

# Effects of Filament Linear Density on the Comfort Related Properties of Polyester Knitted Fabrics

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## Abstract

*One of the most important developments seen in the synthetic fibre industry is absolutely producing microfibres. Microfibres provide many distinguishing properties for different end uses. In this study, the effects of filament linear densities on the comfort related properties of polyester knitted fabrics were investigated. For this aim, microfilament polyester textured yarns of 110 dtex with 0.33 dtex, 0.57 dtex and 0.76 dtex filament linear densities and conventional polyester textured yarns of 110 dtex with 1.14 dtex and 3.05 dtex filament linear densities were knitted. Dynamic liquid moisture management, air permeability, water vapour permeability and thermal properties of the fabrics were tested. Consequently it is seen that fabrics with coarser filaments have a better capability of transferring liquid moisture. Lower air permeability results are observed with finer filaments, while there is no considerable difference among the samples for water vapour permeability. Also higher thermal resistance results are obtained for samples of coarser filaments.*

**Key words:** microfilament, knitted fabric, dynamic liquid moisture management, air permeability, water vapour permeability, thermal resistance.

## Introduction

Due to increasing performance demands from textile products, the synthetic fibre industry has seen very important developments such as producing microfilaments. Many researchers defined the microfilament as a filament finer than 1 dtex or 1 denier [1 - 8]. Microfilaments provide light weight, softness, good drapeability and many distinguishing properties for different end uses. Knitted fabrics offer an important freedom of movement to the users distinctively from their woven counterparts. Unrestricted movement of knitted fabrics and distinguishing properties of microfilaments has caused a market demand for knitted microfilament garments. On the other hand, by the reason of being the most widely used synthetic fiber type, polyester microfilament knitted fabric is frequently utilised in a wide range of knitwear applications, including sportswear and underwear. For next-to-skin end uses, comfort is the foremost property in purchasing. In the literature, there are some studies which deal with the performance properties of microfibre knitted fabrics. Some of them [9 - 12] focused on the performance properties of knitted fabrics produced from staple type microfibres. On the other hand, a limited number of studies revealed the performance and comfort properties of knitted fabrics produced from microfilament yarns. It is seen that microfilament polyester fabric has higher water transportability, water absorbency, water holding capacity and lower drying

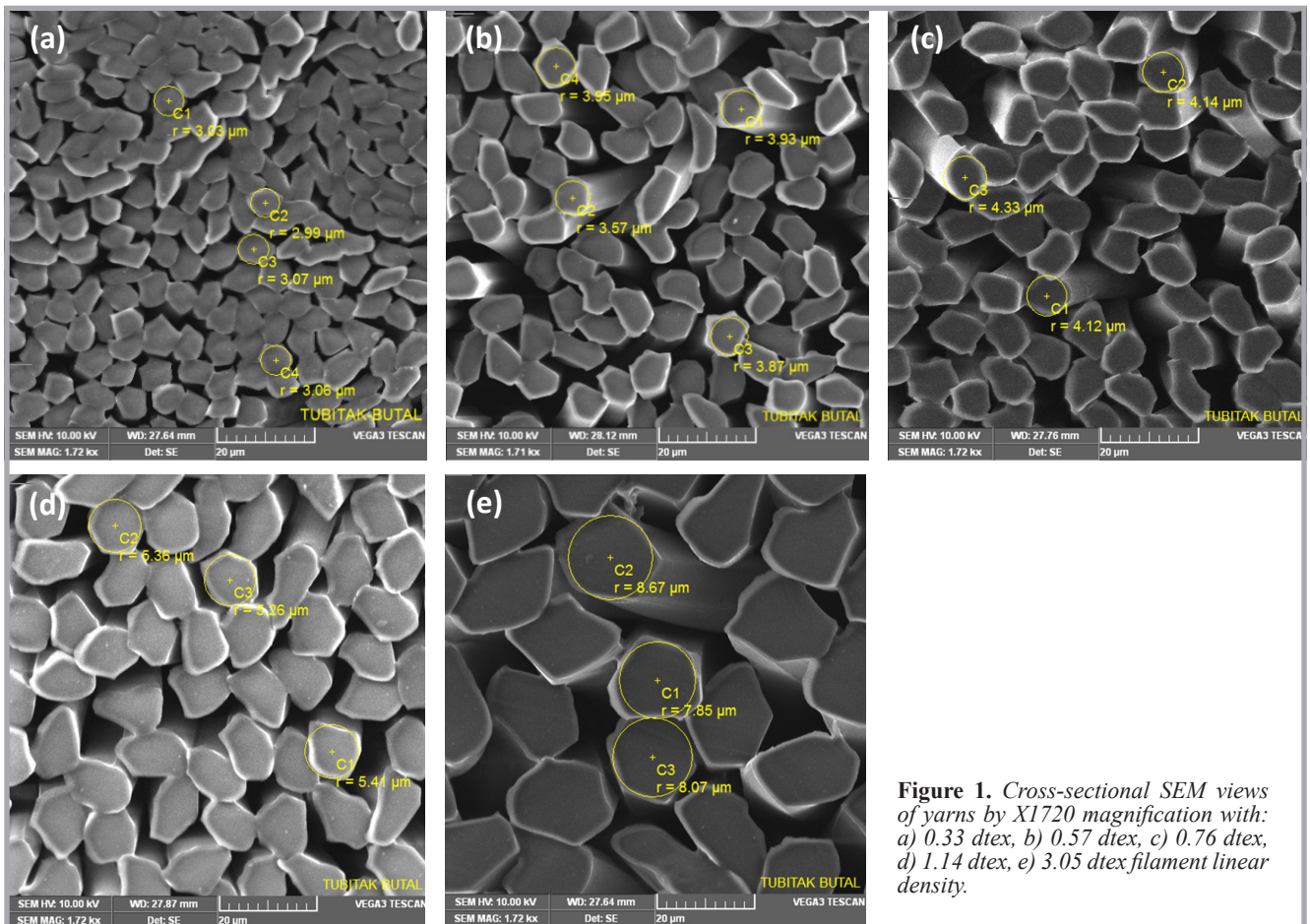
time than conventional filament polyester fabric [13, 14]. In the case of thermal comfort and water vapour permeability properties, some studies revealed contrary results to each other [14 - 16]. On the other hand, with respect to spirality, bursting strength, abrasion resistance and pilling resistance, consistent results cannot be obtained in the literature [13, 17]. Apart from these studies, the present one investigates the comfort related properties of polyester filament knitted fabrics on the basis of filament linear densities. For this aim, the dynamic liquid moisture management property, air permeability, water vapour permeability and thermal conductivity properties of the fabrics were tested.

