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Investigation of The Effects of Physical Parameters of Fabrics Woven with 100% Bamboo Fiber Yarns on Wearing Comfort Properties

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Abstract- Thanks to the developments in the textile and ready-to-wear market, the expectations of individuals from clothing have changed and the concept of wearing comfort has gained importance. This concept has led to the replacement of fashionable clothing design and the production of good quality clothing by comfortable clothing design and production. Wearing comfort is a subjective concept meaning that a person feels comfortable in clothing. Although the concept of feeling comfortable may vary from person to person, clothes protecting us against external factors such as heat, cold, and wind, and causing no annoyance such as itching, pain, stinging, and are suitable for our social environment, make us feel comfortable both psychologically and physiologically. The fact that the human body is in contact with any textile and ready-to-wear product during all day and night indicates the importance and necessity of wearing comfort. It may be seen that both in Turkey and all over the world, some studies to increase wearing comfort have been carried out. These efforts to increase comfort also push manufacturers to find new raw materials and production methods. Bamboo fiber is one of the fibers whose usage and popularity in textile and ready-to-wear is increasing rapidly and showing superior comfort and high performance properties. This study aims to contribute to the limited number of literature researches on the effect of bamboo woven fabric parameters on thermal comfort and thus wearing comfort..

Keywords Comfort, woven fabric, thermal comfort, bamboo fiber.

1. Introduction

The association of human with textiles and clothing and utensils produced from the textiles showed itself as a necessity from the very first creation. In the subsequent development process, these needs have been started to met systematically within the framework of a more conscious and technological logic.

The increasing expectations of people from textile materials have required the textiles to have many functional properties together.

In order for a person to feel comfortable in a garment, the garment must not hinder body movements, provide a large proportion of heat and moisture transfer between the body and the environment, and create a small air space. At this point, the softness, elasticity, breathability, shape retention and thermal comfort properties of the fabric come into prominence [1].

The developing technology and competition conditions also requires progress in the comfort properties of the fabric besides the structure of the woven fabric. And this depends on the construction of the fabric and the production of the fibers making up the fabric under the most optimum conditions.

As all biological processes in the human body depend on temperature, it is vital to maintain the proper temperature and humidity balance of the body according to different environmental conditions [2].

Thermal properties of fabrics are one of the fundamental properties in determining wearing comfort. The fundamental parameters determining thermal comfort can be listed as heat and moisture transfer capability, air permeability, heat retention ability, static electricity tendency, water vapor permeability and water absorbency.

Clothing acts as a protective buffer between people and the environment they live in and thus plays an important role for a healthy life. The capacity of people to adapt to the climatic conditions of the environment they live in, to move freely without feeling any pressure or restriction on them, and to enjoy the activities they perform are directly related to the textile materials/clothes they use [3].

All these functions of clothes are described as "wearing comfort" and as they aim to increase the living standards of people, studies to improve the wearing comfort attract the attention of both researchers and manufacturers. Thus, wearing comfort includes the production of clothes/fabrics giving people a sense of comfort in terms of thermal, psychological, aesthetic and ease of use.

The human body is in optimum comfort when the skin temperature is between 33 - 35 ˚C and there is no liquid sweat. A comfortable garment should allow the passage of water vapor through the skin, and transfer sweat without making the person feel wet when the fabric contacts the skin [4].

The metabolic heat generated to save the thermal equilibrium of the body is balanced by felt and imperceptible perspiration, radiation and the transport of heat on the skin surface [3].

An ideal garment fabric should have these three important properties in terms of thermal comfort:

High thermal resistance for cold Protection,

Low water vapor resistance for effective heat transfer in mild climatic conditions,

High fluid handling capability to prevent discomfort due to sweating.

Besides these, a high-comfort garment is expected to provide features such as ease of movement, quick drying, softness and non-irritating to the skin, lightness, durability, an admirable attitude and easy care [5].

A fabric providing the ideal comfort conditions in terms of its thermal properties should be examined within the frame of a wide variety of properties. These properties are not limited to the weave type, thickness, or yarn count of the fabric.

