

Enhancing the functional properties of weft knitted fabrics made from polyester microfibers for apparel use

R. A. M. Abd El-Hady

A. Prof., Spinning, weaving & knitting Dept., Faculty of Applied Arts, Helwan University, Egypt

Abstract

The aim of this research is to compare the properties of weft knitted fabrics made out of micro denier (< 1 denier) and normal denier (> 1 denier) polyester yarns and to investigate the functional properties of such fabrics to explore the use of microfibers to achieve enhanced levels of comfort for apparel use. Different knitted structures of identical parameters were produced from normal and micro denier polyester fibers. Samples were produced according to an experimental matrix containing technological variables considered significant. The fabrics were tested for functional properties, and the values were compared and discussed. Conclusions regarding the functional properties of weft knitted fabrics are drawn based on the experimental data.

Keywords:

knitted fabrics, Micro denier, Comfort, Functional Properties.

1. Introduction

Synthetic fiber industry has been enforced to make developments due to the increasing performance demand for textile products. One of the most important developments in synthetic fiber industry is absolutely producing extremely fine fibers which are named as microfibers and nanofibers (Kaynak & Babaarslan, 2011). Until today, there is no exact definition for microfibers. But common opinion is defining a fiber finer than 1 dtex or 1 denier as microfiber (Leadbetter & Dervan, 1992; Bianchi & Maglione, 1993; Purane & Panigrahi, 2007; Basu, 2001; Mukhopadhyay, S., 2002; Falkai, 1991; Rupp & Yonenaga, 2000). 1 dtex polyester fiber has a fiber diameter of approximately 10 μm (Falkai, 1991). On the other hand, nanotechnology refers to the science and engineering concerning materials, structures and devices which at least one of the dimensions is 100 nanometers (0.1 μm) or less (Ramakrishna, et al., 2005).

There are various methods of producing microfibers, including modified conventional spinning. All three conventional spinning methods, namely melt spinning, wet spinning, and dry spinning can be employed to manufacture microfibers. For this method, carefully selected polymerization, polymer spinning and drawing conditions are required (Mukhopadhyay, S., 2002). Polyester, nylon, and acrylic microfibers may be manufactured by this method. The extrusion spinnerets should contain many holes of very fine diameter, each of which will make one uninterrupted filament,

in spite of complex thermal and rheological changes (Taro Murata, 1993).

Due to their softer feel, good drape ability, moisture wicking property, water repellent characteristics, this fabric has become a popular choice for performance apparel, clothing and garments (Jurg Rupp, Akira Yonenaga, 2000). They are widely used for making rain wear, sportswear, men suits, kids clothing, inner wears, hosiery, evening wear, outerwear, sheeting, upholstery and many textile accessories. It is fast replacing cotton fabrics in production of these specialty clothing. As microfiber wicks moisture away from the body, it keeps the wearer cool and dry. As such, it has come to occupy an important position in the category of moisture management fabrics (Anonymous, 2000). As this fabric is liquid and stain resistant, it is ideal for office wear even in rainy season.

When blended with other fabrics like nylon fabric and polyester fabric, it results into hybrid cloth having a very superior quality. Comfort properties of polyester microfiber fabric are much better in terms of wicking when compared with polyester micro/cotton blends and pure polyester non-micro fiber fabrics (Anjali Karolia, 2005). Better wicking is found in samples having greater proportion of polypropylene and they also dry fast. Maximum water vapor permeability and air permeability is seen on fabrics having polypropylene on both faces of fabrics (BK. Behara, MP Mani et'al, 2002).

Micro denier fibers have excellent flexibility and yarns with better regularity and elongation

contribute for perfect knit ability ensuring knitted fabrics with better softness, drape, stability and wicking than normal denier fiber knitted fabrics thus ensuring excellent mechanical and comfort properties (R.Chattopadhyay, 1997). The hairiness of the microfiber yarns are very low and this in turn creates a low lint shedding propensity and it will generate lesser fly during knitting. These two aspects of lint shedding and fiber fly are very crucial for the improved efficiency of the knitting machine (Anon, 2001).

