polyester	50/50% Umorfil®/Wool
3rd line	37,17	42,5	38,06	38,44	63,45
2nd line	12,1	22,42	14,18	20,12	37,42
1st line	3,14	11,55	6,22	9,22	15,5

Figure 9. Vertical wicking height time of the fabrics

The results of wicking performance have the same tendency with the absorbency results. 100% Umorfil® and Umorfil®/Tencel® fabrics with shorter wicking height time offer better water transfer properties. This is due to the cross-sectional view of Umorfil® fibre. Umorfil® fibre has a flat surface as illustrated in Figure 2. The cross-sectional view of the fibre affects the size and geometry of the capillary voids between the fibres and also the wicking rate. Because the specific area increases as a fiber's non-roundness increases, a greater percentage of the capillary wall drags the liquid [31]. Umorfil® fibre has a non-roundness cross sectional view within the investigated materials, hence providing better wicking performance. On the other hand, Umorfil®/wool fabric with longer wicking time absorbed the water more slowly than the entire fabric samples. As explained above, wool can quickly absorb moisture up to 30% of its weight without feeling wet or clammy [28-30]. It is thought that, this high absorption capacity of wool prevented the spreading of the liquid in a larger area in a short period.

4. CONCLUSION

Style, colour, fabric construction, design details, functionality, and comfort should all be taken into account when creating a garment assembly. In order to give wearers a comfortable experience, a cloth's primary objective should be the ability to retain heat in cold climates and easily release excess heat in hot environments or during intense activity. With this regard, an ideal cloth should have low thermal resistance/high thermal conductivity for hot climate, high water vapour permeability to be efficient in heat transfer, have rapid water absorption and transport properties to minimise the wetness sensation on skin.

In this study, thermal comfort and wicking characteristics of knitted fabrics produced from newly engineered Umorfil® yarns and their blends with Tencel®, wool, acrylic and polyester yarns were investigated. Regarding the thermoregulation characteristics, it can be stated that 100% Umorfil® and 50/50% Umorfil®/Tencel® fabrics provide better characteristics in terms of thermal conductivity, air permeability, water absorbency, wicking behaviours and colder feeling for the usage of fabrics for hot climate products. It is also suggested that, due to the synergic effect of these two materials, the blend of Umorfil® with Tencel® enhanced the thermal comfort and liquid moisture transmission capacities of the fabrics.

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