Investigation of the Change in Thermal Properties of 100% Wool Woven Fabric Covered with Interlining and Lining with Different Properties

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Abstract- Thanks to the developments in the textile and ready-to-wear market, the expectations of individuals from garments 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 garments with comfortable clothing design and production.Wearing comfort is a subjective concept meaning that a person feels comfortable in a garment. Although the concept of feeling comfortable may vary from person to person, clothes that protect us against external factors such as heat, cold, and wind, and cause 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 all day and night indicates the importance and necessity of wearing comfort.Due to reasons such as today's consumer trends, fast competition conditions, and the wish of creating a difference in clothing, the textile and ready-to-wear market has rapidly turned to produce comfortable clothing. 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. While investigating the effects of these innovations on wearing comfort, various physical properties of woven fabrics, which constitute an important part of ready-to-wear products, should be emphasized.It is known that a classic jacket is an important part of business life, daily life, and special occasions. However, it is an unloved and mostly avoided garment for male consumers because of the feeling of discomfort in addition to its weight and restriction of movement. For this reason, this study aims to examine the materials used in the production of classic jackets in terms of wearing comfort. To find out how the auxiliary materials used in the production phase of the classic jackets affect the comfort properties together with the physical properties of the fabric, the thermal resistance, water vapor resistance, and air permeability measurements were performed together with the fabric, fabric-interlining, and fabric- interlining-lining, the results were compared, and the optimum comfort values were determined. These measurements aim to find the optimum value for 100% wool fabrics.Sheared dirty wool tagged from sheep is called “fleece”. However, in the broad sense, fleece refers to all the hairs that are removed from the animals in form of shirts during tagging and that can be twisted and threaded. In fabric production, washed and cleaned form of fleece is used [1]. Wool is the tagged, washed, and cleaned form of the fleece shirt covering the sheep. However, the hairs obtained from the backs of some other animals are also called wool [2]. Animal fiber, whose basic building block is protein, is preferred in valuable worsted suits and knitted outerwear [3] due to its positive properties such as lightness, soft-touch, warmth, and ease of ironing [4]. As the most used fabric in men's classical clothing in terms of comfort features, wool is chosen to be studied..

Keywords Thermal Comfort, Woven Fabric, Wool Woven, Lining, Interlining.

1. Introduction

The association of humans 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 meet systematically within the framework of more conscious and technological logic.

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

The garment is a barrier consisting of one or more layers and protecting the body against unsuitable physical conditions.

Today's working people prefer useful garments that can be used both in business life and in daily free time. In such a case, besides the performance features, the comfort features of the garments are also important. The feeling of comfort is related to the transmission of a stimulus related to environmental stimuli such as temperature, wind speed, light, and humidity to the brain. The feeling of discomfort to be felt in any of the factors mentioned above due to the garments or the psychological state of the wearer will also eliminate comfort.

Clothing comfort may be defined as not feeling any physical or psychological discomfort due to the touch of the garment on the skin, feeling comfortable, or a sense of satisfaction.

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 [5].

The developing technology and competition conditions also require 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. [6].

The primary purpose of our clothes is to minimize the heat loss of our bodies. Thermal comfort is also directly affected by the insulating properties of the garment. Very thick garments increase thermal stress. In addition, clothes that provide insufficient insulation can cause diseases and even skin injuries.

The 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.

The garment acts as a protective buffer between people and the environment they live in and thus plays an important role in 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 [7].

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 wearer feel wet when the fabric contacts the skin [8].

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 [7].

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

- High thermal resistance for cold protection,
- Enough water vapor resistance for effective heat transfer in mild climatic conditions
- Rapid air permeability to minimize the uncomfortable feeling of contact caused by sweating in high thermal environment conditions and to provide effective heat conduction. [8].

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 [9].

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) The 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) The 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, and movement of surrounding air [10].

The unique physical and chemical structure of wool fiber makes it valuable for apparel. Some features making wool indispensable for apparel are as follows: [4]

• keeping warm and cold
• breathability
• ability to absorb moisture and carry it in its structure
• flexibility
• low odor feature
• odor-absorbing ability
• softness
• flame retardancy and
• biodegradability and suitability for recycling

Wool fiber is also vital in terms of protecting and creating a sustainable environment thanks to features such as being a renewable resource, 100% decomposition in nature, and positive effects on reducing carbon emissions. Wool fiber is highly adaptable to advanced technology and industry. It is also very suitable for meeting the growing trend of eco and sustainable clothing production in the world [11].

Hydrophilic/hygroscopic fibers such as cotton, viscose, and wool absorb moisture, while hydrophobic fibers such as polyester and polypropylene do not. It is stated that hygroscopic fibers that absorb water and have high moisture content pass water vapor more. The hygroscopic fabric absorbs water vapor from the moist air near sweaty skin and releases it into dry air. Compared to non-hygroscopic fabric, the hygroscopic fabric is stated to relatively increase the water vapor flow from the skin to the environment, thus reducing the formation of moisture in the microclimate region between the skin and the fabric [12]. There are many experimental studies in the literature on the water vapor permeability of fabrics consisting of hydrophilic fibers such as cotton, viscose, modal, lyocell, and hydrophobic fibers such as polyester, acrylic, and nylon. However, as the number of studies on the thermal properties of wool and the factors affecting them is limited, 100% wool fabrics were selected to contribute to the literature.