Factors affecting the thermal resistance of textile materials may be listed as:

1. Thermal conductivity of the fiber and air held in the fabric
2. Specific heat of fiber
3. Fabric thickness and number of layers
4. Volumetric density of the fabric (number, size and distribution of air voids in the fabric)
5. Fabric surface (type of fiber used, structure of the fabric, finishing processes on the fabric)
6. Contact area between fabric and surface
7. Contact heat loss between leather and fabric
8. Convection heat loss between skin and fabric
9. Heat loss by radiation
10. Heat loss by evaporation of water from skin or fabric
11. Loss or increase in heat due to the fabric absorbing water
12. Internal atmospheric conditions as temperature, relative humidity, movement of surrounding air [6].

Bamboo is a plant having been used in many areas of daily life since ancient times.

Bamboo fibers are mainly composed of cellulose, semi-cellulose and lignin. When natural bamboo fibers are examined under the microscope, it may be seen that the outer wall has a circular layer structure and consists of fibers that allow moisture to absorb and evaporate immediately. It has a special, natural channeled structure and these spaces in the fiber allow human sweat to be absorbed immediately and evaporated. The analysis on physical properties of bamboo fiber shows that it has a high strength and low elasticity [7].

The cross section of 100% bamboo fiber is not in the form of a full circle, but has a structure formed by the combination of small cylinder clusters and has micro holes (air spaces). It is thought that the high water absorption ability of bamboo fiber comes from its porous structure [8].

Its multi-functional, soft touch and shiny looking structure that can be easily processed, breathable, has antibacterial properties makes bamboo preferable in textile sector [9]

Studies show that textile products made from natural bamboo fibers have advantages in terms of wearing comfort thanks to their properties such as excellent moisture absorption and evaporation of moisture. Bamboo fiber owes these properties to the several small cavities on the fiber surface and the uncountable number of lumens in its cross-section. Thus, natural bamboo fibers are called "breathable fibers" [7]

Studies show that bamboo fiber has high performance and superior comfort. This study aims to find out how fabric parameters of bamboo fiber affect wearing comfort properties in addition to previous studies.

2. Method

2.1. 2.1. Material

In this study, descriptive method has been used to determine the effect of physical parameters of 100% bamboo fiber woven fabric on wearing comfort properties.

The material of the study consists of 4 kinds of 100% bamboo woven fabric in different thickness, weaving type, weight, density and yarn count, and the heat resistance, water vapor permeability and air permeability data obtained from these fabrics.

The physical parameters of 4 types of 100% bamboo fabric used in the study are shown in Table 1.

First of all, the weight and fabric thickness measurements of the fabrics were made in Marmara University physical tests laboratory. Weft and warp densities were found by counting in cm with loops, and weft and warp yarn numbers were calculated with the data obtained. Fabric thickness was measured according to the ISO1 -accepted standard EN ISO 5084: 1996. The fabric thickness was found by measuring the samples with a precision of 0.01 mm by applying a pressure of 10g / cm2 in the fabric thickness measurement device and taking the arithmetic average of the repetitive measurement results for each sample. Fabric weight was measured according to the EN 12127:1997 standard accepted by CEN2. The samples cut with a circular sample cutter were weighed with a precision balance; The weights of the unit areas of the fabrics were calculated and their grammage values were determined.

1: International Organization of Standardization [10],

2: European Committee for Standardization [11].

Table 1. Physical properties of 100% bamboo fabrics

Fabric Code	Weaving Type	Mixture	Weight (gram)	Weft Density	Warp Density	Fabric Thickness (mm)	Weft Yarn No	Warp Yarn No
F1	2/1 Twill weave	100% Bamboo	187	27	30	0,280	33	33
F2	2/2 Plain weave	100% Bamboo	207	24	28	0,316	23	23
F3	2/2 Twill weave (Herringbone)	100% Bamboo	225	25	27	0,364	23	24
F4	2/2 Twill weave (Herringbone)	100% Bamboo	230	27	28	0,532	25	24

2.2. Procedure

Marmara University Permetest device and Sdl-Atlas Air Permeability Tester in Ekoteks3 in Istanbul have been used in data collection. After the thermal resistance and water vapor permeability of the fabrics were measured in the Permetest device, and the air permeability measurements were made in the SDL Atlas Air Permeability Tester, the data obtained have been compared with the physical properties and evaluated.