## Materials and methods

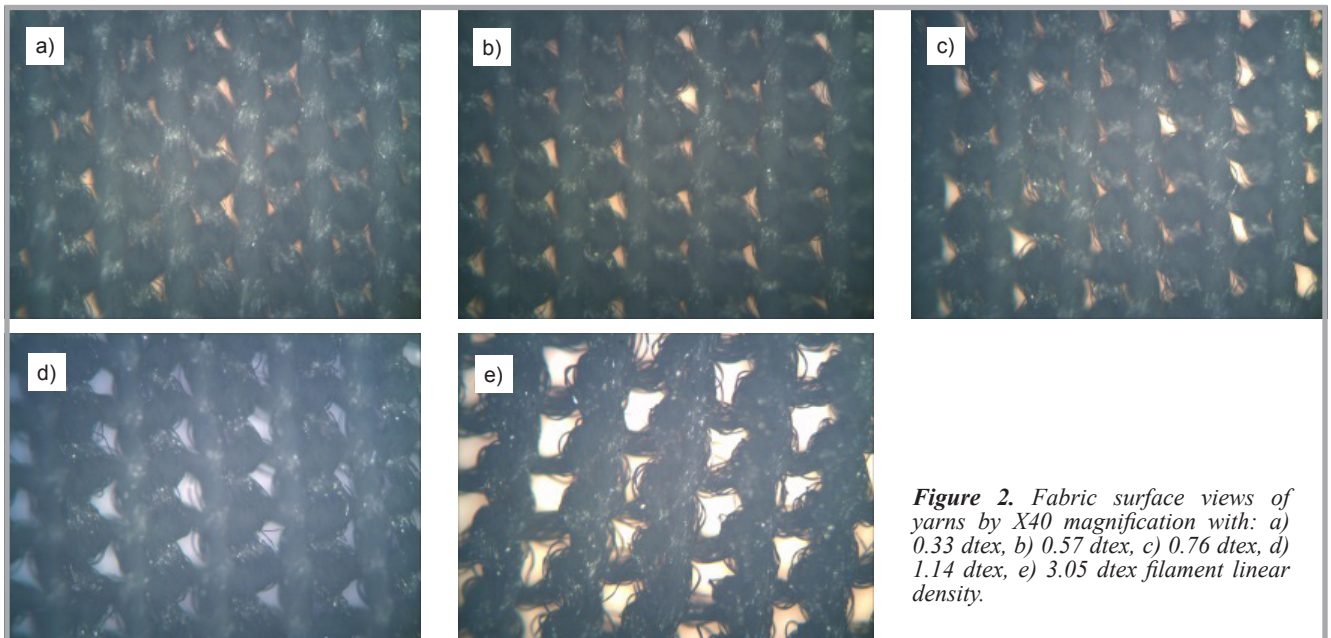
In this study, microfilament polyester textured yarns of 110 dtex with 0.33 dtex, 0.57 dtex and 0.76 dtex filament linear densities and conventional polyester textured yarns of 110 dtex with 1.14 dtex and 3.05 dtex filament linear densities were used in order to investigate the effects of filament linear density on the comfort related properties of microfilament knitted fabrics. In doing so, we examined the effect of filament fineness for both micro and conventional linear densities. Cross-sectional SEM (Scanning Electron Microscopy) views of the yarns at the same magnification are seen in **Figure 1** (see page 90).

