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Evaluation of Fabric Properties and Developing Undershirt Designs for Elderly Women

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ABSTRACT

The issue of clothing is one of the problems that come with ageing. Despite the need, there is no undershirt for women aged 65 and over in the market. In this study, first, a survey was conducted on the issuesfaced by women over the age of 65 while using undershirt. The functional and comfortable special undershirt for summer and winter was designed to solve and eliminate the problems by analysing the obtained results. In the study, first, 95%cotton/5%elastane, 95%bamboo/5%elastane, 95%viscose/5%elastane, cotton/bamboo/elastane, and cotton/viscose/elastane blended fabrics were produced in a single jersey knitting structure for summer undershirt. 100% cotton fabric was produced in the interlock knitting structure for winter undershirt. Second, these fabrics were pre-treated and the finishing treatments to provide some functional properties such as softness (cationic, microemulsion and macroemulsion silicones) and antibacterial properties were applied to these fabrics. After the finishing treatments, tests and analyses were carried out, and the fabric weight, elasticity and bursting strength tests were carried out to determine the physical properties of the fabrics. To determine the comfort properties of the fabrics, air permeability, water vapour permeability and thermal comfort properties tests were performed. According to the results, the functional and comfortable summer and winter undershirt were determined and produced for older women. At the end of the study, the opinions and suggestions of the people who wore them were evaluated by making clothing trials with the women's undershirts produced.

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KEYWORDS
Elderly undershirt, functional design, finishing treatment, physical test, comfort test

1. INTRODUCTION

The World Health Organization (WHO) defines biological ageing as the accumulation of damage in cells over time. This is a natural process that leads to reduced mental and physical capacity and an increased risk of diseases and death. According to a study conducted by the WHO in 2021, one out of every six people in the world willbe over the age of 60 by 2030, and by 2050, individuals over the age of 60 will double the world population [1].

Furthermore, according to the data obtained using population estimation methods, world population in 2020 was 7.693.348.454. The elderly population is estimated to be 729.887.660. According to these data, the elderly population constitutes 9.5% of the world population [2].

Every individual's physical features change with advancing age, their psychomotor skills decrease and their health condition deteriorates. These changes negatively impact their daily. Bodily systems such as the respiratory, cardiovascular, gastrointestinal, neurological, endocrine and immune systems rapidly change when the Individual is ageing. Moreover, skin and other physiological senses such as sight, taste and smell changes and weakens as well [3].

Despite the increase in their physical weakness due to ageing, individuals often wish to be independent,

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specifically when it comes to dressing and undressing oneself. Dressing independently is a fairly common issue among the elderly and physically disabled. Recent studies have reported the use of wireless technologies that are been integrated into textile products. These systems help in improving the quality of life of the elderly [4].

Clothing is one of the basic human needs. Individuals pay attention to the choice of clothing not only to protect themselves from external factors but also to feel good and to indicate their social status. Although the textile industry has seen much advancement recently, products dimensions are often designed according to the standard body sizes. These products are not suitable for the use by the elderly who have slightly different physical characteristics and limited mobility. Thus, considering the physical changes during old age, the importance of clothing increases even more [5].

Undergarments of the wrong size, when used daily, can cause more problems than other textile products, as these undergarments come in direct contact with the body. Brassieres (bras) of wrong sizemay cause pressure, irritation and itching. Due to physical and psychological changes, elderly women may experience problems such as the inability to use fasteners, insufficient support and discomfort. Elderly women often complain that bra clasps are difficult to reach due to limited mobility and lack of hand-finger coordination [6]. Thus designing comfortable clothing is a combination of many factors. These can be multiplied, such as flexibility, a garment wrapping around the body. Garments often act as a second skin. Therefore, clothing comfort also notably affectsa person's psychology [7]. Comfortable dresses can maintain the body heat and moisture balance under different conditions and during various activities [8,9]. Fibres such as cotton, viscose and bamboo are very comfortable textile materials. Cotton fibre is the most commonly used textile fibre globally. The cotton fabrics are comfortable, soft to the touch, have vibrant colours and excellent printing properties [10,11]. The first cellulosic fibre produced was viscose. Cellulose is the raw material used to produce viscose fibres. It is flat, soft, smooth and silky. It can be dyed into a myriad of colours because of its good dye-taking properties [12]. Although its dry and wet strength is lower than that of cotton, it has a better elongation property [13]. Bamboo products are generally recyclable and environmentally friendly, which is often desirable. Furthermore, bamboo fibre stands have remarkable properties as being breathable, cool and soft to the touch [14,15].

Copious amounts of research and studies have been conducted on fibre blends. Prakash et al. (2012) examined the properties of 50%/50% cotton/bamboo blends in their study and concluded that they had properties similar to 100% cotton [16]. Erdumlu and Özipek (2008) stated that bamboo and viscose are very similar to rayon in terms of dry strength, moisture absorption and elongation at break, and bamboo is better than viscose when considering their properties [15]. Gökdal (2007), in his study, concluded that the quality value decreases as the amount of bamboo decreases in the bamboo/cotton fibre-blended yarn mixture decreases [17].

Softening is a finishing process that is essential for textile products. Softeners can add softness, smoothness, flexibility, water resistance, stain resistance and antibacterial properties to textile products [18]. Textile softeners are often classified according to their ionogenity. Accordingly, there are cationic, anionic and non-ionic softeners [19].

According to Mengüç et al. (2019), several studies have been conducted on the use of softeners applied to cotton fabrics, but no studies have evaluated the use of softeners with bamboo. Thus, they examined the behaviour of bamboo with softeners in their study. In their report, they stated that since bamboo fabrics have a softener surface compared to cotton fabrics, the effect ratio of softeners is different and softeners have a significant effect on fabric stiffness [11]. Juodsnuktye et al. (2005) investigated the effect of softeners on washing. They concluded that the softeners applied to the fabric reduce the washing performance [20].

The fabric used to manufacture bras and athletic wear, which are readily available in the market, usually consist of synthetic raw materials and can be uncomfortable for the elderly. Furthermore, there are integrated designs for breast feeding mothers. However, none of these can be utilized by the elderly. Thus, the functional undergarments produced within the scope of this project will be designed entirely for the comfort of the elderly, and they will unique to the market.

The importance of physical properties in textile production is an indisputable. The physical test results help the manufacturers to choosing a fabric according to its seasonal applicability. Additionally, it is necessary to appropriately select a fabric for the purpose the resulting garment will serve. Over the years, clothing comfort and functionality has gained more importance.