A knitted structure consists of interlacing loops and properties of these fabrics depending on the relationships and production methods of these loops. In particular, a weft knitted structure differs from both woven and warp knitted fabrics (D. J. Spencer, 2001). Therefore investigating the characteristics of weft knitted fabrics by structure is useful when designing fabrics for end use. In this research, the effect of structural parameters of weft knitted fabrics and the type of the consumed yarns on the functional properties of produced fabrics was studied. The influences of physical properties of micro denier fiber and processing parameters have been carefully highlighted.

2. Experimental work

This research studied the possibility to take advantage of the polyester fibers produced with microfiber technology in the production of apparel. This is done using the microfiber yarns in different weft knitted structures. In this research six samples of yarns were produced,

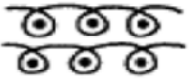
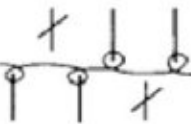
including three samples of microfiber with various yarn count; (75 \ 72), (100 \ 96), (150 \ 144) and three counts from their equivalents but with normal denier: (75 \ 36), (100 \ 36), (150 \ 48). Table (1) shows the specification of the produced yarn samples.

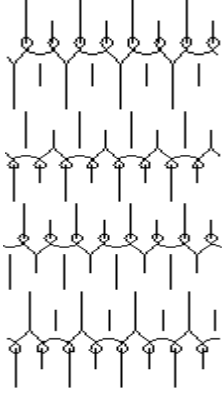
Table 1 The Specification Of The Produced Yarn Samples

No.	Yarn Type	Yarn Count Denier	Fiber Count dtex/f	Number of Fibers in the Cross-Section of the Yarn
1	100% Polyester	75	4.3	36
2		100	2.7	36
3	Multi-Filament	150	5.2	48
4	100% Polyester	75	0.9	72
5		100	0.92	96
6	Microfibers	150	0.94	144

Six samples in different weft knitted structures (Jersey, Rip 2*2, and Pique Rib) were produced in circular weft knitting machine " Diameter 30", Gauge 28", according to the research plan to determine the best specification. Table (2) shows the specification of the produced fabrics samples.

Table 2 The Specification Of The Produced Fabrics Samples

No.	Yarn Count Denier Type	Fabric Structure	Fabric Thickness mm	Fabric Weight gm/m ²
1	150 \ 144 100% Polyester Microfibers	Jersey	0.6	110
2	150 \ 48 100% Polyester Continues Multi- Filament		0.0.62	116
3	150 \ 144 100% Polyester Microfibers	Rib 2*2	0.85	135
4	150 \ 48 100% Polyester Continues Multi- Filament		0.89	142
5	150 \ 144 100% Polyester Microfibers	Pique Rib	0.92	146

6	150 \ 48 100% Polyester Continues Multi- Filament		0.95	152
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Several tests were carried out in order to evaluate the functional properties of produces fabrics, these tests include mechanical and physical properties tests.

1. Tensile and Elongation Test

This test was carried out for all yarns samples, according to the ASTM D2256 / D2256M - 10e1.

2. Linear Density of Fibers Test

This test was carried out for all yarns samples, according to the ASTM D861 - 07(2013).

3. Thickness Test

The thickness samples were measured by the Teclock tester under a pressure 0.2 kg f/cm2 according to the ASTM D1777-96 (2011) e1.

4. Weight Test

This test was carried out by using Mettler H 30 apparatus according to the ASTM ASTM D3776-09ae2.

5. Bursting Strength Test

This test was carried out for all samples by using the strip method according to the ASTM D3786-13.

6. Air Permeability Test

This test was carried out for all samples, according to the ASTM D737-04(2012).

7. Water Absorption Test

This test was carried out for all samples, according to the ASTM D570 - 98(2010)e1.

8. Thermal Resistance Test

This test was carried out for all samples, according to the ASTM D1518 - 11a.

3. Results and Discussion

3.1. Yarn Tests Results

The yarn tests results, as shown in Figures (1) and (2), indicate the superiority of microfiber yarn in terms of the tensile strength and elongation properties.

