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# Evaluation of the Moisture Management, Air and Water Vapour Permeabilities of Knitted Fabrics for Garments

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## ABSTRACT

*The market today offers a variety of fabrics that may be utilised to create any style of clothing. Fabrics are periodically altered as a result of technology's continual growth, to the point that it became difficult for clothes makers to assess the fabric characteristics related to thermal comfort. This paper reports some investigations on the moisture management and permeability properties of several commercial knitted fabrics intended for garment application. The fabric's ability to manage moisture as well as its air and water vapour permeability were assessed. A fabric rating index was used to combine the results from each test to determine the fabric's thermal comfort characteristics. Among the five knitted fabrics, the fabric comprised of nylon & polyester with jersey structure gave the highest assessment rating which is 5. The study serves as a future reference for future textile and garment industry, that implement the laboratory method used in this paper i.e moisture management, water vapour and air permeability in choosing the better thermal comfort qualities for general wear.*

*Keywords: Garment; Thermal Comfort; Moisture Management; Permeability; Rating Assessment*

## INTRODUCTION

Every garment maker must embrace product comfort as their guiding principle. The comfortability of a garment may impact a customer's decision to purchase a product since it indirectly gauges the garment's aptitude and adaptability to severe and unpredictable environment changes and works as a layer of protection for the consumer against the uncertainties of nature [1]. Comfort is a complicated term that defies a single definition since it encompasses several objectives on a garment, one of which is thermos-physiological comfort. Thermo-physiological comfort is emphasised since it is logically related to other comfort categories (physiological, environmental, sensorial, and tactile) and is often correlated with user comfort [2]. It is also one of the essential factors that interacts and responds naturally with the ambient humidity. Due to the innate thermal resistance of the human body and the mechanisms that maintain thermal homeostasis inside the body, the same degree of comfort cannot be simply measured for any two individuals.

The incomprehensible intricacy of the human body that renders the question of comfort attributes are confusing. For instance, two persons may wear the same fabric type under identical climatic conditions, yet one may declare the clothing is ideal for the environment while the other may disagree [3]. The dynamic interaction can be evaluated by taking a few parameters related to this type of comfort property, such as moisture management, water vapour and air permeability, because thermo-physiological comfort is the evaluation of air, heat, and water in both liquid and vapour form passing through a garment to achieve body thermal equilibrium [2,4]. The choice of fabric material is one of the factors that links all of the evaluations under thermal comfort attributes and influences each parameter's depth overview in order to meet market demand. It is also being said that thermal conductivity by nature is anisotropic, meaning that it is highly dependable to the materials' structure, hence the refinement on fibre structure for synthetic fibre for better moisture are present in the voids trapped inside the fabric [5].

To improve the mechanical and physical qualities of natural fibres, synthetic fibres were developed. It may be either regenerated from existing natural fibres or designed from scratch using chemical compounds to mimic the physical look of natural fibres. The popularity of synthetic fibre has increased dramatically in a variety of sectors, particularly those that employ textiles as important components of their products, such as the garment business, the automobile industry, geotextiles, etc. Synthetic fibres account for 63 percent of the world's textile output, followed by cotton at 24 percent, regenerated cellulosic at 7 percent, and other natural fibres and wool at 5 and 1 percent, respectively [6]. Other than developing new fibres, combining two or more materials either in fibre or yarn form were also implemented in the industry were widely used to enhance certain properties e.g incorporating spandex with other cotton to increase fabrics' recovery and structural stability [7].

This study was conducted to aid textile and garment manufacturers in selecting materials for their goods. This research compares the thermal comfort attributes of commercially available clothing fabrics, establishing a connection between the comfortability of clothing, variables that affect comfort in garments, and material selection.

## EXPERIMENTAL DETAILS

Five commercial knitted fabrics designated for garment making were obtained from a local apparel company, Siti Khadijah Apparel Sdn. Bhd (Table 1). The fibre composition for each fabric resembles current market demand for fabric materials. The fabrics were measured for their weight, density and thickness while fibre solubility tests were performed for fibre identification. All the test sample dimensions and methods were conducted with reference to international standards.