In this study, women over 65 years of age, who were primarily from the İzmir (in Turkey) province, were asked to answera questionnaire. This survey revealed that the elderly experience difficulties wearing and taking off their clothes. They complained of difficulties when performing tasks that required precision, such as hooking bras clasps, buttonholes, fasteners. Considering these results, it was decided to develop functional athlete, which can be used daily and comfortably by the elderly. The aim was to design athletes that can be easily put on and taken off, and in which the person can feel comfortable all day long. At the end of the study, a clothing trial was made with the produced woman athletes. A mini survey was prepared for the wearers and the results of this survey were evaluated.

2. MATERIAL AND METHOD

In the research, an outline of the perception process was given in Table 1.

2.1. Material

The physical properties of the fabrics used in this study are given in Table 2.

Table 1. Outline of the research

Research Questionnaire	Physical Properties of Undershirt Fabrics	Thermal Properties of Undershirt Fabrics	Antibacterial Properties of Undershirt Fabrics	Design Properties of Undershirts	Clothing Trials
A Questionnaire	Fabric Tests	Fabric Tests	Fabric Tests	Undershirt Design	Summer and Winter Undershirts Wearing Tests
Participants (Women, The age of 65-80, İzmir) Survey Questions 1. Demographic information 2. Health situation (chronic illness, assistive device used) 3. Activities of daily living (dressing and undressing, going out, daily home chores, preferred clothings)	Fibre content Knitted structure Fabric weight Fabric thickness Elasticity Bursting strength	Air permeability Water vapour permeability Thermal conductivity Thermal absorptivity Thermal resistance Maximum heat flow	In antibacterial test processes, a test trial was conducted with Staphylococcus aureus and Escherichia coli bacteria, which are the most used in textiles.	It is aimed design an underwear that looks like a classic undershirt but is integrated with a bra and can be opened and closed from the front.	Participants (Women, The age of 65-80, İzmir) In the last stage of the study, the produced undershirts were tried and the feedback was evaluated with a questionnaire. Survey Questions 1. Demographic information 2. Is it easy to put on and take off the undershirt? 3. Is the undershirt restrict movements? 4. Is it different from the classic undershirt in terms of comfort?
The questionnaire was applied to 240 women between the ages of 65-80 living in İzmir. The questionnaire consists of 3 section and 15 questions, and all questions are closed-ended.	Standards TS 251 Method 6 (Fabric Weight) [21] TS 7128 EN ISO 5084 (Fabric Thickness) [22] ASTM 2594 (Elasticity) [23] TS EN ISO 13938-1 (Bursting Strength) [24]	Standards TS 391 EN ISO 9237 (Air Permeability) [25] ISO 11092 (Water Vapour Permeability) [26] ISO 11092 (Thermal Comfort) [26]	Standards AATCC TM100 [27]	An undershirt is designed for the elderly or people with limited mobility. Thus, an undershirt has been developed for people who have difficulty in extending their arms back due to frozen shoulder and have difficulty in holding small items such as fasteners.	However, some women found the front velcro fastener hard and impractical. For this reason, it is recommended to use thinner and shorter velcro.

Table 2. Physical properties of knitted fabrics

Fibre content (%)		95% Cotton/ 5%Elastane	95%Bamboo/ 5%Elastane	95%Viscose/ 5%Elastane	47.5%/47.5% Cotton/Viscose /5%Elastane	47.5%/47.5% Cotton/Bambo o /5%Elastane	100% Cotton
Knitted structure of the fabric		Single jersey	Single jersey	Single jersey	Single jersey	Single jersey	Interlock
Yarn count (Nm)		30/1	30/1	30/1	30/1	30/1	30/1
Spinning method		Open-end	Open-end	Open-end	Open-end	Open-end	Open-end
Fabric weight (g/m^2)		165.88	138.20	176.66	165.54	152.74	231.08
Fabric thickness (mm)		0.30	0.28	0.29	0.30	0.29	0.50
Bursting strength (N)		381.0	610.1	370.5	470.6	397.2	1076.5
Loop density (loop/cm)	**Wale yarn**	15	15	15	14	15	12
	Course yarn	16	17	17	16	16	13

Bra cup used in the final product 8 mm thick and produced from soft sponge. The Velcro tape used in the undershirt sewing is 1 cm wide and is sewn across ~~s~~ undershirt's front. Bra cups are generally produced of cotton or synthetic raw materials. In this study, unsupported bra cups obtained from cotton fabrics were used. Bra cup is used to shape the breasts. In addition, using a bra cup is not only aesthetically pleasing, but also important for health. Velcro consists of two main components; two linear fabric bands are clamped to each other's opposite surfaces and adhere. Thanks to this feature, it is easier to use as it does not need to be matched exactly like buttons or zippers.

2.2. Method

In this study, a questionnaire was used to primarily investigate the problems faced by women over the age of 65 while using undershirt in the İzmir province. In the survey study, individuals were asked questions about their health status, such as whether they used drugs and/or a medical device, in addition to their demographic information. In addition, it was aimed to make comments about movement restrictions by asking questions about sports habits to individuals. In the questionnaire, questions such as whether individuals can do their housework on their own, whether they need help while dressing or undressing, and whether they can do daily rıutines such as shopping on their own were asked. During the design of the undershirt, the comfort and ease of use were considered, owing to the needs of the target group. The bra was made of two layers of fabric. A pressed chest cup (sponge) was placed in between these layers. This sponge is called a bra cup. The bra cup used in the designed model was chosen as cotton and unsupported considering its comfort features. It was fixed with stitches from the edges to prevent the sponge from spreading inside with washing. The suspenders of the summer undershirt were thin and the neckline deeper; moreover, the winter undershirt was thicker and the necklinewas shallow.

Fibre types of single jersey fabrics produced for summer athlete were a blend of cotton/elastane, bamboo/elastane, viscose/elastane, cotton/bamboo/elastane and cotton/ viscose/elastane. 5% elastane yarn provided the necessary elasticity in all fabrics produced. Only natural 100% cotton fibrewas selected for the fabrics produced for winter. The knitting structure of winter products is interlockedand elastane fibre is not used since this knitting structure is flexible.

After the fabrics were produced, they were pre-treated because they were raw. The pre-treatment processes included bleaching and other basic processes. Then, softening finishing processes and antibacterial finishing processes were applied to these fabrics to impart their functional properties.

