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Evaluating the thermal comfort properties of Rize's traditional hemp fabric (Feretiko) using a thermal manikin

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ABSTRACT

In the present research, the thermal properties of the traditional fabric of the Rize city (Turkey) were investigated. A Feretiko, which is a fabric produced from hemp fibers at handlooms, were chosen and the thermal properties were evaluated via thermal manikin as well as the Alambeta tester and Air permeability tester. The thermal manikin tests were performed at 23 °C ± 1 constant ambient temperature and 75 ± 5% relative humidity regarding to the past annual average temperature and relative humidity data of Rize city were considered. The thermal resistance of Feretiko was measured 0.011 m^2K/W by Alambeta tester and the total clothing insulation of the shirt manufactured from Feretiko was measured as 0.032 m^2K/W by thermal manikin. Moreover, in ASHRAE Standard 55-2013, the clothing insulation of a long-sleeve shirt ensemble stated as 0.25 clo. The clothing insulation of the shirt manufactured from Feretiko was 0.20 clo, which is close to the value stated in the standard.

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1. Introduction

Feretiko is a local fabric, which is woven from hemp fibers and is produced at handlooms with whips, which is a setup made by ropes connected with the shuttle (Fig. 1). The dimensions of the handlooms differ between 45 cm and 150 cm and the most important feature of these handlooms is that the shuttle is picked by pulling the whip not by hand [1]. Feretiko (Rize Fabric) has still been woven locally in Rize, which is located in the region of the Black Sea [2] and the province was known mainly for hemp cultivation in the past. Due to its climatic conditions and soil structure of the region, the fibers produced from hemp plants cultivated in Rize are finer than others produced in Turkey [3].

Feretiko was started to being weaved in the Ottoman Empire since the 16. Century and due to its thermal behaviors, it was used in the attires of the Ottoman sultans [1]. For instance, according to an official paper dated by 1777, the underwear of sultan was manufactured by Feretiko whereas on 1876 the shirt of sultan Abdulaziz he had on when he died was manufactured by Fretiko [3].

Feretiko is mostly manufactured in plain weave. 20 Ne hemp yarns are used as weft yarns and cotton yarns in different yarn numbers are used as warp yarns [4,5]. The density of typical Feretiko is 16–18 ends/cm and 18–20 picks/cm [5]. The color of Feretiko is beige or dark white when it is first woven [1], and it can be used in this natural form or a bleaching process can be applied. The fabric was put and left in Black Sea or lake during the day and then was washed and dried under the sun. Regarding to the obtained color this process could be repeated several times, which could be reached 30 days in total [3].

Hemp, which is most probably the first plant cultivated by humankind for its textile use [6,7], has great moisture absorption and antibacterial properties [8]. It is a bast fibre and due to the porous structure of bast fibers, hemp fibers are also suitable for thermal insulations [9]. Existing literature mainly focused on investigating thermal insulation of hemp composites [10–12]. There are limited researches about thermal insulation of hemp fabrics for garment production. Stankovic et al. (2008) found out that, textile fabrics made of hemp fibers or their blends exhibit thermal characteristics at a comparable level to cotton and viscose fabric. Besides fabric tests, evaluating the thermal insulation of the final product, in garment form, also has great significance. Therefore, thermal manikins are usually used to measure the thermal

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Fig. 1. Traditional handloom for Feretiko.

insulation of clothes due to their advantages, namely simplicity and repeatability of the experimental procedures and the precision of the results [14]. The thermal manikins exist more than 60 years [15] and provide a good estimate of the total dry heat loss from the body and the distribution of heat flow over the body surface [16]. Although there are researches about investigating the clothing insulation of current-market garments using the thermal manikin method, it is still necessary to study on traditional fabrics and special garments.

This study aimed to investigate the thermal properties of Feretiko fabric by using an Alambeta tester as well as an air permeability tester for the woven fabric and a thermal manikin for the dress shirt.

