Evaluating the effect of spinning systems on thermal comfort properties of modal fabrics

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Abstract. In recent years the importance of clothing comfort became one of the most important feature of the fabrics. The aim of this study is to characterize thermal comfort properties of single jersey fabrics were knitted using 100% modal yarns which were spun in various types of yarn spinning methods such as ring spinning, compact spinning, rotor spinning and airjet spinning. Thermal comfort properties like air permeability, thermal resistance, thermal absorptivity and water vapour permeability of fabrics were tested. The results indicate that compact spinning technology will be appropriate for the summer climate casual wear.

Key Words: Knitted fabric, Thermal comfort, Modal, Spinning methods

1. Introduction
Nowadays, there has been growing interest in knitted fabrics due to its simple production technique, low cost, high levels of clothing comfort and wide product range. Consumers today, not only desire aesthetic appeal of apparel, but also its comfort and performance attributes and knitted fabrics can possess stretch, provide freedom of movement, have good handle and achieve higher permeability properties. That’s why knitted structures are commonly preferred for sportswear, casual wear or underwear.

Thermal comfort, the subject of this study, plays an important role on the comfort of wearer. It is related to fabric’s ability to maintain skin temperature and allow transfer of perspiration. It is depended upon the fibre properties, yarn structures, fabric geometry and finishing treatments. Of the various yarn properties yarn bulk, packing coefficient and especially yarn hairiness are important factors. There are many researches focused on comfort properties [1-7], whereas studies on spinning methods including both conventional and modern technologies are rare [8-12].
This research is focused on the effect of the yarn spinning methods on thermal comfort properties of single jersey fabrics. Samples were produced by using modal fibres which are commonly used in knitting industry because of well moisture absorption, high shrinkage resistance besides softness, shiny nature and silky feeling properties.

2. Experimental

Single jersey fabrics were knitted using ring, rotor, compact and airjet yarns from 100 % Modal fibers (Table 1). Whole yarns were spun in the same yarn count (30 Ne). Characteristics of yarns are given in Table 2. The knitting process of the single jersey fabrics was performed on the 28 gauge and 32” diameter circular knitting machine. The knitting process was completed with constant machine settings and the samples were kept under the standard atmospheric conditions for 24 hours for the relaxation.

Comfort properties (thermal conductivity, thermal resistance, thermal absorptivity, relative water vapor permeability, air permeability) were measured besides the stitch densities, weight and thickness of the fabrics. Alambeta instrument was used to measure thermal conductivity, fabric thickness, thermal resistance and thermal absorptivity values; relative water vapor permeability was measured on Permetest instrument according to ISO 11092. Air permeability measurements were done according to TS 391 EN ISO 9237 using tester FX3300 (Table 3). All measurements were repeated five times and the results were evaluated statistically.
### Table 1. Characteristics of Modal fiber

| Made in   | Trading Name   | Fibre length (mm) | Fibre fineness (dtex) | Type       |
|-----------|----------------|-------------------|-----------------------|------------|
| Austria   | Lenzing Modal  | 38-39 mm          | 1.30 dtex (3.3 micron)| Bright     |

### Table 2. Characteristics of yarns

| Yarn Type | Yarn Count (Ne) | Twist Coeff. (ae) | Um  | CVm | Thin 50% | Thick +50% | Thick +200% | Neps +200% | H  |
|-----------|-----------------|-------------------|-----|-----|----------|-------------|-------------|-------------|----|
| Ring      | 30              | 3.7               | 9.31| 11.78| 0.0      | 9.20        | 20.80       | 6.31        |
| Rotor     | 30              | 3.7               | 11.53| 14.57| 19.0     | 35.80       | 198.30      | 4.84        |
| Compact   | 30              | 3.7               | 9.52| 12.03| 0.0      | 7.50        | 13.30       | 4.88        |
| Airjet    | 30              | 3.7               | 9.4  | 11.86| 1.5      | 8.30        | 8.30        | 4.39        |

### 3. Results and Conclusion

The physical and thermal comfort values of the fabrics are given in Table 3.