These finishing processes make fabrics soft to the touch and impart antibacterial properties. Different softeners such as cationic, microsilicone and macrosilicone were used in the softening processes. For antibacterial finishing processes, organofunctional silane chemical (dimethyloctadecyl [3-(trimethoxysilyl) propyl] ammonium chloride) the most widely used in the market. An antibacterial chemical was also added to the solutions prepared using three different softeners. The solutions prepared with each softener and antibacterial chemicals were applied to the fabrics using the impregnation method utilised the Ernst Benz brand laboratory-type vertical foulard device. After the applications, the drying processes were carried out on the fabrics using the ATAÇ GK-40 brand laboratory-type stenter. The chemicals used during the finishing processes in this study and the protocol and conditions of the finishing processes are depicted in Tables 3 and 4. While drying, only the cotton interlock fabric was dried within 3 min.

Table 3. Chemicals used in the finishing processes

Chemical type	Chemical structure	Ionic character	Company
Cationic softener (ALFALINA CT CONC)	Carbamide derivative	Cationic	Bozzetto Chemical
Microsilicone (SEBOSAN LES PLUS)	Modified microsilicone emulsion	Light cationic	Bozzetto Chemical
Macrosilicone (CEROFIL NH4)	Macroemulsion of polyamino siloxanes	Light cationic	Bozzetto Chemical
Antibacterialagent (BI-OME AM5)	Dimethyloctadecyl [3-(trimethoxysilyl) propyl] ammonium chloride	Cationic	Sardes Textile and Chemical

Table 4. Recipes and conditions of the finishing processes

Chemical type	Code	Recipe
Cationic softener + Antibacterial agent	K	20 g/L Cationic softener, pH 5 (With acetic acid) 50 g/L Antibacterial agent Impregnation (Pick-up: 80%) → Drying (100°C for 2 min.)
Microsilicone + Antibacterial agent	S	20 g/L Microsilicone, pH 5–5.5 (With acetic acid) 50 g/L Antibacterial agent Impregnation (Pick-up: 80%) → Drying (130°C for 2 min.)
Macrosilicone + Antibacterial agent	M	20 g/L Macrosilicone, pH 4.5–5 (With acetic acid) 50 g/L Antibacterial agent Impregnation (Pick-up: 80%) → Drying (130°C for 2 min.)

After finishing the treatments, the physical, performance and comfort tests of the untreated and treated fabrics were carried out. The final results were compared and evaluated. Finally, functional and comfortable winter and summer undershirt products for the elderly, which was the main purpose of the study, were designed and produced. And then, the summer and winter undershirts for elderly women were produced (Figure 1) according to the technical drawing of the undershirt (Figure 2). Undershirts were produced from fabrics determined as a result of this study.

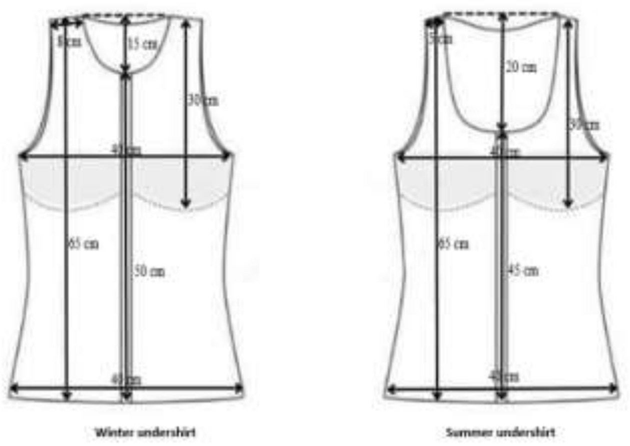

Figure 1. Winter and summer undershirts technical drawing

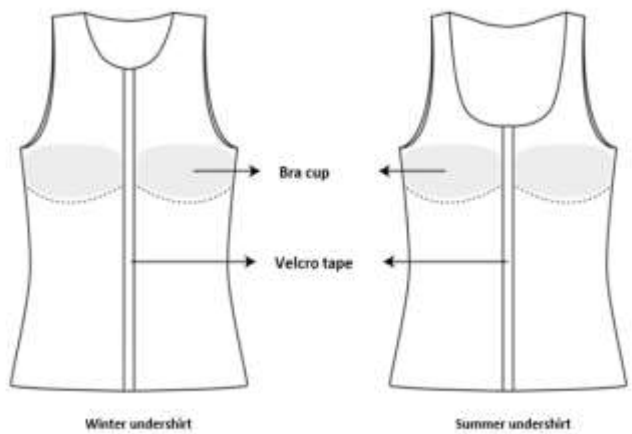

Figure 2. Winter and summer undershirts for elderly women

In the last stage of the study, the produced undershirts were tried by women, who are at 65 to 80 age, and the feedback of these trials was evaluated with a questionnaire. Demographic information of the participants was asked in the garment trial questionnaire made after sewing the designed model. In addition, questions were asked about whether the final product produced is comfortable to put on or take off, what is feels like when compared to standard undershirt models in terms of comfort, and whether it restricts movements. The answers to these questions were evaluated statistically by the authors and suggestions for improvement were made as a result of the study.

3. RESULT AND DISCUSSION

3.1. Physical Test Results of Undershirt Fabrics

3.1.1. Fabric weight

The fabric weights of the untreated and treated fabrics are illustrated in Figure 3.

According to the results of the untreated fabrics, 100% cotton interlock knitted fabric had the highest weight. The lowest weight was obtained in 95%bamboo/5%elastane knitted fabric. For the fabrics treated with cationic softener and antibacterial chemicals, the highest weight was obtained in 100% cotton interlock knitted fabric. The lowest weight was obtained in 95%bamboo/5%elastane knitted fabric. For the fabrics treated with microsilicone and antibacterial chemicals, the highest weight was obtained in 100% cotton interlock knitted fabric, and the lowest weight was obtained in 95%cotton/5%elastane knitted fabric. For the fabrics treated with macrosilicone and antibacterial chemicals, the highest weight was obtained in 100% cotton interlock knitted fabric, and the lowest weight was obtained in 95%cotton/5%elastane knitted fabric.

3.1.2. Fabric Thickness

The fabric thickness data of the untreated and treated fabrics are presented in Figure 4.