2. Method

2.1. Material

In this study, as the auxiliary materials used in the production of classical jackets, lining and interlining were selected and examined in terms of their effects on comfort properties. The physical properties of the samples used for analysis are given in Table 2 and Table 3.

This study was carried out through a descriptive method, in which a woven fabric made of 100% wool fiber was adhered to an interlining and then coated with a lining to determine the effect of thermal comfort on the characteristics of wearing comfort.

The lining is a type of thin and shiny fabric that is usually put inside clothes. However, apart from the upper fabric, any fabric used inside may also be qualified as lining.

Interlining is an intermediate material used to strengthen the quality and appearance of garments and to preserve the form of the garment for a long time. It is generally adhered to the inner surface of the garment or used between the fabric and the lining without being adhered to. Interlining is a material used to prevent stretching and wrinkling, provide full stance, increase durability, and provide ease of sewing, ironing and use [13].

The materials of the research consist of three different 100% wool woven fabrics in different thicknesses, weaving types, weight, density, and yarn count, and the thermal resistance, water vapor resistance, and air permeability data obtained from these fabrics besides the thermal resistance, water vapor resistance, and air permeability data obtained after coated with interlining and then lining respectively.

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

Table 1. Physical properties of 100% wool fabrics

Fabric Code	**Weaving Type**	**Mixture**	**Basis Weight (g/m^2)**	**Weft Density (piece/cm)**	**Warp Density (piece/cm)**	**Fabric Thickness (mm)**	**Weft Yarn Count (Nm)**	**Warp Yarn Count (Nm)**
K1	Plain Weave	100% Wool	142	23	26	0,246	49	38
K2	2/2 Twill	100% Wool	163	27	29	0,295	55	42
K3	Tartan	100% Wool	160	24	29	0,262	34	36

Table 2. Physical properties of linings used in the study

Material	Mixture	Weaving Type	Basis Weight (g/m^2)	Thickness (mm)
Lining 1	%100 Pes	Plain Weave	0,560	0,11
Lining 2	%100 Pes	Twill	0,910	0,14

(PES: Polyester)

Table 3. Characteristics of interlinings used in the study

Material	Mixture	Weaving Type	Adhesion Temperature (℃)	Adhesion Pressure (N/cm^2)	Adhesion Duration (sec)	Total Weight (g/m^2)
Interlining 1	%100 Pes	Plain Weave	127-143	2-4	10-12	50
Interlining 2	%100 Pes	Twill 3/1	127-143	2-4	12-18	70
Interlining 3	%100 Pes	Twill 3/1	127-143	20-40	10-12	85

After the weight and thickness of the fabrics and lining were measured in the physical test laboratory of Marmara University, weft and warp densities were detected by counting in cm with loops and weft, and then warp yarn numbers were calculated with the data obtained. Fabric thickness was measured according to the EN ISO 5084:1996 standard accepted by ISO (International Organization for Standardization). To find the fabric thickness, the samples were measured under 10g/cm2 pressure in the fabric thickness measuring device with 0.01mm precision and the arithmetic average of the repeated measurement results was taken separately for each sample. Fabric weight measurement was performed by EN (European Norm) 12127:1997 standard accepted by CEN (European Standards Committee). The samples cut with a circular sample cutter were weighed with a precision balance, and after calculating the weights of the unit areas, the basis weights of the fabrics were found. The values are the average of three measurements performed on the pieces taken from different parts of the fabrics from all samples in the devices calibrated before the measurement.

2.2. Procedure

Marmara University Permetest device and SDL Atlas Air Permeability Tester in Ekoteks Textile Laboratory 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 performed in the SDL Atlas Air Permeability Tester, the data obtained were compared and evaluated. The interlining process was carried out at Stp Mt Interlining Press in Istanbul Lupoteks. Lining sewing processes on interlining fabrics were done manually by me.

Permetest is a device developed by Lubos Hes and used to measure the water vapor permeability and thermal resistance of woven, knitted fabrics and non-woven textile surfaces. Called a skin model, this device represents the dry and wet human skin using 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. [10].

Water vapor resistance measurement range: 1-200 m2Pa/W-1

Thermal resistance measurement range: 0.02 - 1 m2˚C/W

Fig. 1. STP MT interlining press

Fig. 2. Permetest device

Measurements with the air permeability tester have been carried out by the ISO 9237 standard. Air permeability measurement results have been taken at a pressure of 100 Pascal from a surface area of 5 cm2.

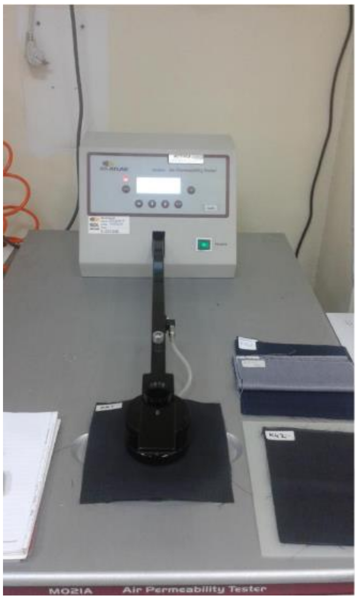


Fig. 3. SDL Atlas air permeability tester

After performed for all fabric samples, all these measurements were repeated by sticking interlining to the fabrics to observe the effect of the lining and interlining, and then repeated by sewing the lining to all the interlining fabric samples. At the end of five measurements, the average of each sample was taken and used in the study.