The sample yarns were knitted in a single jersey structure by a 3.5" gauge and 22 fein sample circular knitting machine with one feeder at a  $20 \pm 2$  rev/min production speed and same machine settings. Surface views of the fabrics at 40 times magnification are seen in **Figure 2** (see page 90).

It is seen from **Figure 2** that the sample fabrics have different structural views despite being knitted with the same production parameters. This is a probable result of different bulkiness properties of the sample yarns, which have different filament linear densities. All fabric samples were conditioned according to ISO 139 before the tests, performed in a standard atmosphere of  $20 \pm 2$  °C and  $65 \pm 4\%$  humidity. Fabric thickness, fabric surface mass, the number of stitches per unit length and stitch length properties of the sample fabrics were determined according to ISO 5084: 1996, TS EN 12127: 1999, TS EN 14971: 2006 and TS EN 14970: 2006 [18 - 21], respectively. Fabric structural properties are given in **Table 1** (see page 91). It is seen from **Table 1** that the loop length is same for all samples because of the same production parameters, whereas the other structural parameters are different among samples, because sample yarns behave differently from each other due to having different filament linear densities in the yarn cross section. The samples of yarns with coarser filaments exhibit higher contraction in the fabric structure, causing a lower num-



**Figure 1.** Cross-sectional SEM views of yarns by X1720 magnification with: a) 0.33 dtex, b) 0.57 dtex, c) 0.76 dtex, d) 1.14 dtex, e) 3.05 dtex filament linear density.



**Figure 2.** Fabric surface views of yarns by X40 magnification with: a) 0.33 dtex, b) 0.57 dtex, c) 0.76 dtex, d) 1.14 dtex, e) 3.05 dtex filament linear density.

ber of stitches per unit length and fabric surface mass.

Liquid moisture management properties were determined by an SDL Atlas MMT (Moisture Management Tester) test device according to AATCC 195: 2010 Liquid moisture management properties

of textile fabrics [22]. Air permeability properties of the fabrics were tested by SDL Atlas Digital air permeability tester according to ISO 9237:1995 Determination of the permeability of fabrics to air [23]. A 20 cm<sup>2</sup> test area was used and a 100 Pa air pressure applied during the test. Thermal resistance and thermal

absorptivity properties of the sample fabrics were determined by an Alambeta Test Device. Water vapour permeability properties were tested by a Permetest Test Device. In order to understand the statistical importance of filament linear density for fabric comfort related properties, ANOVA was performed. For this

aim the statistical software package SPSS 17.0 was used to interpret the experimental data. All test results were assessed at a 95% confidence interval.

## Results and discussion

In this experimental study, comfort related properties of polyester knitted fabrics such as dynamic liquid moisture management, air permeability, water vapour permeability and thermal conductivity properties were investigated as a function of the filament linear density of the component yarn.