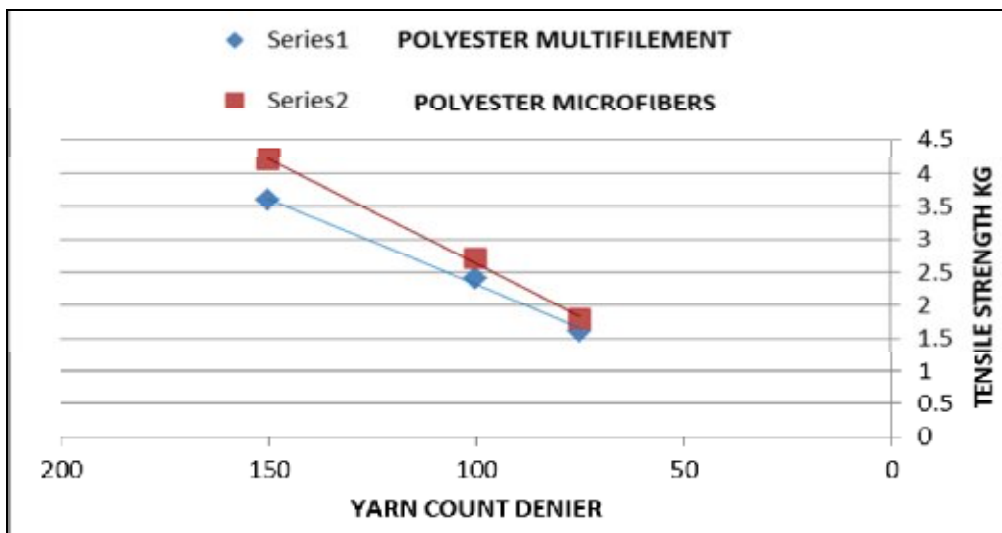


Figure 1 The Effect of Yarn Count (Denier) on Tensile Strength Values (Kg) for Experimental Yarn Samples

It is observed that, as shown in Figure (1), there is a direct relation between the yarn count (denier) and its tensile strength values. As the

yarn count (denier) increases, the tensile strength values increase in produced yarn samples.

To get a mathematical relationship between the yarn counts (denier) in the polyester multifilament yarn samples on tensile strength values (Kg), a linear regression technique was used to get this relationship. The following equation is applied on the (Kg) values:

$$y = 0.0263 x - 0.3143 \quad (1)$$

Where:

- y tensile strength values (Kg).
- x yarn count (denier).

As $R=0.994$, the correlation is considered too high which means that the regression equation is reliable for prediction of the tensile strength

values (Kg) in the yarn count (denier) range using polyester multifilament yarn samples.

To get a mathematical relationship between the yarn counts (denier) in the polyester microfibrils yarn samples on tensile strength values (Kg), a linear regression technique was used to get this relationship. The following equation is applied on the (Kg) values:

$$y = 0.0317 x - 0.5357 \quad (2)$$

Where:

- y tensile strength values (Kg).
- x yarn count (denier).

As $R=0.9978$, the correlation is considered too high which means that the regression equation is reliable for prediction of the tensile strength values (Kg) in the yarn count (denier) range using polyester microfibrils yarn samples.