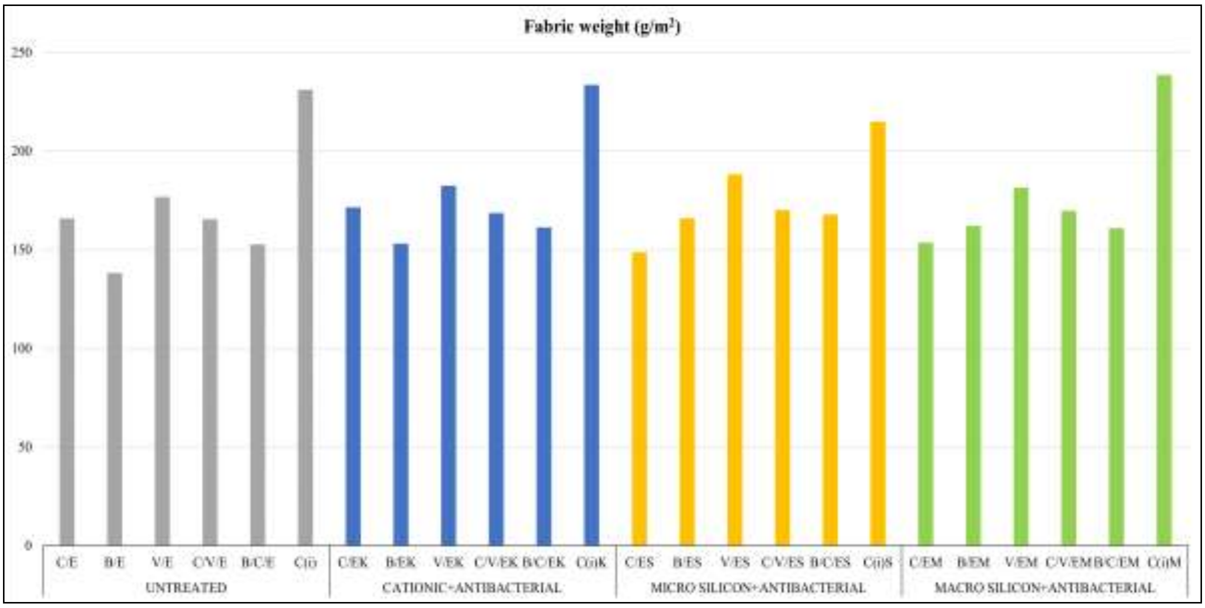

Figure 3. Fabric weight data of untreated and treated fabrics

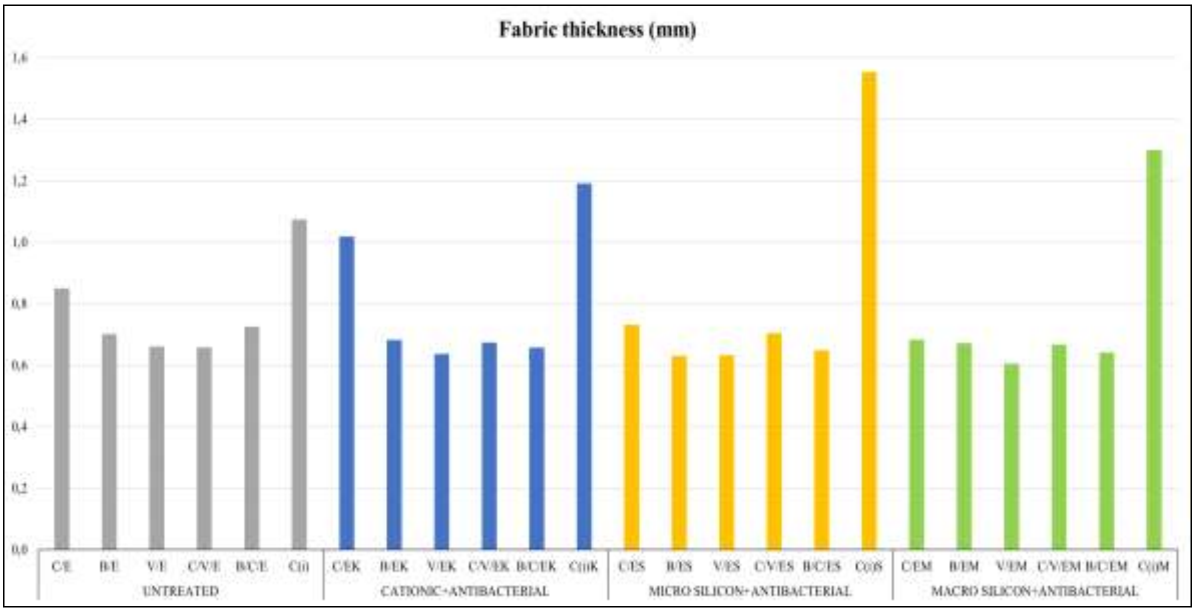

Figure 4. Fabric thickness data of untreated and treated fabrics

According to the fabric thickness data of the untreated fabrics, the highest and lowest thickness values obtained in 100% cotton interlock knitted and 95%viscose/5%elastane and cotton/viscose/elastane blended knitted fabric, respectively. For the fabrics treated with cationic softener and antibacterial chemicals, the highest fabric thickness was obtained in 100% cotton interlock knitted fabric and the lowest fabric thickness was obtained in 95%viscose/5%elastane knitted fabric. For the fabrics treated with microsilicone and antibacterial chemicals, the highest thickness was obtained in 100% cotton interlock knitted fabric and the lowest fabric thickness was obtained in 95%viscose/5%elastane and 95%bamboo/5%elastane knitted fabric. For the fabrics treated with macrosilicone and antibacterial chemicals, the highest fabric thickness was obtained in 100% cotton interlock knitted fabric, and the lowest fabric thickness was obtained in 95%viscose/ 5%elastane knitted fabric.

3.1.3. Elasticity

The fabric elasticity values of the untreated and treated fabrics are depicted in Figure 5.

According to the elasticity data of untreated fabrics, the highest elasticity was obtained in 100% cotton interlock knitted fabric. The lowest elasticity was obtained in 95%bamboo/5%elastane knitted fabric. For the fabric treated with cationic softener and antibacterial chemicals, the highest elasticity was obtained in 95%bamboo/ 5%elastane knitted fabric and the lowest elasticity was obtained in cotton/viscose/elastane blend knitted fabric. For the fabric treated with microsilicone and antibacterial chemicals, the highest elasticity was obtained in 100% cotton interlock knitted fabric. The lowest elasticity was obtained in cotton/bamboo/elastane blend knitted fabric. For the fabric treated with macrosilicone and antibacterial chemicals, the highest elasticity was obtained in 100% cotton interlock knitted fabric and the lowest elasticity was obtained in 95%viscose/5%elastane knitted fabric.