3. Findings and Discussion

This study aims to explore the thermal effect of adding interlining and lining to the fabrics woven with yarns obtained from 100% wool fibers on the wearing comfort, and thermal resistance data of the fabric without interlining obtained from the permetest device are shown in Table 4. The uninterrupted water vapor resistance measurement data of the fabric without interlining are shown in Table 5.

The concept of thermal resistance refers to the resistance of the material to heat flow and is expressed as shown below [14].

Resistance is an important comfort parameter referring to the ability of a garment to protect the wearer from the cold on cold days. In fabrics with low thermal resistance value, heat energy decreases and the person feels cold and uncomfortable [15].

Table 4. Thermal resistance measurement results of 100% wool fabrics from permetest device

Fabric Code	Measurement 1	Measurement 2	Measurement 3	Average Thermal Resistance (m^2k/W)
K1	0,6	0,6	0,6	0,6
K2	1,05	1,05	1,05	1,05
K3	0,72	0,72	0,72	0,72

When the body temperature rises due to various reasons such as high air temperature, high levels of physical activity, or intense emotions, the body sweats to lower the temperature. Evaporation of sweat from the skin creates moisture vapor in the area between the garment and the skin. For the person to be comfortable in the garment, the garment should be able to transmit the sweat in the form of vapor to the surrounding air. The ability of the garment to transmit sweat in the form of vapor is called water vapor permeability, and it is one of the important parameters providing garment comfort.

Otherwise, the relative humidity in the garment increases causing an uncomfortable feeling of wetness on the skin [12-16].

Water vapor permeability is the ability of a fabric to release its moisture and vapor outside. A garment fabric with a low water vapor permeability value shows that the fabric fails to expel the sweat and heat generated by the body and gives the wearer a feeling of discomfort [17].

Therefore, thermal comfort also depends on the extent to which the garment transmits heat and the sweat evaporates from the skin [18].

Sweating is a body mechanism lowering the body temperature starting to rise, and providing the sweat formed on the skin surface to evaporate. Liquid and vapor sweat permeability of the garment fabric is an expected feature for the wearer to feel comfortable.

The water vapor resistance of fabrics is affected by many parameters. These factors are the structural properties of fabrics (porosity, thickness, and density of the fabric), the structural properties of yarns (count, twist, hairiness, geometry, and packing density of the yarns), and fiber properties (type, blend ratio, fineness, density, porosity, and cross-section of the fiber) [19].

Table 5. The results of water vapor resistance of 100% wool fabrics without interlining obtained from permetest device

Fabric Code	Measurement 1	Measurement 2	Measurement 3	Average Water Vapor Resistance (m^2Pa/W^{-1})
K1	1,9	2	2	1,96
K2	2	2,2	2,1	2,1
K3	2,3	2,2	2,2	2,23

Air permeability is defined as the amount of air passing through a material at a unit pressure over a unit area in a given time. Its unit is lt/m2s. As known, as the heat transfer properties of fabrics with high air permeability are better, the wearer feels more comfortable in such a garment [20].

The transfer and permeability properties of fabrics, such as air and water vapor resistance, depending on their geometric properties, especially thickness and porosity (frequency) [21].

The tighter the knit, the lower the air permeability. In other words, there is a strong relationship between air permeability and fabric porosity in tightly woven fabrics, unlike the weak relationship between air permeability and fabric porosity in loosely woven fabrics [22].

Air permeable fabrics can also transfer liquid and vapor forms of water. The movement of air and water vapor in a garment is one of the most important factors affecting the comfort of that garment [23].

Table 6. The Results of Air Permeability Measurements of 100% Wool Fabrics without Interlining Obtained from SDL Atlas Air Permeability Tester

Fabric Code	Measurement 1	Measurement 2	Measurement 3	Average Air Permeability (lt/m2/sn)
K1	265	244	257	255,3
K2	96,8	101	111	102,9
K3	95,8	97,5	93,4	95,57

The samples were prepared by adhering to three different types of interlining 50 grams, 70 grams, and 85 grams, on the three 100% wool woven fabric samples with different physical properties used in the study. The results of thermal resistance and water vapor resistance measurement results of fabrics with interlining are given in Table 7 and Table 8.

Table7. Thermal resistance measurement results of fabrics with interlining

	Thermal Resistance with Interlining (m^2k/W)											
Fabric Code	**50g**	**50g**	**50g**	**Ort.**	**70g**	**70g**	**70g**	**Ort.**	**85g**	**85g**	**85g**	**Ort.**
K1	1,3	0,9	1,2	**1,13**	1,3	1,3	1,2	**1,26**	1,7	1,4	1,8	**1,63**
K2	1,65	1,65	1,65	**1,65**	1,35	0,85	1,15	**1,11**	1,6	1,7	1,7	**1,66**
K3	1,9	1,45	1,7	**1,68**	1,05	1,2	1,35	**1,2**	0,8	1,4	1,2	**1,13**

Table 8. Water vapor resistance measurement results of fabrics with interlining

	Water Vapor Resistance with Interlining (m^2Pa/W^{-1})											
Fabric Code	**50g**	**50g**	**50g**	**Avg.**	**70g**	**70g**	**70g**	**Avg.**	**85g**	**85g**	**85g**	**Avg.**
K1	3,4	3,3	3,1	**3,26**	3,1	3,4	3,8	**3,43**	3,7	3,8	3,8	**3,76**

K2	3,5	3,2	3,4	**3,36**	4,1	4	4,1	**4,06**	4,2	4,3	4,1	**4,2**
K3	3,7	3,5	3,6	**3,6**	3,9	4,1	3,9	**3,96**	4,4	4	4,4	**4,26**

The measurement results of 100% wool-woven fabrics with interlining in the SDL Atlas Air Permeability Tester are given in Table 9.