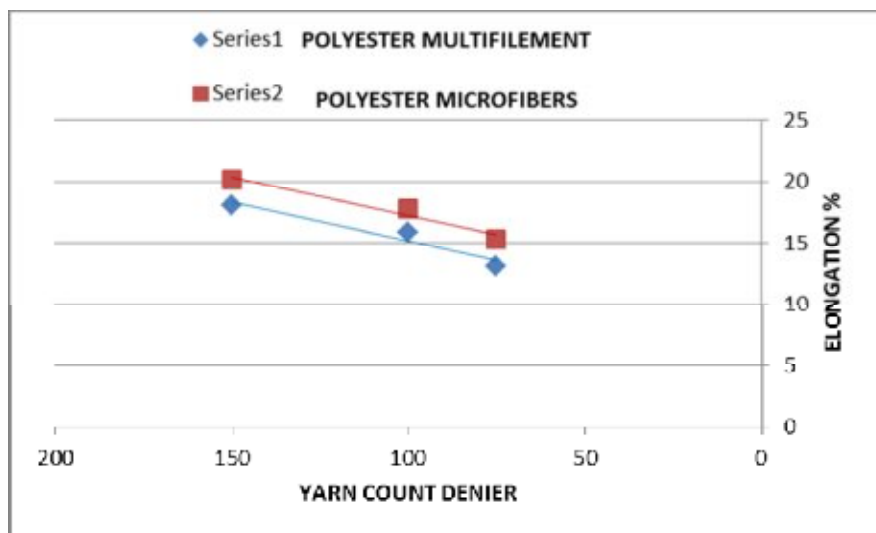


Figure 2 The Effect of Yarn Count (Denier) on Elongation Values (%) for Experimental Yarn Samples

It is observed that, as shown in Figure (2), there is a direct relation between the yarn count (denier) and its elongation values. As the yarn count (denier) increases, the elongation values increase in produced yarn samples.

To get a mathematical relationship between the yarn counts (denier) in the polyester multifilament yarn samples on elongation values (%), a linear regression technique was used to get this relationship. The following equation is applied on the (%) values:

$$y = 0.0627 x + 8.9157 \quad (3)$$

Where:

- y elongation values (%).
- x yarn count (denier).

As $R=0.935$, the correlation is considered too high which means that the regression equation is reliable for prediction of the elongation values

(%) in the yarn count (denier) range using polyester multifilament yarn samples.

To get a mathematical relationship between the yarn counts (denier) in the polyester microfibrils yarn samples on elongation values (%), a linear regression technique was used to get this relationship. The following equation is applied on the (%) values:

$$y = 0.063 x + 10.941 \quad (4)$$

Where:

- y elongation values (%).
- x yarn count (denier).

As $R=0.9593$, the correlation is considered too high which means that the regression equation is reliable for prediction of the elongation values (%) in the yarn count (denier) range using polyester microfibrils yarn samples.

Based on the results obtained in Figures (1), (2) and by applying the statistics regression, signify that:

- Polyester microfibers have better tensile strength and elongation properties when compared to normal denier fiber polyester yarn. Due to the high number of fiber per cross sectional are, many fibers can be packed together very tightly making the yarn has better tensile strength properties. Since bending and torsional stiffness are inversely proportional to fiber diameter, ultrafine fibers are extremely flexible when compared to normal denier fiber polyester yarn.

Yarn count (denier) has a significant effect on tensile strength and elongation values for all tested yarn samples.

3.2. Fabric Tests Results

Since one the main objectives of this research is to study the effect of major factors associated with fabric structure on functional properties of apparel fabrics produced thereof, this is done in order to optimize the microfibers role; different fabric types with various structure parameters were made, as shown in Table (2). Results obtained along with their appropriate discussion are given below.

All fabrics samples were made using yarns with count 150 denier, for both micro denier and normal denier polyester yarns, as they have the best tensile strength and elongation properties according to the yarn tests results.

3.2.1. Bursting Strength

This test was made for all weft knitted samples. Figure (3) shows the bursting strength values (Kg.f/cm²).