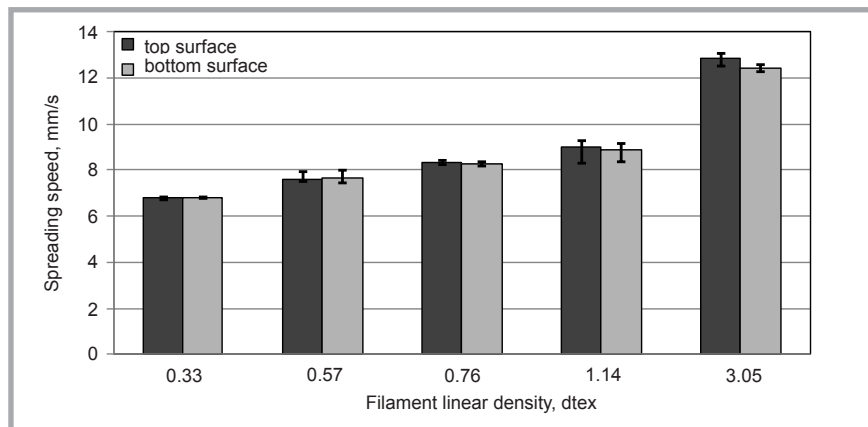
### Dynamic liquid moisture management

Perspiration plays an important role in the cooling mechanism of the human body and occurs in two ways: insensible perspiration and sensible perspiration (sweating). For human comfort, to eliminate dampness, clinginess and stickiness, it is crucial to realise the fabric behaviour during liquid contact. Consequently transferring liquid moisture from the surface of the skin to the atmosphere is the foremost comfort property for next-to-skin use. There are many test methods to evaluate the liquid contact behaviors of fabrics such as wetting, wicking, liquid absorption and liquid strike through. Two important phenomena occur simultaneously during contact between liquid moisture and fabric for transferring the liquid moisture from the surface of the skin to the atmosphere: firstly in the plane transfer of liquid moisture, and secondly through plane transfer of liquid moisture. The MMT device measures different properties for dynamic liquid moisture management. In this study, we decided to consider the in-plane transfer of liquid moisture, termed 'the spreading speed', and through plane transfer of liquid moisture, termed 'one way transport capability', by means of an MMT device. The spreading speed and one way transport capability results of the MMT test device are seen in *Figures 3* and *4*, respectively.

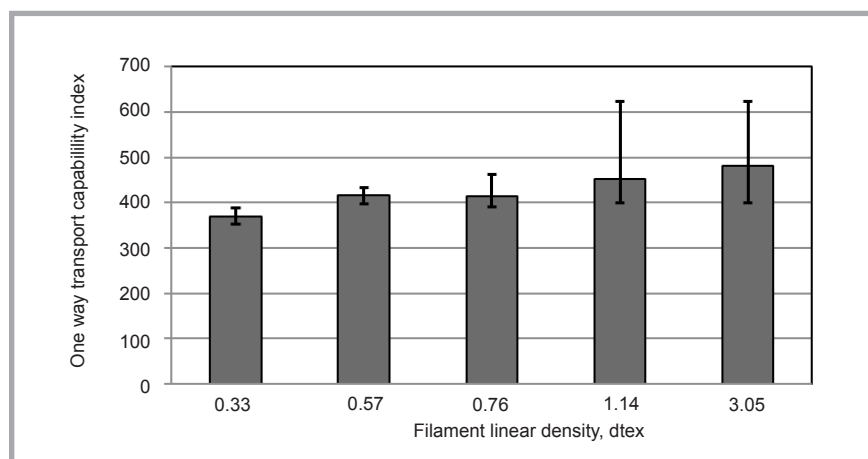
The MMT test device measures the spreading speed of liquid moisture on the top and bottom surfaces. *Figure 3* exhibits the bottom and top spreading speed properties of the samples. According to the MMT device's grading scales, all samples have a "very fast" spreading speed. In spite of this grading, it is seen from *Figure 3* that the spreading speed of liquid moisture increases by rais-

**Table 1.** Structural properties of samples.

Samples	Properties				
	Fabric thickness, mm	Mass per square meter, g/m <sup>2</sup>	Loop length, mm	Number of wales per cm	Number of courses per cm
0.33 dtex	0.50	111	2.9	16	18
0.57 dtex					
0.76 dtex					
1.14 dtex		14			
3.05 dtex				88	16



**Figure 3.** Spreading speed of samples.



**Figure 4.** One way transport capability of samples.

**Table 2.** ANOVA for dynamic liquid moisture management properties.

Top spreading speed		Sum of squares	Degree of freedom	Mean square	F	Significance
	Filament density	linear	76.141	4	19.035	388.707
Within groups		0.881	18	0.049		
Total		77.022	22			
Bottom spreading speed		Sum of squares	Degree of freedom	Mean square	F	Significance
	Filament density	linear	64.754	4	16.189	456.728
Within groups		0.638	18	0.035		
Total		65.392	22			
One way transport capability		Sum of squares	Degree of freedom	Mean square	F	Significance
	Filament density	linear	28403.929	4	7100.982	2.766
Within groups		46206.372	18	2567.021		
Total		74610.301	22			



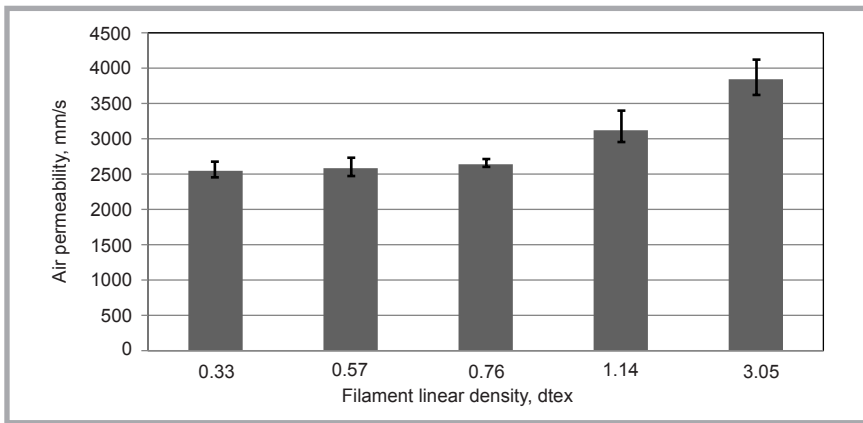


Figure 5. Air permeability of samples.