**Table 1: Fibre Composition and Fabric Structure**

| Sample Identification | Composition (%) | Fabric Structure |
|---|---|---|
| A | 100 % Cotton | Jersey |
| B | 90 % Polyester/ 10 % Spandex | Jersey |
| C | 85 % Nylon/ 15 % Polyester | Interlock |
| D | 85 % Nylon/ 15 % Polyester | Jersey |
| E | 87 %Nylon/ 13 % Spandex | Jersey |

## Fabric Thermal Comfort Test

Selected fabric thermal comfort tests and parameter determination were conducted which include moisture management, air permeability, and water vapour permeability. The standard methods that are used to evaluate the thermal comfort properties of commercial fabrics are given in Table 2. The Moisture Management Test was conducted using a tester (MMT), designed to measure the fabric's liquid moisture transport capabilities. As the fabric will be formed into some type of garment, it is fundamental to examine the fabric moisture management property as it affects the sweat droplets permeability through the fabric. In the test, a mixture of distilled water and sodium chloride (to imitate human sweat) was used. The evaluation started as soon as the droplet falls onto the surface of the fabric and the machine sensor will detect the penetration process within 120 s interframe. The fabric was placed at the inner side upwards to imitate sweat from the skin meets the fabric as wearing a garment on a human body.

**Table 2: Standard Method and Equipment for Thermal Comfort Tests**

| Test | Standard Method | Equipment |
|---|---|---|
| Moisture Management | AATCC 195 | MMT® (Moisture Management Tester) M290 |
| Air Permeability | ASTM D737-18 | MESDAN Air-Tronic |
| Water Vapour Permeability | ISO 8096 | SDL Water Vapour Permeability Tester |

The air permeability test was conducted to determine the air flow rate passing through the fabric. The measurement was taken in meter per second (m/s) with fixed air volume and pressure of 10 litres and 100 Pa. The sample area was cut into 20 $cm^2$. This test is relevant as air flow from the body to the environment and vice versa influences the breathability of fabric and affects the comfort feeling on the wearer itself.

As for water vapour permeability, the test measures the fabric's resistance to water vapour penetrations between two distinct faces, under controlled conditions. It is important to examine the water vapour permeability of fabrics used to make clothing since it might impact the comfort of the user. The test consisted of securing the fabric sample between the cover ring and the dish after trimming the sample to the diameter of the dish.

### Analysis Method

The results from each individual test were executed to a ranking scale to act as a standard interpretation for Fabric Ranking Index (FRI) as adapted from Yusuf & Yusuf, 2020 [8]. The FRI was developed to provide better illustration, by calculating the frequency of the total rating as to conclude overall evaluation on which fabric performs better in terms of the tested thermal comfort properties.

## RESULTS AND DISCUSSION

### Fabric physical properties

The physical properties of the selected commercial fabrics are presented in Table 3. Out of all five fabrics evaluated, three are made from nylon blend with either polyester or spandex while other are made of cotton and polyester-spandex blend.

**Table 3: Fabric Physical Properties**

| Sample Identification | Thickness (mm) | Weight ($g/m^2$) | Density (wale x course)/$cm^2$ |
|---|---|---|---|
| A | 0.68 | 210 | 6 x 6 |
| B | 0.56 | 175 | 10 x 6 |
| C | 0.38 | 170 | 4 x 6 |
| D | 0.38 | 150 | 11 x 8 |
| E | 0.40 | 145 | 17 x 9 |

### Moisture Management Test

Figure 1 shows the results of all five samples for Moisture Management Test (MMT) in mean distribution. OMMC or Overall Moisture Management Capacity is one of the parameters from the MMT test that concludes the overall fabric performance toward liquid moisture penetration. It combines three criteria i.e one-way liquid transport ability, maximum spreading speed of the bottom side and moisture absorption rate [9]. The OMMC values were used to construct the graph as this value concludes the other nine indexes (wetting time top, wetting time bottom, top absorption rate, bottom absorption rate, top maximum wetted radius, bottom maximum wetted radius, top spreading speed, bottom spreading speed and accumulative one-way transport index) value given by the MMT, where the value is interpreted from 0 to 1 and grade is given based on Table 4.