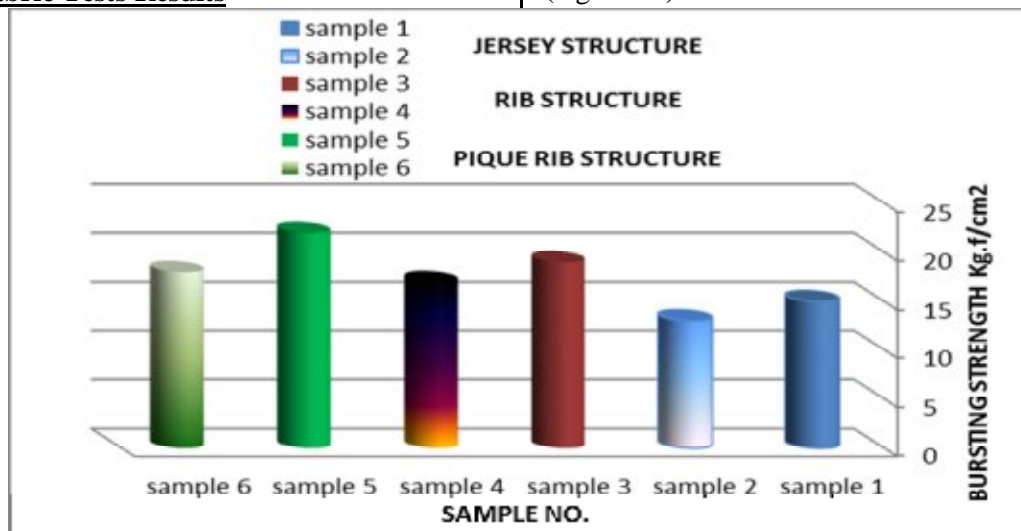


Figure 3 The Bursting Strength Values (Kg.f/cm²) for Experimental Samples

It is observed that, as shown in Figure (3);

- There is difference in the bursting strength values according to the construction of experimental samples. Pique rib structure recorded the best bursting strength values compared to rib 2*2 and jersey structures due to that the rib fabrics which are knitted in two needle series (cylinder/dial in circular in circular knitting machines) have two series of courses in two surfaces. In these kinds of knitted fabrics the loops are connected together in two directions of both courses. Therefore, it seems rib 2*2 fabrics can present better bursting strength properties in comparison with plain ones. Elements of knitted fabrics, which are knit, tuck and miss stitches, demonstrate different structures of

fabric depend on design of fabric. Usually, tuck and miss stitches in pique rib structures cause more stability and less shrinkage in knitted fabric. Miss stitches have no noticeable effect on thickness of fabric while tuck stitches causes increasing thickness, covering factor of fabric and bursting strength properties.

- Microdenier fabrics have comparatively higher bursting strength than normal denier using the same other parameter construction factors. This result due to the fact that more number of fibers can be accommodated in the yarn cross section for the same yarn diameter in case of microdenier yarns there by increasing the basic tenacity of yarn and also partly due to higher stitch density and

tightness factor values in micro denier fabrics.

3.2.2. Air Permeability

This test was made for all samples. Figure (4) shows the air permeability values (cm³/cm²/s).

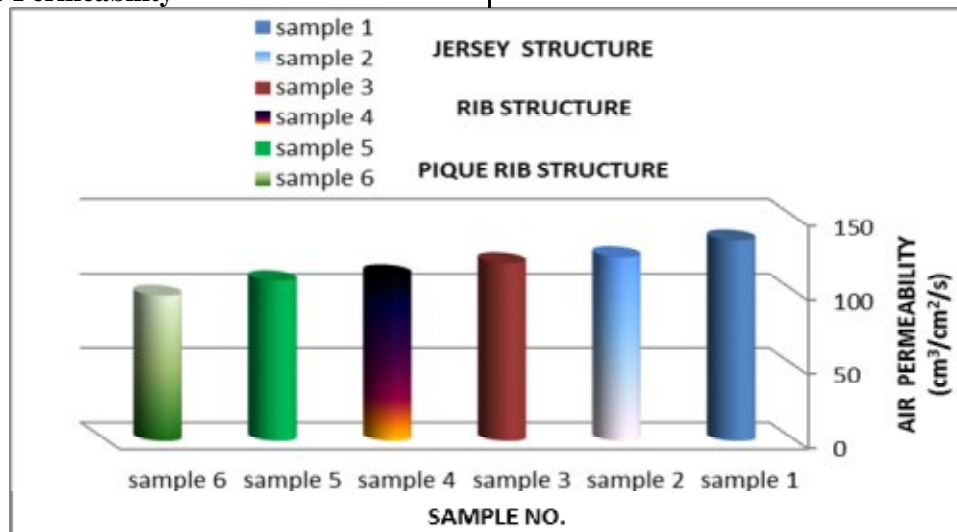


Figure 4 The Air Permeability Values (cm³/cm²/s) for Experimental Samples

It is clear that, as shown in Figure (4);