### Table 3. Fabric properties

| Properties                          | Ring     | Rotor    | Compact  | Airjet   |
|-------------------------------------|----------|----------|----------|----------|
| Stitch density course/cm            | 20       | 19       | 20       | 20       |
| Stitch density wale/cm              | 14       | 13       | 14       | 14       |
| Thickness (mm)                      | 0.46     | 0.36     | 0.42     | 0.48     |
| Weight (g/m²)                       | 130      | 138      | 127      | 133      |
| Air permeability (lt/m²s)           | 1924     | 1710     | 2020     | 1650     |
| Thermal conductivity (W/mK)         | 0.04603  | 0.04559  | 0.04468  | 0.0451   |
| Thermal resistance (m² K/W)         | 0.01004  | 0.00795  | 0.00951  | 0.01055  |
| Thermal absorptivity (Ws¹/²/m²K)    | 165.97   | 185.73   | 156.03   | 153.8    |
| Relative water vapor permeability   | 58.43    | 63.05    | 63.96    | 66.81    |

As it is known, the yarn structure is dependent primarily upon the raw material, spinning process, spinning unit, machine settings, twist, etc. Length and frequency of fiber ends that are not integrated in the yarn and therefore protrude from the yarn bundle causes hairiness. The fabric structure can be open or closed; voluminous or compact; smooth or rough or hairy; soft or hard; round or flat; thin or thick, etc. [14].

Yarn results showed that the maximum and minimum hairiness values belongs that ring-spun and airjet-spun yarns respectively. In addition, modal fibers cannot be spun effectively in the compact spinning.

The results revealed that difference of stitch density values in both course- and wale-direction of samples are not important. On the other hand, the sample from rotor-spun yarn has the lowest thickness but maximum weight values.

#### 3.1. Air Permeability

Air permeability is the rate of air flow passing perpendicularly through a known area under a prescribed air pressure differential between the two surfaces of a material [17]. The results indicate that the air permeability values increase while the weights of the fabrics decrease. The highest air
permeability value belongs to the fabric produced from compact spun yarn which has the lowest weight.

Figure 2. Air permeability values

3.2. Thermal Resistance and Thermal Absorptivity
Thermal resistance is an indication of how well a material insulates and thermal absorptivity determines the contact temperature of two materials.

Figure 3. Thermal conductivity, thermal resistance and thickness

According to results, there was not significant difference in thermal conductivity values with different yarn spinning methods. Thermal resistance is a measure of the body's ability to prevent heat from flowing through it. Under a certain condition of climate, if the thermal resistance of clothing is small, the heat energy will gradually reduce with a sense of coolness [5]. The results showed that when the thickness of fabrics increases, the thermal resistance value increases also. Fabric samples knitted using compact spun and rotor spun yarns had the lowest thermal resistance values, whereas the highest values were obtained for the fabrics made from ring and airjet spun yarns.
3.3. Thermal Absorptivity

![Thermal absorptivity values of samples](image)

**Figure 4.** Thermal absorptivity values of samples

Thermal absorptivity is the objective measurement of the warm-cool feeling of fabrics [5-13]. When a human touches a garment that has a different temperature than the skin, heat exchange occurs between the hand and the fabric. If the thermal absorptivity of clothing is high, it gives a cooler feeling at first contact [5-15].

The fabric sample is produced from rotor spun yarn has the coolest feeling at the first skin contact with the highest thermal absorptivity value (Figure 4). The samples is knitted using compact and airjet spun yarns have warmer feeling because of the lowest thermal absorptivity value.

3.4. Relative water vapour permeability

![Relative water vapor permeability results](image)

**Figure 5.** Water vapour permeability results
Relative water vapour permeability is the ability to transmit vapour from the body. If the moisture resistance is too high to transmit heat, by the transport of mass and at the same time the thermal resistance of the textile layers considered by us is high, the stored heat in the body cannot be dissipated and causes an uncomfortable sensation [5-16]. The results are given in Figure 5. According to the results there are significant differences between the relative water vapour permeability values of samples. were produced using different yarns depending on yarn spinning processes. Samples were knitted with airjet spun yarn and ring spun yarn have maximum and minimum water vapour permeability values respectively. This value is approximately same for the samples were produced with rotor and compact spun yarns. Difference is most probably a consequence of the hairiness of the yarns. As can be seen from the results water vapour permeability value decreases while the hairiness of the yarn increases.

4. Conclusion
In this study the effect of yarn spinning methods on thermal comfort properties of single jersey fabrics were produced by using modal fibres which are commonly used in knitting industry because of well moisture absorption, high shrinkage resistance besides softness, shiny nature and silky feeling properties. According to the results, yarn spinning method generally had a significant effect on the physical and thermal comfort properties of samples. For example;

- the air permeability value of sample from compact spun yarn was higher because of less fabric weight,
- thermal resistance value of sample from rotor spun yarn were minimum because of the less fabric thickness,
- thermal conductivity values of whole samples were approximately same,
- thermal absorptivity value of sample from rotor spun yarn had the maximum value and it gave cooler feeling at the initial contact,
- a higher water vapour permeability was provided for the samples from compact and airjet spun yarns,

Ultimately, the results indicated that compact spinning technology for modal fibers will be appropriate for the summer climate casual wear with higher air permeability, higher relative water vapour permeability, sufficient thermal resistance, and also lower weight and thickness values.

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