3: Ekoteks Laboratory is accredited by TÜRKAK (Turkish Accreditation Agency), a member of the international laboratory accreditation committee ILAC, with the EU – 0583T number according to the TS EN ISO/IEC 17025 standard. [12]

Permetest is a device used to measure the water vapor permeability and thermal resistance of woven, knitted fabrics and non-woven textile surfaces. Called as skin model, this device represents the dry and wet human skin by means of thermal sensation and enables the water vapor permeability and thermal resistance of the fabrics to be determined. The measurement results are explained with the units defined in ISO 11092. When used in the laboratory under standard atmospheric conditions, Permetest gives acceptable accurate measurement results. As the device is affected rapidly by the changes in the ambient conditions, great care should be given to prevent these environmental conditions to change during the measurement [6].

Fig. 1. Permetest instrument [13]

Measurements with the air permeability tester have been carried out in accordance with the ERT 140.2-99 standard. Air permeability measurement results have been taken at a pressure of 100 Pascal from a surface area of 5 cm^2.

Fig. 2. SDL Atlas Air Permeability Tester[14]

Three samples taken from the different parts of the fabrics were measured with the devices calibrated before, and their average values have been evaluated by comparing them with physical fabric parameters.

3. Findings and Discussion

Thermal resistance measurement data given by the Permetest device within the frame of this study aiming to determinate the effect of physical properties of fabrics woven with yarns obtained from 100% bamboo fibers on wearing comfort is shown in Table 2.

Table 2. Thermal Resistance Measurement Results of 100% Bamboo Fabrics Given by the Permetest Device

Fabric Code	Measurement 1	Measurement 2	Measurement 3	Average Thermal Resistance
F1	0,70	0,65	0,60	0,65
F2	0,60	0,64	0,62	0,62
F3	0,85	1,00	1,30	1,05
F4	0,70	0,85	0,70	0,78

Table 1 shows that there is an increase in weight and thickness, respectively, in 100% bamboo fabrics according to the fabric codes. However, when these values are compared with Table 2, it may be seen that these two physical parameters do not affect the increase or decrease in thermal resistance.

In order to understand these value differences between thermal resistances, other fabric parameters should be examined as well. According to the Table 2, the smallest thermal resistance value is in the F2 coded fabric. The table shows that F2 fabric is different from the others in terms of weaving type –plain weave- besides having the smallest values in terms of weft density and weft - warp yarn numbers. Thus, the decrease in the thermal resistance value may be said to vary depending on the yarn count, density and weaving type in 100% bamboo fabrics. Based on the table, it may be seen that F1, F3 and F4 fabrics are all twill weave. However, the F1 coded fabric, whose thermal resistance value is lower than F3 and F4, has the highest value of 2/1 twill and yarn count. Thus, the thermal resistance value again varies according to the weaving type and yarn count.

However, when the F3 and F4 numbered fabrics with the same weaving type are examined, it may be seen that, as mentioned at the beginning, thermal resistance increases depending on the decrease in density, yarn number decrease and weight and thickness decrease provided that the weaving type is the same.

Table 3. Water Vapor Permeability Measurement Results of 100% Bamboo Fabrics Given by the Permetest Device

Fabric Code	Measurement 1	Measurement 2	Measurement 3	Average Water Vapor Permeability
F1	3,2	3,0	3,1	3,10
F2	3,3	3,3	3,2	3,26
F3	3,4	3,4	3,5	3,43
F4	4,1	3,9	4,2	4,06

The unit of water vapor permeability of fabrics woven with yarns obtained from 100% bamboo fibers given by Permetest device is Pa.m2.w-1. The average values in Table 3 show an increase trend from F1 to F4. When this increase is attributed to the physical properties of sample fabrics in Table 1, the density, yarn number or weaving type are not useful. However, the weight and fabric thickness shows an increase trend from F1 to F4 in also Table 1. Thus, from these data, it may be inferred that the increase in the water vapor permeability value is due to the increase in weight and fabric thickness in fabrics woven with yarns obtained from 100% bamboo fiber. The effect of bamboo fiber being cellulose-based, having a structure formed by the combination of small cylinder clusters in its cross section and having micro-holes in it has high water absorption ability is clearly seen here. When the mixing ratio of all the sample fabrics is 100% bamboo, the effect of the natural structure of bamboo for reasons such as thickness and weight directly affects the increase of the water vapor permeability value.