Table 3. ANOVA for air permeability

	Sum of squares	Degree of freedom	Mean square	F	Significance
Filament linear density	1.195×10 <sup>7</sup>	4	2988694.614	209.004	0.000
Within groups	600587.500	42	14299.702		
Total	1.256×10 <sup>7</sup>	46			

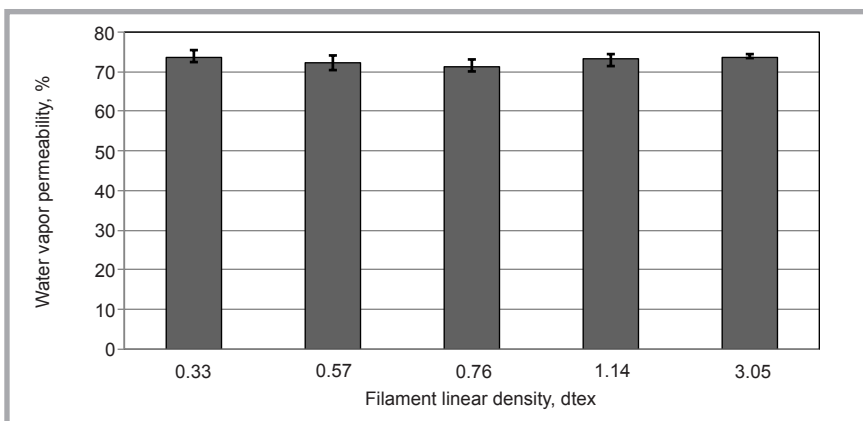


Figure 6. Water vapour permeability of samples.

Table 4. ANOVA for water vapour permeability.

	Sum of squares	Degree of freedom	Mean square	F	Significance
Filament linear density	19.128	4	4.782	2.681	0.083
Within groups	21.402	12	1.783		
Total	40.529	16			

ing the filament linear density for both the top and bottom surfaces. Especially for the 3.05 dtex sample, both the top and bottom spreading speed values are considerably higher than those of other samples. As seen from Figure 1, yarns with finer filaments have a high number of micro pores between the filaments. On the other hand, if Figure 2 is observed, it is seen that fabrics with finer filaments have a bulky and compact structure of small macro pores between the yarns. Especially the 3.05 dtex sample has

a lower number of loops in the unit area and also considerably larger macro pores between the yarns than other samples. Rapid in plane transfer of the liquid for samples which have coarser filaments can be explained by large macro pores, because during liquid contact the macro pores are responsible for the rapid diffusion of liquid. In a short time duration, the macro pores absorb liquid rapidly [24] and the measurement duration of the MMT device is 120 seconds, whereas in a long time duration, the mi-

cro channels are responsible for reaching the maximum height with a slow diffusion rate [24, 25]. Consequently our samples with coarser filaments, which have large macro pores, have higher in plane transfer capability of liquid moisture. In other words, fabrics with coarser filaments transfer liquid moisture through the fabric surface more rapidly. According to statistical analysis, filament linear density has a significant effect on both the top ( $p < 0.000$ ) and bottom ( $p < 0.000$ ) spreading speed properties at a 95% confidence interval.

The one way transport capability property denotes the ability of the fabric to transfer liquid moisture from one side of the fabric to the other. In other words, a higher one way transport capability means that sweat can be easily and quickly transferred from the skin to the outer surface of the garment to keep the skin dry.

As exhibited in Figure 4, the one way transport capability is higher for coarser filaments. The samples, except 0.33 dtex filament linear density, have “excellent” one way transport capability according to the MMT grading scale, while the 0.33 dtex sample has a lower grading of “very good” according to the MMT scale. But the difference among the samples is not so obvious. There is a slight increase in one way transport capability as the filaments get coarser. This situation is a result of having larger macro pores for fabrics produced with coarser filaments. Furthermore the effect of filament linear density on the one way transport capability is not significant ( $p = 0.059$ ) statistically, as seen in Table 2. One way transport capability and the spreading speed are increased with higher filament linear density values. High one way transport capability and spreading speed means a high capability of transferring the liquid through the fabric [26, 27]. As a consequence of test results, it can be concluded that fabrics with coarser filaments tend to keep the skin dry more than those of finer ones.