**Table 4: Grading Scale for The OMMC Value**

| Index/ grade | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| OMMC | 0-0.19 Very Poor | 0.2-0.39 Poor | 0.4-0.59 Good | 0.6-0.8 Very Good | >0.8 Excellent |

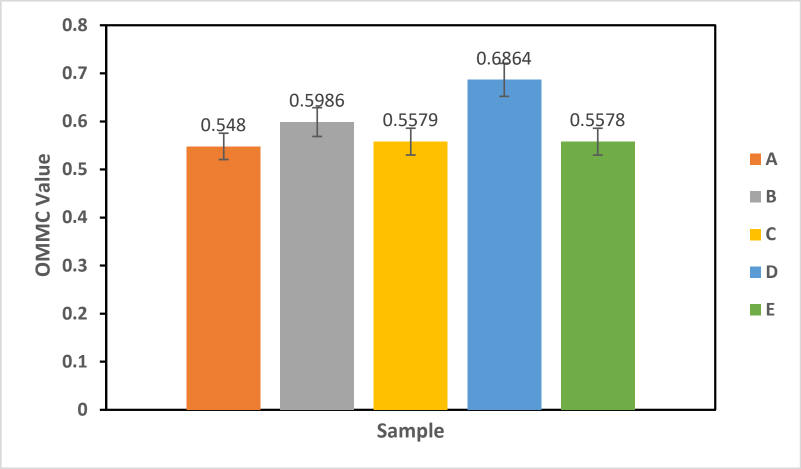


**Figure 1: Mean for OMMC Value of Fabric MMT**

The results show all the values ranged between 0.54~0.68, which can be said the data retrieved falls in between grades 3 and 4. Sample D came out the highest among other 4 samples mainly due to the much lower thickness compared to the others. Although, sample C shared the same thickness value, the difference that affect the MMT value for sample C is the lower fabric weight than sample D having 20g/m$^2$ more than sample C. Furthermore, both sample C and D were affected by differences in fabric structure. Despite sample E for having the lowest weight compared to other samples, this fabric MMT value came out as one of the lowest due to its fabric density. Sample A, B, C and E came out as the poorest out of all five samples as the OMMC value difference between these four samples were insignificant and were supported by error bar shown in Figure 1.

## Air Permeability

The mean average values of air permeability for all five samples are shown in Figure 2. Sample D showed the highest air permeability reading among all samples which was 840.3 mm/s. This was expected, as this sample also has the lowest thickness value which is 0.38 mm. Although sample C has the same thickness value as sample D, the air permeability results came on second with 517 mm/s as the factor that may contribute to this result difference between these two samples is the fabric structures. Sample C is a warp knitted fabric with an interlock structure (Figure 3) whereas sample D is a jersey knit structure (Figure 4), which acts as the variable that influences the differences of air permeability rate because of interlock structure (Figure 5). This structure reduces fabric porosity due to the existence of overlap loops [10] and more fibre contain as compared to jersey knit structure (Figure 6) which only constructed by continuous single looping motion.