3.1.4. Bursting strength

The fabric bursting strength values of the untreated and treated fabrics are shown in Figure 6.

According to the bursting strength data of untreated fabrics, the highest bursting strength values were obtained in 100% cotton interlock knitted fabric. The lowest bursting strength values were obtained in 95%viscose/5%elastane knitted fabric. Furthermore, for the fabrics treated with cationic softener and antibacterial agents, the highest bursting strength values were obtained in 100% cotton interlock knitted fabric and the lowest bursting strength values were obtained in 95%cotton/5%elastane knitted fabric. For the fabrics treated with microsilicone and antibacterial, the highest bursting strength values were obtained in 100% cotton interlock knitted fabric. The the lowest bursting strength values were obtained in 95%viscose/5%elastane knitted fabric. For the fabrics treated with macrosilicone and antibacterial, the highest bursting strength were obtained in 100% cotton interlock knitted fabric and the lowest bursting strength were obtained in 95%viscose/5%elastane knitted fabric.

3.2. Comfort Test Results of Undershirt Fabrics

3.2.1. Air permability

The airpermeability data of the untreated and treated fabrics were given in Figure 7.

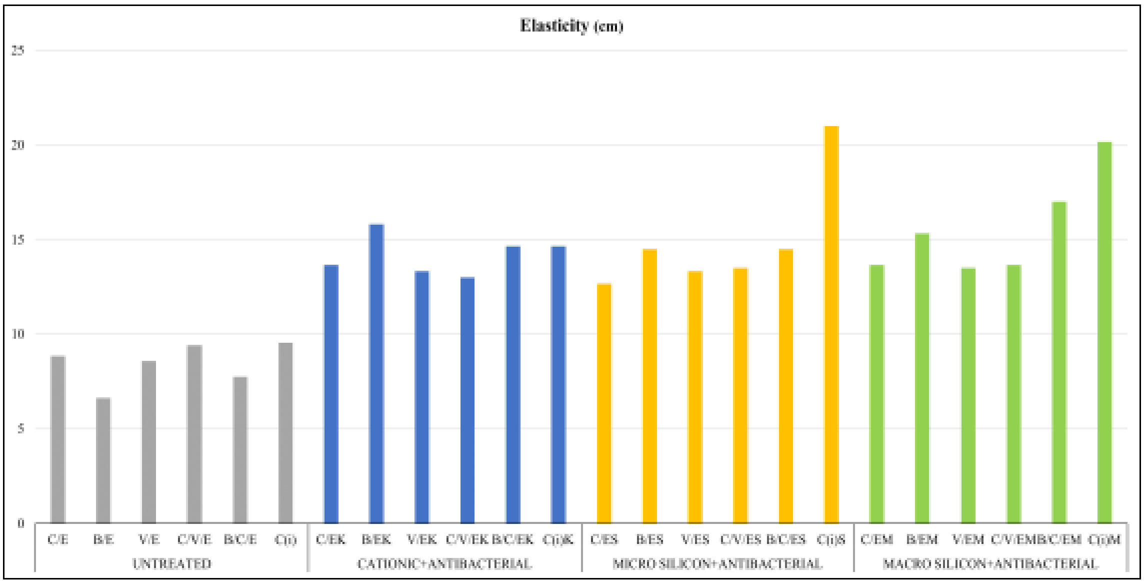

Figure 5. Elasticity data of untreated and treated fabrics

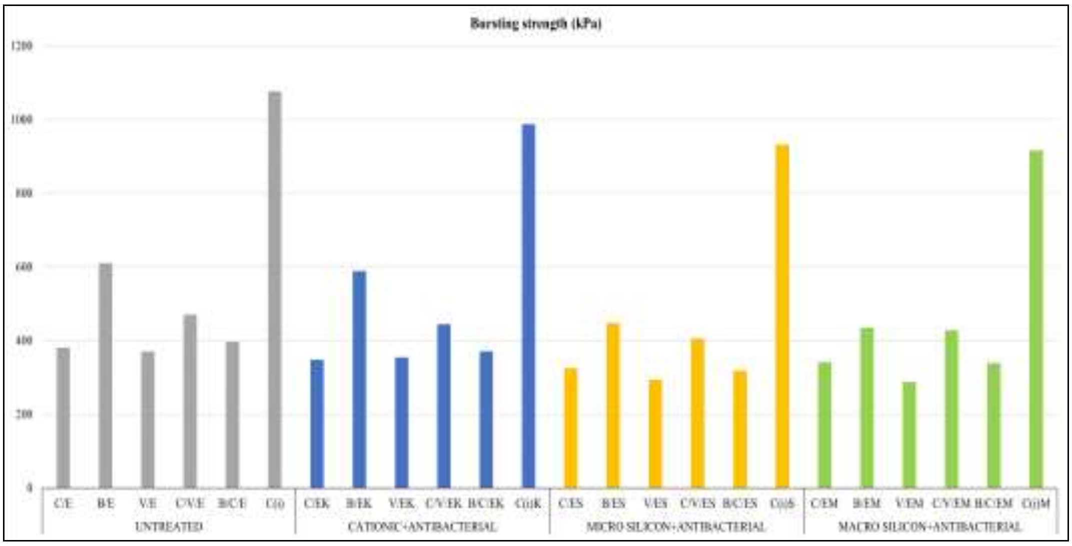

Figure 6. Bursting strength data of untreated and treated fabrics

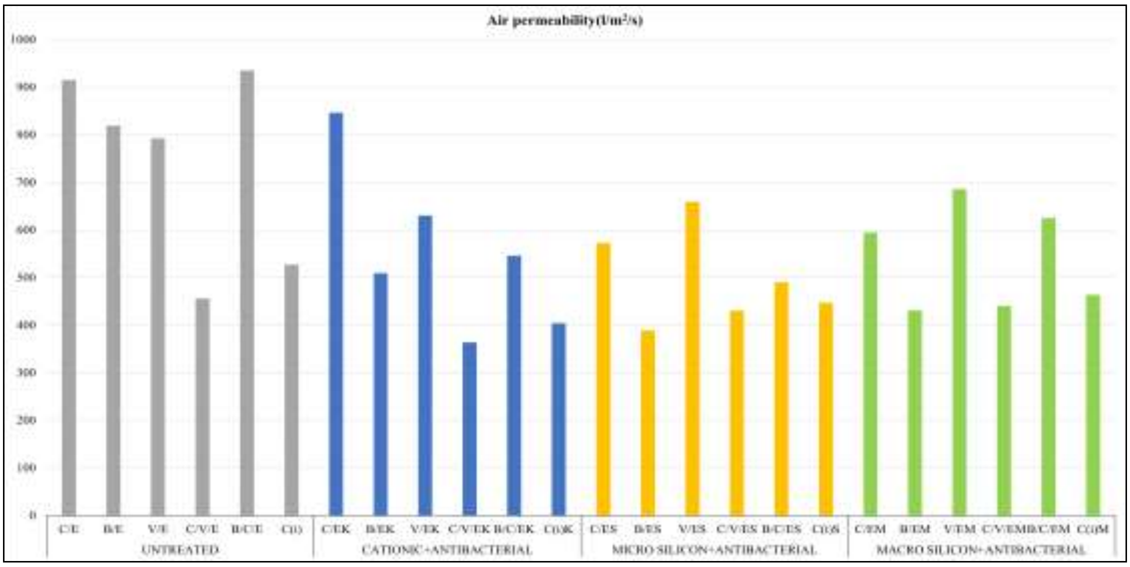

Figure 7. Air permeability data of untreated and treated fabrics

According to the air permeability data of untreated fabrics, the fabric with the highest air permeability was obtained in cotton/bamboo/elastane blended knitted fabric, and the lowest air permeability values were obtained in cotton/viscose/elastane blended knitted fabric. Furthermore, for the fabrics treated with cationic softener and antibacterial agents, the highest air permeability values were obtained in 95%cotton/5%elastane knitted fabrics, and the lowest air permeability values were obtained in