The thermal resistance measurements of the samples obtained by coating two different types of lining on 50, 70, and 85-gram non-woven fabric samples were made, and the average of the results is given in Table 10.

The average results of water vapor resistance measurements of the 50, 70, and 85-gram fabric samples with interlining and lining are given in Table 11.

The average results of water vapor resistance measurements of the 50, 70, and 85-gram fabric samples with interlining and coated with two different types of lining are given in Table 12.

Table 9. Air permeability measurement results of fabrics with interlining

	Air Permeability of Fabrics with Interlining (lt/m^2/sec)		
Fabric Code	**50g Avg.**	**70g Avg.**	**85g Avg.**
K1	122	124	112
K2	76,1	71,3	76,6
K3	66,9	67,8	53,5

Table 10: Average values of thermal resistance measurement results of 50g, 70g, 85g fabrics with interlining and lining

Fabric Code	**50g interlining + lining 1 thermal resistance (m^{2}k/W)**	**50g interlining + lining 1 thermal resistance (m^{2}k/W)**	**70g interlining + lining 1 thermal resistance (m^{2}k/W)**	**70g interlining + lining 1 thermal resistance (m^{2}k/W)**	**85g interlining + lining 1 thermal resistance (m^{2}k/W)**	**85g interlining + lining 1 thermal resistance (m^{2}k/W)**
K1	6,2	0,5	4,05	2,85	1,5	2,5
K2	3,5	1,4	6,85	4,7	2,3	2,4
K3	4,85	1,25	4,7	3,2	0,75	2

Table 11: Average values of water vapor resistance measurement results of 50g, 70g, 85g fabrics with interlining and lining

Fabric Code	**50g interlining + lining 1 water vapor resistance (m^{2}Pa/W^{-1})**	**50g interlining + lining 2 water vapor resistance (m^{2}Pa/W^{-1})**	**70g interlining + lining 1 water vapor resistance (m^{2}Pa/W^{-1})**	**70g interlining + lining 2 water vapor resistance (m^{2}Pa/W^{-1})**	**85g interlining + lining 1 water vapor resistance (m^{2}Pa/W^{-1})**	**85g interlining + lining 2 water vapor resistance (m^{2}Pa/W^{-1})**
K1	4,6	5,2	4,7	5,35	4,9	5,35
K2	4,55	5,25	4,7	5,6	5,05	5,6
K3	4,9	5,65	4,75	5,85	4,8	5,75

Table 12: Average values of air permeability measurement results of 50g, 70g, 85g fabrics with interlining and lining

Fabric Code	50g interlining + lining 1 air permeability (lt/m^2/sec)	50g interlining + lining 2 air permeability (lt/m^2/sec)	70g interlining + lining 1 air permeability (lt/m^2/sec)	70g interlining + lining 2 air permeability (lt/m^2/sec)	85g interlining + lining 1 air permeability (lt/m^2/sec)	85g interlining + lining 2 air permeability (lt/m^2/sec)
K1	115,5	55,5	115,3	56	112,5	57,35
K2	91,05	44,95	72,7	42,6	75,4	40,9
K3	72,75	42,06	72,1	39,8	79,65	44,25

In the study, thermal resistance, water vapor resistance, and air permeability tests were carried out on fabric samples without interlining to evaluate the thermal properties of 100% wool-woven fabrics and determine how the interlining and lining will affect the thermal properties of the fabric. It was detected that the thermal resistance results of samples without interlining are high for the K2 coded fabric. When the table showing the physical properties of the fabrics is examined, it may be easily inferred that the fabric is directly related to the parameters such as increasing yarn number, thickness, weight, and weft-warp density compared to the other two fabrics.

When the water vapor resistance measurement results of fabric samples without interlining are examined, a decrease is observed in the K1 coded fabric. When the physical properties of the fabric are examined, it may be stated that the lower the weight and thickness values of the fabric are, the lower the water vapor resistance value is. For a clear conclusion on weft warp density and yarn counts, more sample comparisons are required.

When the results of air permeability measurements performed on the samples without interlining are examined, any definite correlation with any physical property can be observed. It is possible to state that the effect of thickness and weight changes by the weaving type of the fabric and this affects the air permeability. As shown in the table, other thermal properties, except air permeability, have a direct relationship with the physical properties of the fabric. This exact effect on air permeability may be shown more clearly by testing more samples.