### Air permeability

Air permeability is often used in evaluating and comparing the comfort property of fabrics. The influence of filament linear density on air permeability is evident from Figure 5. Air permeability values are increased with coarser filaments, as seen in earlier studies [17, 28]. In the case of microfilament linear density (0.33, 0.57 and 0.76 dtex), air permeability values of samples are close to each other. In regard to conventional filament

linear density (1.14 and 3.05 dtex), air permeability is considerably increased with 3.05 dtex filament linear density. As seen from **Figure 1**, yarns with coarser filaments have large pores between the filaments than finer ones. In addition, **Figure 2** exhibits the inter yarn porosity of fabrics, where larger inter yarn porosity is seen for fabrics with 1.14 dtex and 3.05 dtex filament linear density. Air passes through the larger pores more easily than those of smaller pores due to the strong relation between air permeability and porosity in knitted fabrics [29]. As the filament linear density decreases, the number of filaments in the yarn cross sections increases. Thus the specific surface area of filaments increases. This situation causes a higher drag resistance to air flow through the fabric. Consequently air permeability decreases with finer filaments. Samples of microfilament linear density values of 0.33, 0.57 and 0.76 dtex have close and low air permeability values, whereas those of conventional filament linear density of 1.14 and 3.05 dtex have higher air permeability values. Also the statistical analysis exhibited in **Table 3** indicates the significant effect of filament linear density on air permeability ( $p < 0.000$ ).

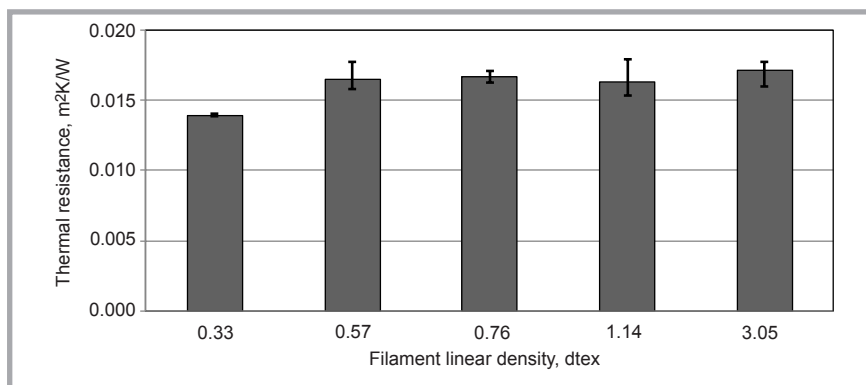
### Water vapour permeability

Water vapour permeability is an important property that indicates the fabric transfer capability of water vapour from the inner to outer side of the fabric. If sufficient water vapour transfer does not exist, the wearer feels uncomfortable due to the high temperature of the microclimate inside the fabric as well as dampness as a result of condensation. The water vapour permeability test results are given in **Figure 6**.

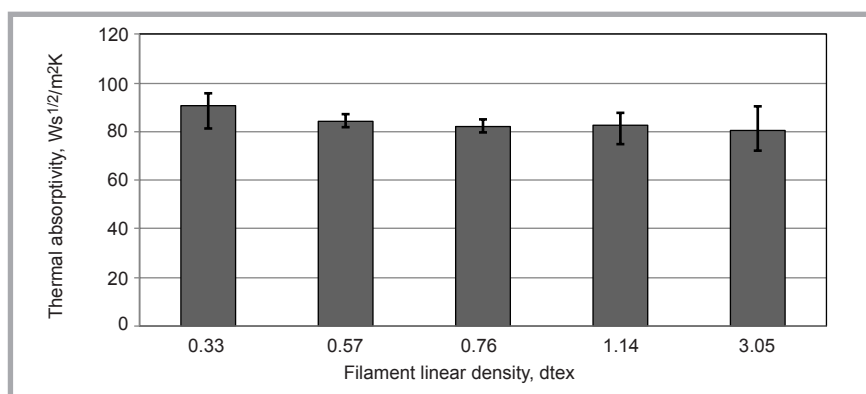
As seen from **Figure 6**, the sample fabrics exhibited similar levels of water vapour permeability. In addition, according to the statistical analysis in **Table 4**, there is an insignificant effect of filament linear density on water vapour permeability ( $p = 0.083$ ).