cotton/viscose/elastane blended knitted fabrics. Furthermore, for the fabrics treated with microsilicone and antibacterial chemicals, the highest air permeability values were obtained in 95%viscose/5%elastane knitted fabrics. The lowest air permeability values were obtained in 95%bamboo/5%elastane knitted fabrics. Finally, according to the air permeability data of the fabric treated with macrosilicone and antibacterial chemicals, the highest air permeability values were obtained in 95%viscose/5%elastane knitted fabrics and the lowest air permeability values were obtained in 95%bamboo/5%elastane knitted fabrics.

3.2.2. Water vapour permeability

Relative water vapour permeability data of untreated and treated fabrics are shown in Figure 8.

According to the relative water vapour permeability data of untreated fabrics, the fabric with the highest relative water vapour permeability was obtained in 95%cotton/5%elastane knitted and the lowest relative water vapour permeability was obtained in 100% cotton interlock knitted. For the fabric treated with cationic softener and antibacterial chemicals, the highest relative water vapour permeability was obtained in 95%viscose/5%elastane knitted and the lowest relative water vapour permeability was obtained in 100% cotton interlock knitted. For the fabric treated with microsilicone and antibacterial chemicals, the highest relative water vapour permeability was obtained in cotton/bamboo/elastane blended knitted fabric and the lowest relative water vapour permeability was obtained in 100% cotton interlock knitted fabric. For the fabric treated with macrosilicone and antibacterial fabrics, the highest relative water vapour permeability was obtained in cotton/bamboo/elastane blended knitted and the lowest relative water vapour permeability was obtained in 100% cotton interlock knitted fabric.

3.2.3. Thermal conductivity

The thermal conductivity data of untreated and treated fabrics are presented in Figure 9.

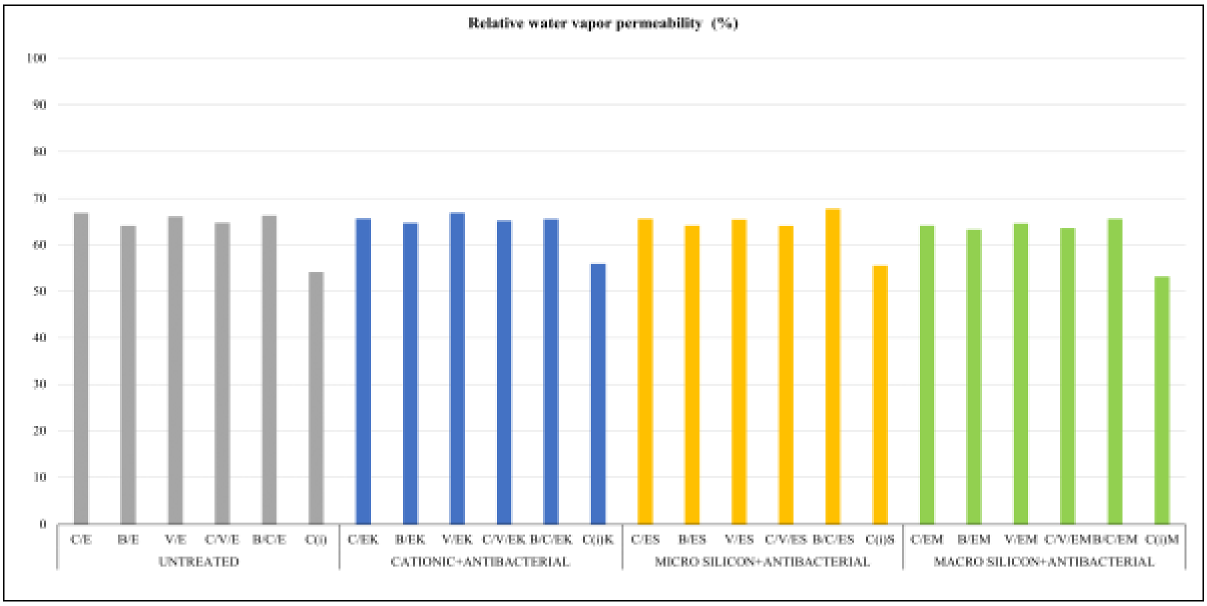

Figure 8. Relative water vapour permeability data of untreated and treated fabrics