To determine the effect of interlining on the thermal properties of the fabric, three interlinings in different weights adhered to the fabric surfaces, and the measurements were renewed. At the end of the measurement, it was observed that the thermal resistance value increases in all interlining coated fabrics. However, this increase is not directly proportional to the weight of the interlining in every fabric type. In the K1 numbered fabric, the thermal resistance increases along with the increasing interlining weight. K2 and K3, on the other hand, do not have physical properties to imply any effect of the weight of the interlining on the increase and decrease of thermal resistance. At this point, the fact that the samples measured were taken from different parts of the fabric is noteworthy. The regionally varying weight and thickness differences in the fabric refute the argument that an increase in weight in interlining directly increases the thermal resistance. It is thought that the fabric numbered K1 shows less deviation in weight and thickness. However, when compared with the physical properties table of the interlining, it may be seen that 50 grams of interlining is plain weave and the others are twill weave, and this interlining increases the thermal resistance value of all fabric types. It may be inferred that the weaving type of the interlining affects thermal resistance. At the same time, the fabric coded as K1 is also plain weave.

When the results of the water vapor resistance measurement carried on the 100% wool woven fabrics with interlining was examined, it may be seen that interlining increases the water vapor resistance for each fabric type. At the same time, as the weight of the interlinings increase, the water vapor permeability for all fabrics used increases, too. Water vapor permeability also adds breathability to fabrics. For this reason, it is a sought-after feature not only in sportswear but also in all types of garments. The transmission of water vapor from the textile structure is a quite complex process and is affected by many properties such as fiber, yarn, and fabric parameters.

For all fabric types used in the study, it may be seen that covering with interlining significantly reduced the air permeability values. However, only for the fabric coded as K1, as the weight of the interlining increases, the air permeability decreases. However, it is not possible to observe this effect in other fabric types. Here, this effect may be attributed to the type of weaving rather than the physical properties of the fabric. As mentioned before, the fabric coded as K1 is plain weave.

Air permeability, which is a useful feature related to holding or transmitting the air passing through the fabric, is affected by the fiber structure forming the fabric, the yarn structure, the construction of the fabric besides the finishing processes applied. At the same time, as a parameter dependent on fabric porosity and referring to the breathability of the fabric, air permeability also affects thermal comfort properties.

To determine the effect of the lining on the thermal properties of the fabric, the interlinings in different weights adhered to three fabric surfaces were covered with two different linings and the measurements were repeated. First of all, when the thermal resistance measurements are examined, a significant increase in thermal resistance values of all fabrics coated with 50 gram interlining and lining 1 is observed. However, thermal resistance values decrease in all fabric types coated with 50 grams of interlining and lining 2. Here, lining 1 is a lighter and thinner plain cloth than the other. When the table is examined, the highest increase is observed in plain fabric and plain interlining.

When the thermal resistance measurements of 100% wool woven fabrics coated with lining 1 or 2 and 70 grams of interlining are examined, an increase in both lining 1 and lining 2 may be seen. If the increase between the lining types is compared, it may be seen that lining 1 creates higher thermal resistance values than number 2, as in 50 grams of interlining.

It is also observed that the thermal resistance values of the fabrics with lining 2 and 85 grams of interlining increase, despite being not as high as in the 70 grams of interlining. In addition, the thermal resistance values of fabrics coated with lining 2 are higher than those of lining 1. On the other hand, there is no or very little increase in fabrics coated with 85 grams of interlining and lining 1. It is possible to attribute these increases to the weight and thickness of the linings.

Similarly, when the water vapor resistance measurement results of the fabrics with linings are evaluated, it is observed the water vapor resistance values of all fabrics coated with lining 1 and lining 2 among fabrics with 50 grams of interlinings increase. Lining 2 has higher values than lining 1. It is possible to attribute the change here to the greater thickness and weight of lining 2.

When the 100% wool woven fabrics are covered with both 70 grams and 85 grams of interlining besides lining 1 and lining 2, and the water vapor measurements are repeated, an increase in the measurement results in both lining types is observed. Again, as in the previous result, the values in the fabrics coated with lining 2 are higher than those of lining 1.

Finally, when the air permeability measurements with lining are examined, the air permeability measurements of the fabrics with 50 grams of interlining show a slight decrease for K1 and a slight increase for K2 and K3, all coated with lining 1. The fabric showing the decrease is the plain weave. In lining 2, the air permeability decreases significantly for all fabrics. The thicker and heavier lining is a twill weave.

The air permeability values of the fabrics coated with lining 1 and 70 grams of interlining either did not change at all or showed little increase or decrease, as in the fabrics with 50 grams of interlining and lining 1. The effect of the lining is negligible. However, decreases are still evident in the twill woven lining 2. Indeed, regardless of the interlining weight, lining 2 shows a decrease at the same rates. The decrease in air permeability means that the garment keeps the wearer warmer.

When the air permeability measurement values of the fabrics with 85 grams of interlining and lining 1 are compared with the fabrics with 85 grams of interlining and lining 2, it is determined that the air permeability decreases significantly in the fabrics covered with a thicker and heavier twill woven lining.

The weaving structure of the fabrics affects the air permeability. Thickness, air permeability, and thermal insulation values of twill fabrics are higher than plain fabrics [24, 25]. As for fabric thickness and density increase, and as a result, air permeability decreases, fabric thermal conductivity values decrease. As the frequency decreases, air permeability and thermal conductivity increase [26].