### Thermal resistance and thermal absorptivity

The thermal properties of a garment are important to determine its suitability for use in different environmental conditions. For this assessment, the protection capability of the garment from environmental thermal conditions is of prime importance. This property can be identified from the thermal resistance. In addition,



**Figure 7.** Thermal resistance of samples.



**Figure 8.** Thermal absorptivity of samples.

**Table 5.** ANOVA for thermal properties.

Thermal resistance		Sum of squares	Degree of freedom	Mean square	F	Significance
	Filament linear density	0.000	4	0.000	4.232	0.034
	Within groups	0.000	9	0.000		
	Total	0.000	13			
Thermal absorptivity		Sum of squares	Degree of freedom	Mean square	F	Significance
	Filament linear density	230.368	4	57.596	1.227	0.365
	Within groups	422.366	9	46.930		
	Total	652.751	13			

tion, the feeling of warm or cool sensed by the wearer is also an important thermal comfort descriptor for next-to-skin use. The measurement of this sense is explained by thermal absorptivity. Thermal resistance and thermal absorptivity properties of the samples are illustrated in **Figures 7** and **8**, respectively.

In **Figure 7**, the lower thermal resistance of the 0.33 dtex sample than those of other filament linear densities is obvious, as the other samples show higher thermal resistance values. In addition, for the samples, except that of 0.33 dtex filament linear density, there is a slight increase in thermal resistance as the filaments get coarser, which is a probable

result of the increase in the total pore dimension for coarser filaments, because air is held in the inter fibre and inter yarn pores, and the thermal conductivity of air is lower than that of textile fibres. As a consequence, fabrics which have more pores in the structure, where more air is held, have higher thermal resistance [28, 30 - 32]. The increase in the pores is particularly evident from **Figure 1**, which deals with inter fibre pore dimensions, and **Figure 2**, which deals with inter yarn pore dimensions. This means that finer filaments have worse protection capability for the wearer against environmental conditions. Besides this, the effect of filament linear density on ther-

mal resistance is statistically significant ( $p = 0.034$ ), as seen in **Table 5**.

In the case of the thermal absorptivity of the sample fabrics, which are exhibited in **Figure 8**, it is seen that there is a minor decrease in thermal absorptivity due to the increase in filament linear density. The surface character of the fabric greatly influences this sensation. A rough fabric surface reduces the area of contact appreciably, and a smoother surface increases the area of contact and heat flow, thereby creating a cooler feeling [28, 30]. It is a well-known fact that fabrics produced from microfilaments have a soft touch and smooth surface, which is a probable reason for the higher thermal absorptivity or cool feeling of microfilament fabrics. On the other hand, filament linear density has no significant effect on the warm-cool feeling of these fabrics according to statistical analysis ( $p = 0.365$ ).

## Conclusions

In this study, we intended to investigate the effect of filament linear density on the comfort related properties of polyester filament knitted fabrics. According to experimental results, a noteworthy effect of filament linear density is observed on dynamic liquid moisture management properties. Rapid in plane and through plane transfer of liquid is observed for samples which have coarser filaments. Especially 3.05 dtex filament linear density samples exhibit considerably different liquid transfer values. This situation may be attributed to the fact that the macro pores absorb liquid rapidly in a short time duration [24, 25]. Lower air permeability values are obtained for samples with microfilament linear density values, whereas those with conventional filament linear density have higher air permeability. In the case of water vapour permeability, there is no considerable effect of filament linear density on the water vapour permeability of the samples. With respect to thermal properties, the sample which has the lowest filament linear density of 0.33 dtex has the lowest thermal resistance. The other samples which have coarser filaments in the fabric structure have similar and also higher thermal resistance values than the 0.33 dtex sample. In the case of thermal absorptivity, the 0.33 dtex sample differs from others with a higher value. Besides, for the rest of the samples, there is a slight increase in thermal absorptivity with a decrease in filament linear density by the reason of the soft touch and smooth surface.