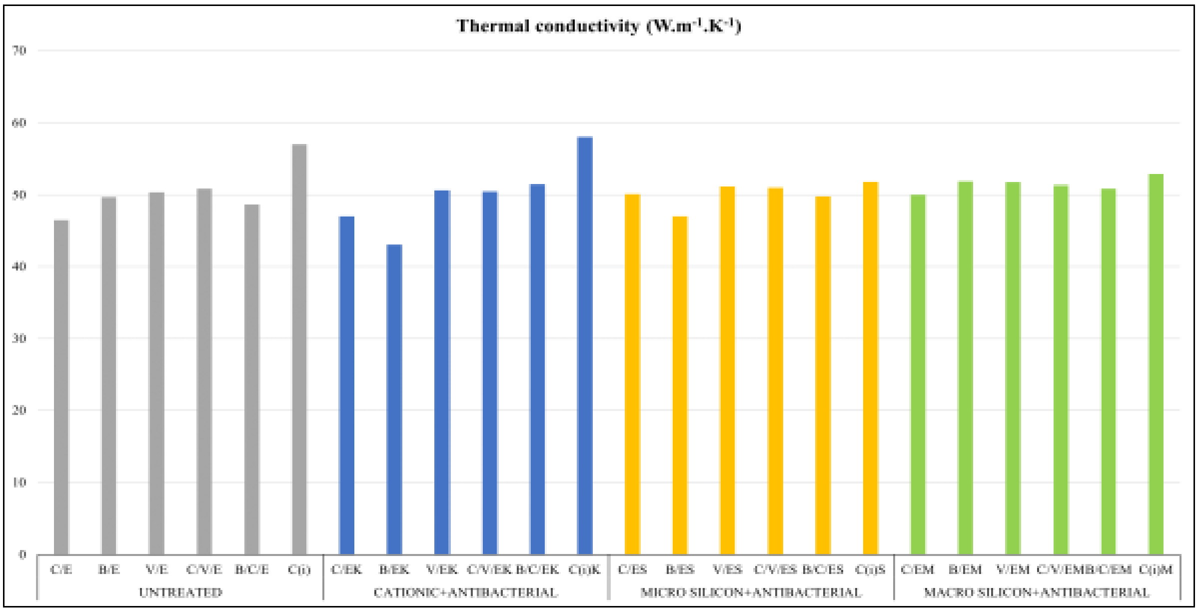

Figure 9. Thermal conductivity data of untreated and treated fabrics

According to the thermal conductivity data of untreated fabrics, the highest thermal conductivity was obtained in 100% cotton interlock knitted and the lowest thermal conductivity was obtained in 95%cotton/5%elastane knitted fabric. For the fabrics treated with cationic and antibacterial agents and the microsilicone and antibacterial agents, the highest thermal conductivity was obtained in 100% cotton interlock knitted and the lowest thermal conductivity was obtained in 95%bamboo/5%elastane knitted fabric. For the fabric treated with macrosilicone and antibacterial fabrics, the highest thermal conductivity was obtained in 100% cotton interlock and the lowest thermal conductivity was obtained in 95%cotton/5%elastane knitted fabric.

3.2.4. Thermal absorptivity

The thermal absorptivity data of the untreated and treated fabrics are shown in Figure 10.

According to the thermal absorptivity data of untreated fabrics, the highest thermal absorptivity was obtained in 95%viscose/5%elastane and cotton/viscose/elastane blended knitted fabric and the lowest thermal absorptivity was obtained in 95%bamboo/5%elastane knitted fabric. For the fabric treated with cationic softener and antibacterial, the highest thermal absorptivity was obtained in 95%viscose/5%elastane and cotton/bamboo/elastane blended knitted fabric and the lowest thermal absorptivity was obtained in 100% cotton interlock knitted fabric. For the fabric treated with microsilicone and antibacterial, the highest thermal absorptivity was obtained in 95%viscose/5%elastane knitted and the lowest thermal absorptivity was obtained in 100% cotton interlock knitted fabric. For the fabric treated with macrosilicone and antibacterial, the highest thermal absorptivity was obtained in 95%viscose/5%elastane knitted fabric and the lowest thermal absorptivity was obtained in 100% cotton interlock knitted fabric.

3.2.5. Thermal resistance

Thermal resistance data of untreated and treated fabrics are shown in Figure 11.

According to the thermal resistance data of untreated fabrics, the highest and lowest thermal resistance values were obtained in 100% cotton interlock knitted fabric and the cotton/viscose/elastane blended knitted fabric, respectively. For the fabric treated with cationic, microsilicone, and macrosilicone softeners, the highest and lowest thermal resistance values were obtained in 100% cotton interlock knitted fabric and were obtained in 95%viscose/5%elastane knitted fabric, respectively.

3.2.6. Maximum heat flow

The maximum heat flow data of the untreated and treated fabrics are shown in Figure 12.