- There is difference in the air permeability values according to the construction of experimental samples. The results indicate that pique rib structures have the least air permeability value than others jersey and rib structures as noticed in Figure (4). The existence of this decline is most probably a consequence of the thicker structure of pique rib fabrics, where the transportation of air through a thick fabric will be difficult also from rib2*2 structure, the open structure of the jersey fabric gives the ability to the air to pass through fabric without any obstacles due to the lower thickness of the fabric compared to rib2*2 and pique rib structures.
- Microfibers fabrics have comparatively higher air permeability properties than normal denier using the same other parameter construction factors. The yarns made from micro denier fiber contain many more filaments than regular yarns producing fabrics with improved breathability. Airflow through textiles is mainly affected by the pore characteristics of fabrics (Bivainyte & ikucioniene, 2011). As fabric interstices increase in number and size, air permeability increases. In other words as fabric porosity increases, air permeability increases (Collier & Epps, 1999). When comparing two similar fabrics, one made from a conventional polyester fiber and one from a microfiber, generally the microfiber fabric will be more breathable and more comfortable to wear.

Microfibers seem to be less "clammy" in warm weather than conventional synthetics.

3.2.3. Water Absorption

This test was carried out for all samples; Figure (5) shows the water absorption percentage values (%).

$$\text{Water Absorption Percent} = \left[\frac{\text{Wet weight} - \text{Dry weight}}{\text{Dry weight}} \right] \times 100 \quad (5)$$

Water absorption percentage of the fabrics were obtained according to the equation (5) and shown in Figure (5). From this figure, it is cleared that;

- The wick ability rate of pique rib structure makes it to have the highest water absorption amount while the jersey has the least amount in comparison with the other structures. Pique rib can take up the water with higher amount and allow less air passage. These findings indicate that the pique rib clothing for the consumer made of microfibers generated fibers can absorb a lot of sweat, perspiration moves fast from skin to outside and as a result user can feel dry and more comfort Furthermore, pique rib structures demonstrated the highest water up-take capacity and very high initial wicking rate. This performance is most likely due to the structures' capability to act like a capillary system, rapidly removing and transporting water through the structure. As the fabric becomes tighter, it will have high water absorption capability due to the more fiber

material contained and the high fabric thickness accompanied with this fabric specification.

- Since microfibers have an increased surface area, Microfibers are super-absorbent, it can be inferred that wicking values which are better for micro denier fabrics due to better packing coefficient of micro denier spun yarns than that of corresponding normal denier yarns. It is therefore expected that average capillary size would be less in micro denier spun yarns. Low capillary diameter is expected to increase capillary pressure and

drive water faster into the capillaries of yarn. This has resulted in higher wicking height in micro-denier yarns than normal denier yarns at any given time it can be inferred that drops of water on micro denier fabrics, spread quickly than fabrics of normal denier yarns, which is due to higher surface area of microfibers.

2.3.4. Thermal Resistance

This test was carried out for all samples; Figure (6) shows the thermal resistance values (CLO).