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## References

1. Leadbetter P, Dervan S. The micro-fiber step change. *Journal of the Society of Dyers and Colourists* 1992; 108: 369–371.
2. Bianchi R, Maglione R. Manufacturing of fine denier filaments. In: Brunnschweiler D, Hearle J. (eds) *Polyester: 50 Years of Achievement, Tomorrow's Ideas and Profits*. England: Dewsbury, 1993, p. 196-198.
3. Purane SV, Panigrahi NR. Microfibers, microfilaments and their applications. *AUTEX Research Journal* 2007; 7: 148-158.
4. Basu A. Microfibers: Properties, processing and use. *Asian Textile Journal* 2001; 10: 43-52.
5. Mukhopadhyay S. Microfibers – An Overview. *Indian Journal of Fibre and Textile Research* 2002; 27: 307-314.
6. Falkai BV. Production and properties of microfibers and microfilaments. *The Indian Textile Journal* 1991; 2: 62-70.
7. Rupp J, Yonenaga A. Microfibers-The new man made fiber image. *International Textile Bulletin* 2000; 4: 12-24.
8. Kaynak HK, Babaarslan O. Polyester microfilament woven fabrics: In: Han-Yong Jeon (Ed) *Woven Fabrics*. Croatia, 2012, p. 155-178.
9. Srinivasan J, Ramakrishnan G. Study on high performance viscose micro fibres knitted fabrics. *Asian Textile Journal* 2004; 13: 78-80.
10. Ramakrishnan G, Dhurai B, Mukhopadhyay S. An investigation into the properties of knitted fabrics made from viscose microfibers. *Journal of Textile and Apparel Technology and Management* 2009; 6: 1-9.
11. Gün Demiröz A. Dimensional, Physical and Thermal Properties of Plain Knitted Fabrics Made from 50/50 blend of Modal Viscose Fiber in Microfiber Form with Cotton Fiber. *Fibres and Polymers* 2011; 12: 1083-1090.
12. Gün Demiröz A. Dimensional, Physical and Thermal Properties of Plain Knitted Fabrics Made from Modal Viscose Yarns Having Microfibers and Conventional Fibers. *Fibres and Polymers* 2011; 12: 258-267.
13. Srinivasan J, Ramakrishnan G, Mukhopadhyay S, Manoharan S. A study of knitted fabrics from polyester microdenier fibres. *Journal of the Textile Institute* 2007; 98: 31-35.
14. Jun Y, Kang YK, Park C, Choi C. Evaluation of textile performance of soccer wear. *Textile Asia* 2002; 33: 43–44.
15. Nahla Abd El-Mohsen HA, Ghada Abd Alla EK. Effect of Number of Fibers per Yarn Cross-section on Moisture Vapour

Transport in Knitted Garment. *Journal of American Science* 2012; 8: 370-378.

16. Sampath MB, Senthilkumar M, Nalankilli G. Effect of Filament Fineness on Comfort Characteristics of Moisture Management Finished Polyester Knitted Fabrics. *Journal of Industrial Textiles* 2011; 41: 160–173.
17. Kaynak HK, Babaarslan O. Investigation of the Effects of Filament Fineness on the Performance Properties of Microfiber Knitted Sportswear Fabrics. In: *IV International Technical Textiles Congress*, Istanbul, Turkey, 2010.
18. ISO 5084: 1996. Determination of thickness of textiles and textile products.
19. TS EN 12127: 1999. Determination of mass per unit area using small samples.
20. TS EN 14971: 2006. Determination of number of stitches per unit length and unit area.
21. TS EN 14970: 2006. Determination of stitch length and yarn linear density in weft knitted fabrics
22. AATCC Test Method 195-2010 Liquid Moisture Management Properties of Textile Fabrics
23. ISO 9237:1995 Textiles -- Determination of the permeability of fabrics to air
24. Benltoufa S, Fayala F, Nasrallah SB. Capillary Rise in Macro and Micro Pores of Jersey Knitting Structure. *Journal of Engineered Fibers and Fabrics* 2008; 3: 47-54.
25. Birrfelder P, Dorrestijn M, Roth C, Rossi RM. Effect of fiber count and knit structure on intra- and inter-yarn transport of liquid water. *Textile Research Journal* 2013; 83: 1477-1488.
26. Hu J, Li Y, Yeung K, Wong ASW, Xu W. Moisture Management Tester: A Method to Characterize Fabric Liquid Moisture Management Properties. *Textile Research Journal* 2005; 75: 57–62.
27. Yao B, Li Y, Hu J, Kwok Y, Yeung K. An improved test method for characterizing the dynamic liquid moisture transfer in porous polymeric materials. *Polymer Testing* 2006; 25: 677-689.
28. Özçelik G, Çay A, Kirtay E. A Study of the Thermal Properties of Textured Knitted Fabrics. *Fibres & Textiles in Eastern Europe* 2007; 15: 55-58.
29. Oğulata RT, Mavruz S. Investigation of Porosity and Air Permeability Values of Plain Knitted Fabrics. *Fibres & Textiles in Eastern Europe* 2010; 18: 71-75.
30. Das BR, Bhattacharjee D, Kumar K, Srivastava A. Thermo-physiological Comfort Characteristics of Fine-denier Polypropylene Fabrics. *Research Journal of Textile and Apparel* 2013; 17: 133-140.
31. Uçar N, Yılmaz T. Thermal Properties of 1×1, 2×2, 3×3 Rib Knit Fabrics. *Fibres & Textiles in Eastern Europe* 2004; 12: 34-38.
32. Marmarali A, Dönmez Kretschmar S, Özdil N, Gülsevin Oğlakcioğlu N. Parameters That Affect Thermal Comfort of Garment. *Tekstil ve Konfeksiyon* 2006; 4: 241-246.

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