Table 4. Air Permeability Measurement Results of 100% Bamboo Fabrics Given by Sdl - Atlas Air Permeability Tester

Fabric Code	Measurement 1	Measurement 2	Measurement 3	Average Air Permeability
F1	40.3	46.5	36	40.9
F2	108	108	107	107.6
F3	102	114	114	110
F4	42.8	46.3	39.5	42.8

The unit of air permeability of fabrics woven with yarns obtained from 100% bamboo fibers given by Sdl-Atlas air permeability device is lt/m2/sec The measurement values were obtained with a surface area of 5 cm2 with a pressure of 100 Pascal. The average air permeability values in Table 4 show that the air permeability values of F2 and F3 coded fabrics and the air permeability values of F1 and F4 coded fabrics are relatively close to each other. When the values related to the physical parameters of the fabrics in Table 1 and the air permeability values are compared, the close values of the F2 and F3 fabrics cannot be explained by the different types of weaving. The striking point here is that the F2 and F3 fabrics have similar density and yarn counts rather than the effect of increase or decrease in weight and thickness on air permeability. However, although the exact effect of the yarn number cannot be shown here, it is thought that the close weft and warp density of the F1 and F4 fabrics cause the air permeability to come out close to each other. Moreover, another remarkable factor is that in each pairwise comparison, the air permeability value of woven fabrics made of 100% bamboo fibers, provided that the density values are close to each other, decreases as the weight and thickness decreases.

4. Conclusion

It is expected that highly developed designs and products in terms of wearing comfort will be produced thanks to the developments to be made in objective and subjective comfort measurement and evaluation methods and new materials to be produced for the purpose in future.

Developing technology and competition conditions directly affect the textile and ready-to-wear industry. Moreover, it is also known that uninterrupted comfort provided thanks to the comfortable clothing increases the motivation and efficiency of the employees. When the fact that people wear clothes during all day and night is considered, the importance of wearing comfort may be understood better.

Thanks to its excellent moisture absorption and rapid evaporation ability, natural bamboo fibers provide functionality as well as the comfort features expected from clothing to the textile products.

In this study aiming to shed light on new materials, technologies and designs to be brought into ready-to-wear clothing for production of clothes with wearing comfort features, physical properties of fabrics woven with 100% bamboo fiber yarns were compared to the thermal resistance, water vapor permeability and air permeability data from the parameters of wearing comfort and the following results have been obtained.

- The thermal resistance value varies according to the type of weaving. It has been observed that twill weaves have higher cloth feet than weaving.
- The thermal resistance value increases as the density and yarn count decreases and, provided that the weaving type is the same, as the thickness and weight decrease.
- Water vapor permeability directly increases with increasing weight or thickness regardless of weaving type or density and yarn count.
- The close air permeability values of 100% bamboo woven fabrics with different physical properties may be explained by the close density values.
- The closeness of air permeability values decreases as the weight or thickness decreases in 100% bamboo woven fabrics with different physical properties, provided that the density values are close.

Along with the results obtained from this study, the examination of how the close weight and thickness values and the water vapor permeability changes according to other physical properties of fabric and how the air permeability value changes according to the parameter in the difference frequency values may also be the subject of future research. Moreover, the effect of weaving type on air permeability may also be investigated.

Combining the unique properties of bamboo fiber with fabric parameters examining its effect on the comfort properties is of capital importance in terms of wearing comfort. Thus, it is believed that increasing the number of researches on the subject will provide new ideas to the sector in terms of wearing comfort and functional clothing production and design.

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