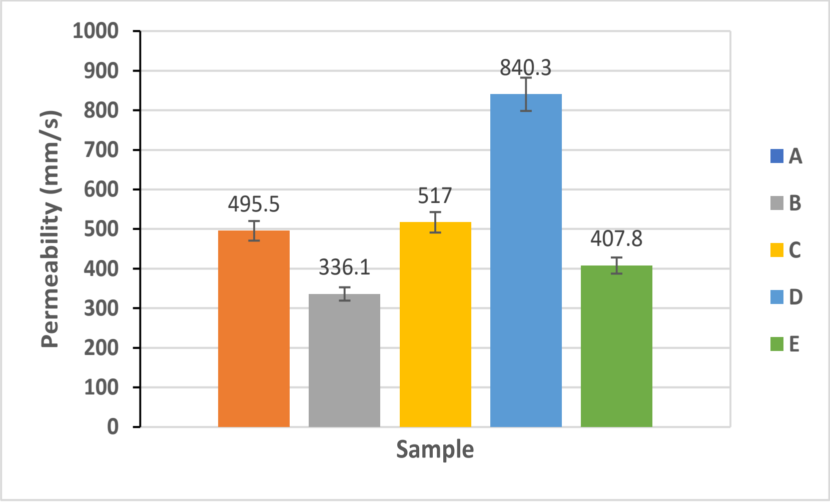


**Figure 2: Fabric Air Permeability Performance**

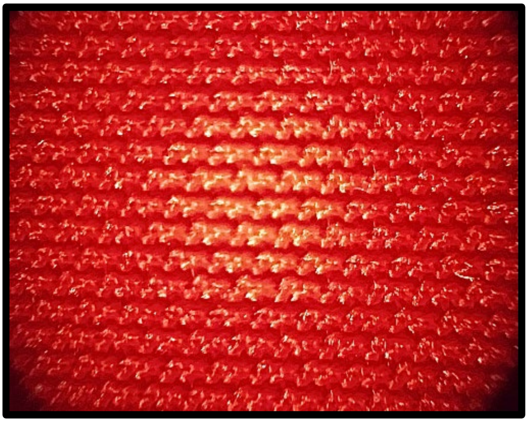

**Figure 3: Structure Sample C**

**Figure 4: Structure Sample D**

The air permeability results are then followed by sample C with 517 mm/s, sample A (495.5 mm/s), sample E (407.8 mm/s) and sample B (336.1 mm/s). However, the rate of air permeability between sample A and C is insignificant as shown by error bar in Figure 2. The results obtained were influenced by certain parameter for each sample, where sample A gave higher rate compared to sample E although sample E is thinner than sample A, however sample E is denser than sample A which reduced the fabric porosity significantly. Therefore, it can be concluded for these two samples that the fabric density affects air permeability rate more than fabric thickness. Sample B resulted as a sample that have the least air permeability rate compared to the other four samples, due to specific parameter distinctions i.e high fabric thickness, high fabric weight and high areal density to compare with certain samples. In terms of density, sample E had one of the highest numbers among other samples, which is fair to expect for sample E to have lower air permeability rate compared to sample A and C.

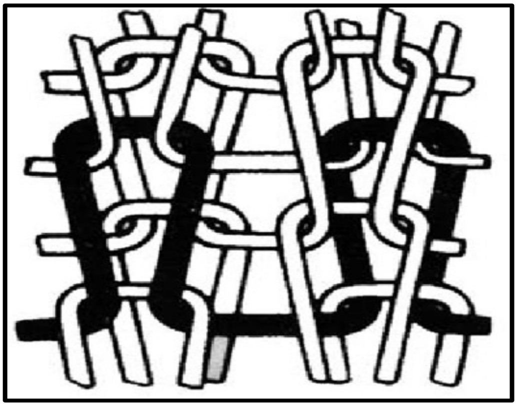

**Figure 5: Schematic Diagram for Sample C**
*(Source by Hong Hu et al., 2010 [11])*

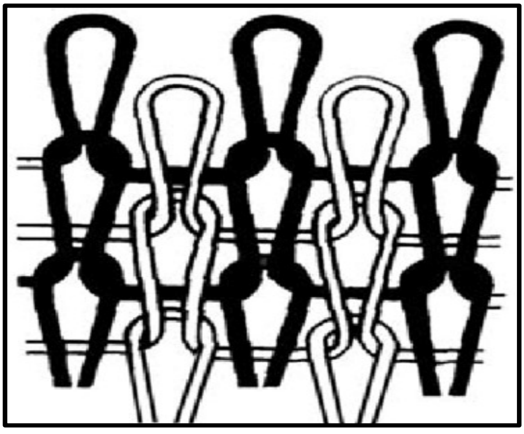

**Figure 6: Schematic Diagram for Sample D**
*(Source by Hong Hu et al., 2010 [11])*

## Water Vapour Permeability

The relationship between fabric thickness and Water Vapour Permeability (WVP) is shown in Figure 7. Fabric thickness can affect water vapour resistance properties significantly as the relation is directly proportional where the resistance towards water vapour increases as fabric are thicker [12]. Following the relationship stated earlier, fabric with the lowest thickness value which is sample D tend to have the highest WVP compared to the other four samples. Although sample C has the same thickness as sample D, the reason behind the different results for WVP for these two samples lies on their fabric structure.