4. Conclusion and Recommendations

In this study, the aforementioned tests were carried out to determine the effect of auxiliary materials such as interlining and lining used in the production of classical jackets on the thermal comfort of the jacket and the most ideal thermal compatibility in the fabric, interlining, and lining. The tests were carried out based on determining comfort characteristics by methods based on objective measurements. Fabric parameters were determined as weight, fabric thickness, weft-warp yarn count, and weft-warp density. In the light of other studies, it is known that the properties of fiber, yarn, and fabric are always in relationship with each other and affect each other in terms of comfort properties. Today, in the ready-made clothing industry, the possibility of adding comfort features besides many advanced technology features to the garment in many product groups is of great importance for consumers as a reason for preference. This study aims to show the classic jacket sector which scientific parameters to use for producing a more comfortable garment.

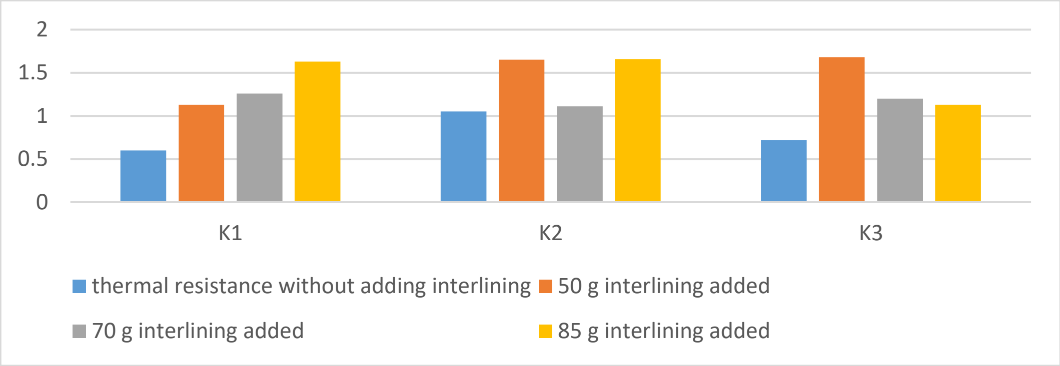
It is expected that highly developed designs and products in terms of wearing comfort will be produced thanks to the developments to be made in objective and subjective comfort measurement and evaluation methods and new materials to be produced for the purpose in the future.

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 comfortable clothing increases the motivation and efficiency of the employees. When the fact that people wear clothes all day and night is considered, the importance of wearing comfort may be understood better.

Despite the high cost of wool fibers, as the percentage of wool fiber in the fabric increases, the cold protection feature of the fabric improves. Wool fiber is highly and mostly preferred for being environmentally friendly, 100% natural, and ecological besides being renewable. As one of the most important thermal features of animal fibers, the ability to retain heat is directly related to the comfort of the garment. At the same time, natural fibers provide higher thermal insulation than artificial fibers [27].

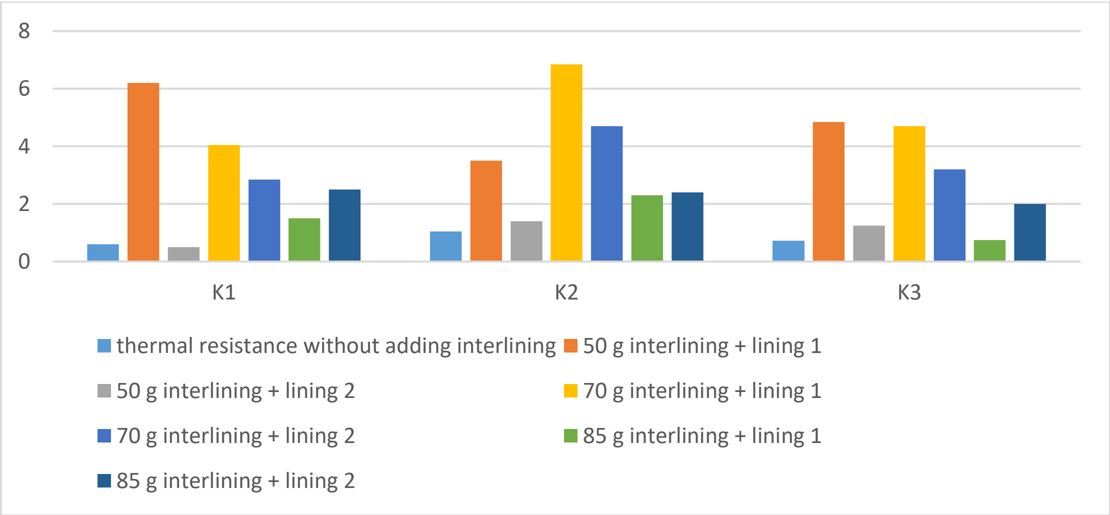
In this study, which aims to shed light on the production of garments to be brought to ready-to-wear with new materials, technology, and designs along with the characteristics of wearing comfort, the physical properties of the fabrics woven with yarns obtained from 100% wool fiber and the thermal resistance, water vapor resistance and air permeability data obtained from the clothing comfort parameters were compared and obtained and the results were shared.