2. Experimental

2.1. Materials

Feretiko, evaluated in this research, was manufactured traditionally in Rize city. The fabric weight of the Feretiko was measured as 107.29 g/m^2. Moreover, the yarn numbers as well as the density regarding to warp and weft directions are presented in Table 1.

2.2. Methods

In this research, in order to investigate the thermal comfort properties of Feretiko, firstly some fabric tests were performed, namely the air permeability, fabric thickness, thermal conductivity, thermal resistance and thermal absorptivity over the woven fabric.

Afterwards, a long sleeve shirt was manufactured regarding to the body measurements of the thermal manikin in order to ensure ergonomic fit (Fig. 2). Furthermore, the shirt was tested by using a female model thermal manikin (PT-Teknik made in Denmark) which has 20 thermally independent sections and only sense dry heat transfer. Each section has its own unique micro controller system which calculates the temperature of the entire surface by measuring the resistance of the nickel wire, calculates the needed power and controls a power switch for heating [17].The calculations are generated by relating the heat flow from the manikin's surface area through the clothing into the ambient air with the heat flow from the nude manikin's body surface area, considering

Table 1
The warp/weft yarn numbers and the density in warp and weft directions.

	Yarn Number (Ne)	Density (yarns/cm)
Warp (Cotton)	60/2	18
Weft (Hemp)	20/1	22

Fig. 2. The evaluated hemp shirt.

the temperature difference between the manikin's skin surface and the ambient air [18]. The thermal manikin was set up from a computer and the heat loss data was recorded in every minute during the tests.

Thermal manikin enables to measure thermal comfort of the final product, such as shirts, pants etc. and it is an important test equipment to evaluate the thermal comfort in simulated real-use conditions.

In this research, the testing conditions were specified according to the past weather data of Rize city. Regarding to the annual average temperature and relative humidity data [19], the hottest month was chosen and the conditions were determined as 23C ± 1 constant ambient temperature and 75 ± 5% relative humidity. The tests were set out according to "ISO 9920:2007: Ergonomics of the thermal environment - Estimation of thermal insulation and water vapor resistance of a clothing ensemble" standard. The trials were carried out in constant skin temperature mode and the skin temperature was set at 33 °C ± 0.2. In order to determine the thermal insulation of the boundary air layer, a test with nude manikin was also conducted under same static conditions.

At the end of each measurement, the heat loss was obtained and recorded to the computer. Afterwards, the total thermal clothing insulation (It) was calculated with the heat loss data according to the global method under static conditions. In global method, the heat losses and skin temperatures of each body part are summed up as only one segment. The effective thermal clothing insulation (Icle); consists of the difference between (It) and the thermal insulation of the boundary air layer (Ia), was also calculated.

3. Results and discussion

The fabric thickness, thermal resistance, thermal absorptivity and air permeability test results of Feretiko were presented in Table 2. Resulting from the fabric structure, it can be said that, the air permeability of Feretiko fabric is quite high. The fabric

Table 2
Thermal properties of Feretiko.

Material	Thickness (mm)	Thermal resistance (m^2 K/W)	Thermal absorptivity (W $s^{1/2}/m^2$ K)	Air permeability (l/m^2 sec)
Hemp/cotton fabric	0.44	0.0114	100.56	2600

Table 3
Thermal insulation values of the hemp shirt and the air layer.

Material	It (m^2K/W)	Ia (m^2K/W)	Icle (m^2K/W)	Icle (clo)
Hemp/cotton shirt	0.127	0.095	0.032	0.206