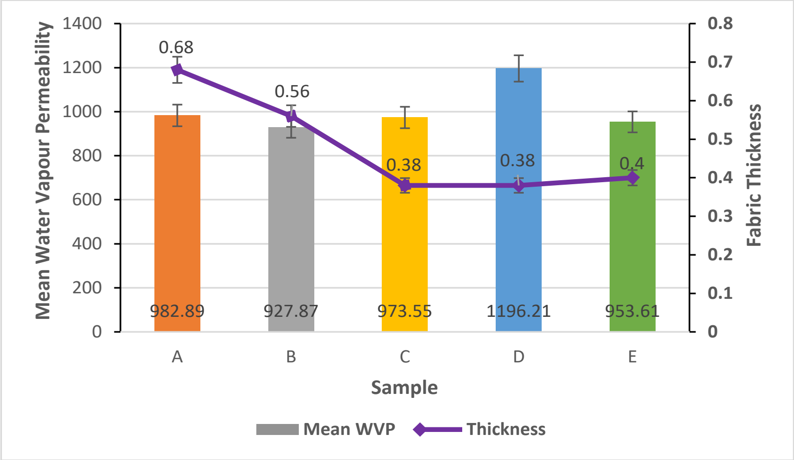


**Figure 7: Relationship between water vapour permeability and thickness**

Sample D is made from jersey knit structure which is also known as a plain knitted structure, and this structure possesses excellent water vapour permeability compared to other structures [13]. Comparing the results between sample A, B, and E, sample A gave the highest WVP rating among these three samples although it has the highest thickness value. This is because sample A has the lowest fabric density compared to sample B and E with plausible for the fabric to show better performance for WVP as low-density fabric possesses high porosity capacity makes water vapour easily diffuses in between fibres and clearances [14].

*Overall Assessment*

For the overall assessment, the samples were ranked for Fabric Ranking Index (1 to 5), where 1 is considered as the lowest ranked fabric for each test according to each test value evaluation and vice versa for 5. The value for thermal properties assessment index is determined by finding the average value from all three test rankings. The ranking is illustrated in Table 5. Two fabrics can be labelled with excellent thermal properties, one fabric with moderate level and two with poor level for thermal properties. Sample D executed excellent thermal properties, whereas sample C shows moderate excellency and poor execution as shown by sample A, B and E.

**Table 5: Fabric Ranking Index**

| Sample/ Assessment | Moisture Management (MMT) | Water Vapour Permeability (WVP) | Air Permeability | Thermal Comfort Properties Assessment Index |
|---|---|---|---|---|
| A | 1 | 2 | 3 | 2 |
| B | 4 | 1 | 1 | 2 |
| C | 3 | 3 | 4 | 3 |
| D | 5 | 5 | 5 | 5 |
| E | 2 | 2 | 2 | 2 |

## CONCLUSION

The comparisons on thermal comfort properties of several fabrics have been studied and analysed. It is observed that the air permeability, water vapour permeability and moisture management values were affected by fabric structure, density and thickness significantly. These three factors correlate between one and another in determining the results for each test i.e the relationship between fabric thickness and structure was elaborated when sample C and D that have the same thickness but different outcome for WVP and air permeability. Fabric thickness was also mentioned as a factor to distinguish results for MMT. Another factor that heavily affects the MMT results was fabric weight, as this factor elaborates the MMT result for sample E. As to conclude from all tests done in this study, it can be said that nylon-polyester blend fabric with jersey structure reflects excellent thermal comfort properties. This decision can be a highly useful information for manufacturers, as a future reference to consider this type of fabric in selecting material for garment that tailored to consumer's comfort experience.

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