Graphic 1. The effect of interlining on the thermal resistance of the fabric according to the weight



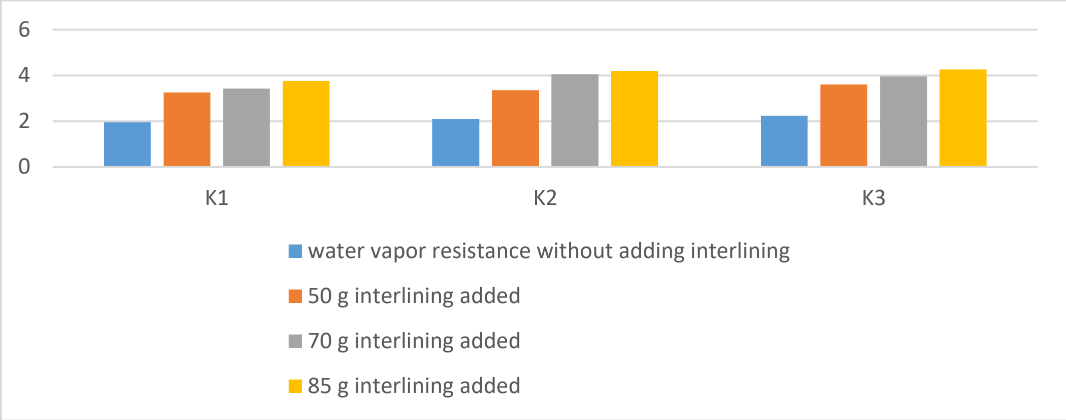
As can be seen from the graph, an increase in thermal resistance values is observed with the interlining effect. While the maximum increase for fabric number 1 was with the addition of 85 grams of interlining, it is observed that the effect of both 50 and 85 grams of interlining on the thermal resistance in our fabric number two is great. In fabric number three, 50 grams of interlining provided the highest thermal resistance increase. When we examine it in terms of thermal comfort, since it is thought that high thermal resistance is required to protect it from cold, the interlinings that will meet this vary depending on the fabric type, but are 50 and 85 grams. If we are going to make a product that we want to provide thermal resistance with fabric number 3, our choice of interlining should be the 50 gram one.

Graphic 2. The effect of interlining and lining addition on the thermal resistance of the fabric



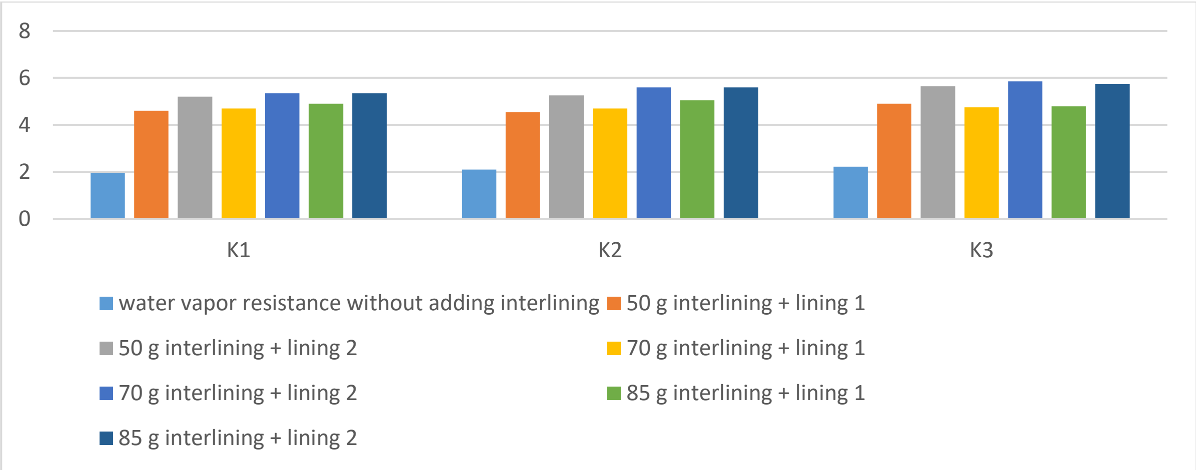
When the graph is examined, the thermal resistance of each lining type and the addition of interlinings in different weights has increased more or less compared to the uninterrupted fabrics. When looking at fabric types, the highest thermal resistance effect is for the number 1 fabric, the number 1 lining and 50 grams of interlining. For fabric number 2, it is 70 grams of interlining and again number 1 lining. For our fabric K3, the highest thermal resistance effect is achieved with the lining no. 1. The lining number 1 is 100% polyester, made of plain fabric. In places of use where high thermal resistance values are required, it would be appropriate to choose the lining number 1 and to select the high thermal resistance values in the first graphic according to the fabric type.