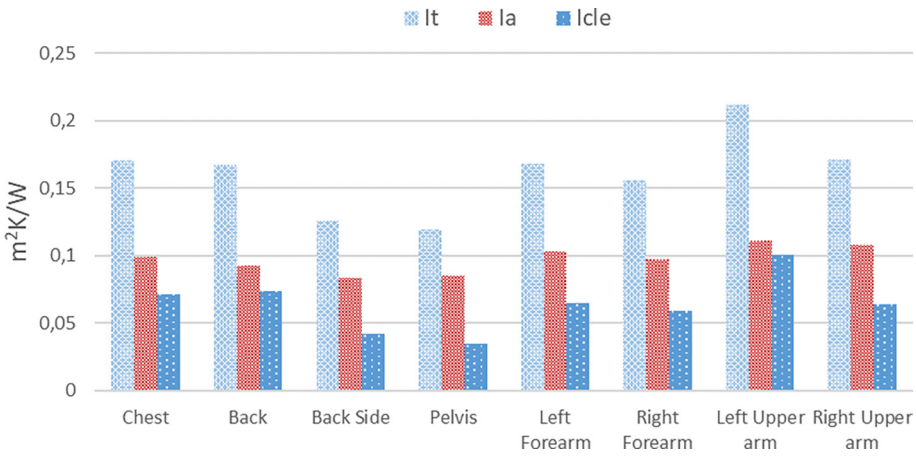

Fig. 3. Thermal insulation values regarding to body parts.

thickness is lower than 0.5 mm, especially, due to its fibre combination, regarding to the yarn number of hemp yarn. The thermal resistance of Feretiko was measured as 0.011 m^2K/W.

Table 3 shows the thermal manikin test results of the shirt manufactured from Feretiko.

Regarding the results, the clothing insulation (Icl) of hemp shirt was 0.20 clo. The clothing insulation of a long-sleeve shirt ensemble stated in ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) Standard 55–2013 is 0.25 clo [20]. Even though the evaluated hemp fabric was a thin fabric with high air permeability, it still presented close thermal insulation value stated in the standard. The ensemble was a loose fitting shirt that generated air layer between the surface of the thermal manikin and the shirt. It was obtained that, the thermal insulation of air layer was 75% of total thermal insulation. Thus, the thermal insulation of clothing was calculated as 0.032 m^2K/W.

The It, Ia and Icle values were calculated for eight body parts and were presented graphically in Fig. 3. As it can be clearly seen in Fig. 3, the thermal insulation of the shirt, of the air layer as well as the clothing insulation of the shirt differed regarding to the body parts. By the statistical analyses, it was obtained that, the differences were statistically significance. Due to the human body structure, the surface area and curves are different for each body part. Therefore, the thermal insulation of air layer between the shirt and the body differed for each body part and the difference was statistically significant ($p = 0.00$). Ia values of pelvis and back side were lowest, which might have been caused by the air circulation around the hemp line. The difference in thermal insulation of the shirt between chest and right upper arm was not statistically significant ($p = 0.096$). Likewise, the difference in clothing insulation of the shirt between right upper arm and left forearm was not statistically significant ($p = 0.122$).

4. Conclusions

This study examined the thermal insulation as well as the air permeability of Feretiko, which is a traditional hemp and cotton combination woven fabric of the Rize city (Turkey). Besides fabric tests, the thermal insulation values were measured using the thermal manikin method. In order to determine the testing conditions for thermal manikin tests, the annual average temperature and relative humidity data were considered and the conditions were specified as 23℃ ± 1 constant ambient temperature and 75 ± 5% relative humidity.

Hemp fiber has a good drape ability and the evaluated fabric was a thin fabric with quite high air permeability. The thermal resistance of Feretiko was measured 0.011 m^2K/W by Alambeta tester and the total clothing insulation of the shirt manufactured from Feretiko was measured as 0.032 m^2K/W by thermal manikin. With respect to this difference in thermal insulation values of the fabric and the final product, it can be concluded that, the thermal insulation might differ by the garment form as well as the using conditions.

Moreover, in ASHRAE Standard 55–2013, the clothing insulation of a long-sleeve shirt ensemble stated as 0.25 clo. The clothing insulation of the shirt manufactured from Feretiko was 0.20 clo, which is close to the value stated in the standard.

In further study, the thermal properties of hemp fabrics will be compared with the other traditional fabrics produced by natural fibres such as blended linen and cotton fabrics.

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Further reading

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