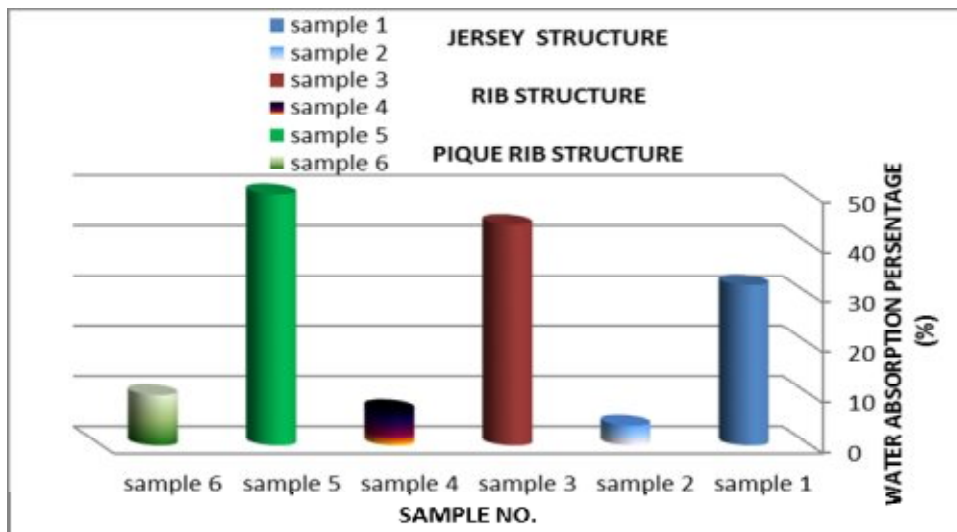


Figure 5 The Water Absorption Percent Values (cm³/cm²/s) for Experimental Samples

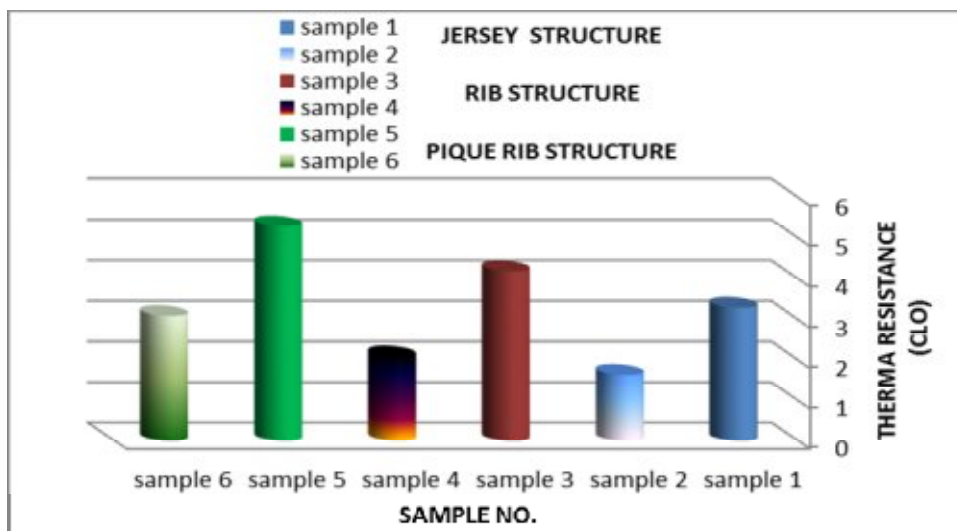


Figure 6 The Thermal Resistance Values (CLO) for Experimental Samples

Thermal resistance expresses the thermal insulation of fabrics and is inversely proportional to thermal conductivity, and is proportional to the fabric structure. It is clear that, as shown in Figure (6);

- Pique rib structures recorded the best thermal insulation properties, this be referred to the extra amount on increase in fabric thickness than the increase in thermal conductivity value. As expected due to the previous

behavior, Pique rib fabrics have higher thermal resistance. The fabrics with the higher thickness have the higher thermal resistance.

- Microfibers are high thermal insulation properties; one caution related to synthetic microfibers is heat sensitivity. Because the fiber strands are so fine, heat penetrates more quickly than with thicker conventional fibers. As a result, microfibers are more heat sensitive and will scorch or glaze if too much heat is applied or if it is applied for too long a period.

4. **Conclusions**

Knitted apparel made from polyester microfibers is getting more and more popular throughout the whole world, this increasing demand is only due to comfort ability and comparatively lower price of these fabrics. Micro denier polyester fabrics have shown superior properties when compared to normal denier polyester fabrics in various aspects of physical, mechanical and comfort properties.

The microfiber fabrics are characterized by acceptable strength, excellent moisture transmission properties such as, wicking rate, and water absorbency. The microfiber knitted fabric is dimensionally more breathable compared to that of normal denier knitted fabric. The superior properties of microfiber fabric can be conveniently utilized to explore and optimize new products for apparel. The fineness of the microfibers produces so dense a fabric structure that the apparel is waterproof but also air and water vapor permeable at the same time. In these end uses, a suitable combination of the fiber assembly structure and the fiber material is important in realizing excellent performance and functional properties.

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