Graphic 3. The effect of interlining on the water vapor resistance of the fabric according to the weight



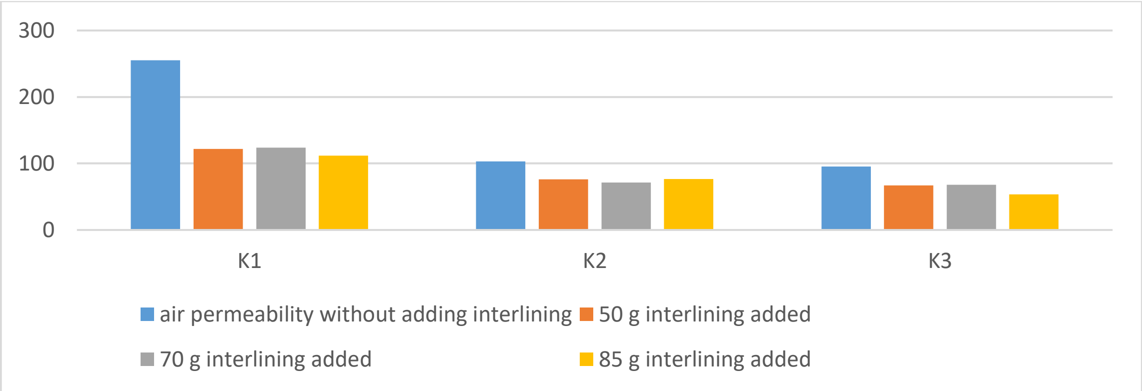
As can be seen from the graphic, the addition of interlining increases the water vapor resistance on the fabric. The highest increase was in the addition of 85 grams of interlining in direct proportion to the weight. It is also useful to remember that our increase in thermal resistance values was not directly proportional to the weight of the interlining.

Graphic 4. The effect of the addition of interlining and lining on the water vapor resistance on the fabric



When the graph is examined, it is seen that the water vapor resistance values increase for each lining and interlining of each weight. However, the highest increase was with the addition of the number 2 lining for each fabric type. The lining number 2 is twill weave and 100% polyester. Here, it is thought that the main reason for showing more water vapor resistance than the number 1 lining is the higher weight of the lining, rather than the type of fabric.

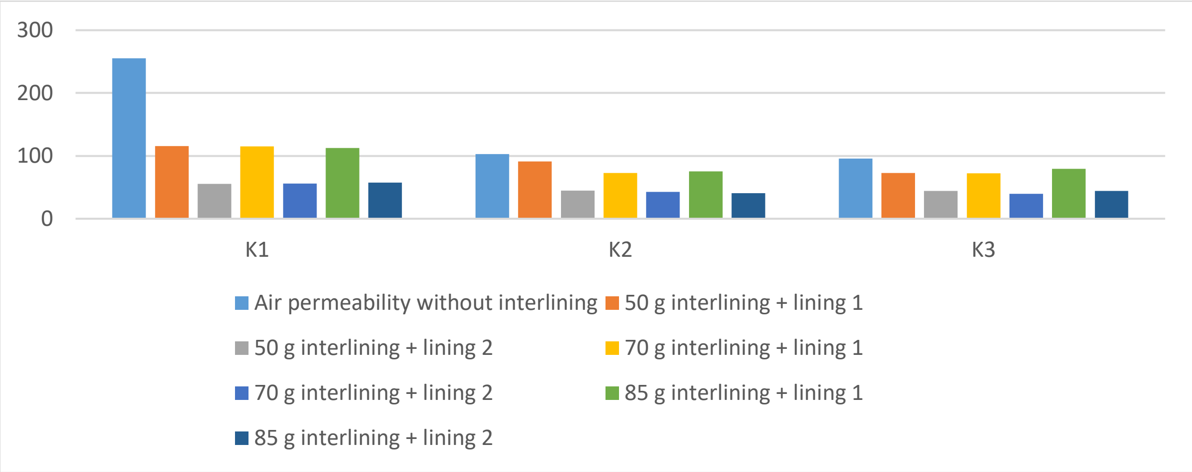
Graphic 5. The effect of interlining on the air permeability of the fabric according to the weight.



When the graph number 5 is examined, the air permeability values of each fabric type decrease according to the uninterrupted weight, regardless of weight. The decrease is proportional to the weight. As the interlining thickens, the air permeability decreases.

An ideal fabric in terms of thermal comfort should provide rapid air permeability in order to minimize the uncomfortable feeling of contact caused by sweating in high temperature ambient conditions and to provide effective heat conduction. [8] So, we can say that we can provide this in 50 grams of interlining for every fabric type.

Graphic 6. The effect of interlining and lining addition on air permeability on the fabric



When the graph is examined, it is seen that the air permeability values decrease for each lining and interlining of each weight. However, the greatest decrease was with the addition of the number 2 lining for each fabric type. The lining number 2 is twill weave and 100% polyester. Here, it can be said that the main reason why it shows less air permeability than the number 1 lining is that the weight of the lining is more than the type of weaving. It would be correct to prefer the number 1 lining in places of use where effective heat conduction is desired. However, in places of use where air permeability is not desired, it would be a good decision to cover the fabric with the number 2 lining.

Many parameters as structural properties of fabrics (porosity, thickness, and density of the fabric), structural properties of yarns (count, twist, hairiness, geometry, and packing density of yarns), and fiber properties (type, blend ratio, fineness, porosity, and section of fiber) besides even the finishing processes affect the thermal properties of the fabric. This study proves that in addition to all these, auxiliary materials added to the fabric, alone or together, also affect the thermal properties of the fabric. A thermally comfortable fabric may turn into a more comfortable or uncomfortable one with additional materials.

Today, clothing comfort is given increasing importance and thus, the effects of all the parts making up the clothing comfort should be investigated and comfort-specific garments should continue to be produced in line with the results. Today, clothing refers to comfort as well as elegance, status, and veiling. A person is happy and productive to the extent that he or she feels comfortable.

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