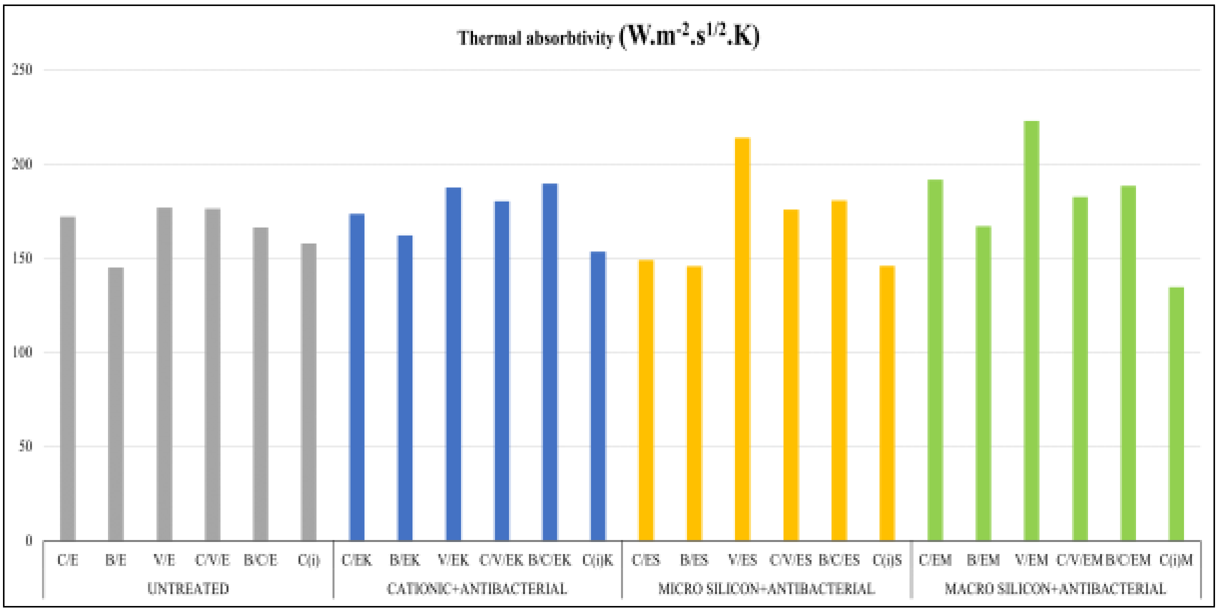

Figure 10. Thermal absorptivity data of untreated and treated fabrics

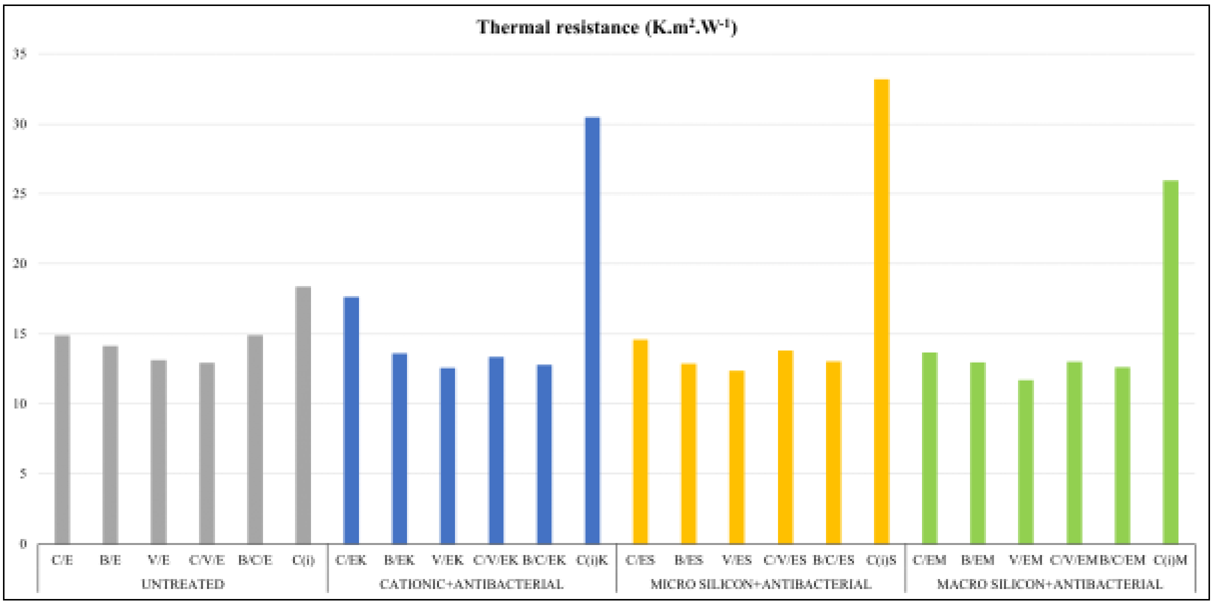

Figure 11. Thermal resistance data of the untreated and treated fabrics

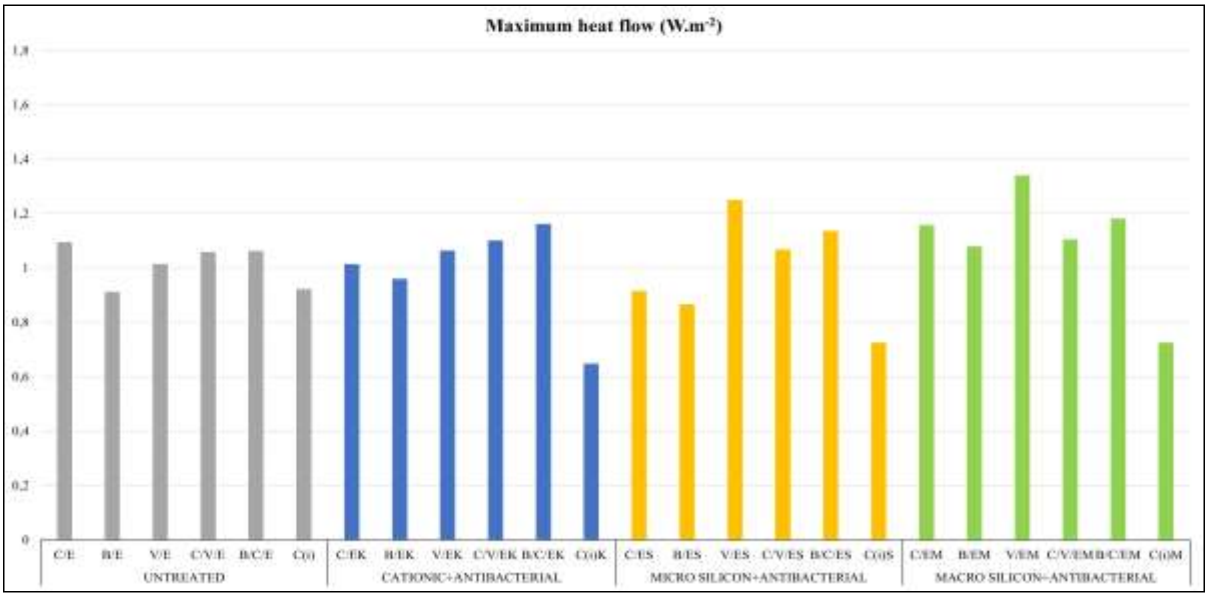

Figure 12. Maximum heat flow data of the untreated and treated fabrics

According to the maximum heat flow data of untreated fabrics, the fabric with the highest maximum heat flow was obtained in 95%cotton/5%elastane knitted fabric, and the fabric with the lowest maximum heat flow was obtained in 100% cotton interlock and 95%bamboo/5%elastane knitted fabric. For the fabric treated with cationic softener and antibacterial chemicals, the fabric with the highest maximum heat flow was obtained in cotton/bamboo/ elastane blended knitted fabric and the lowest maximum heat flow was obtained in 100% cotton interlock knitted fabric. For the fabrics treated with microsilicone and macrosilicone softeners, the highest heat flow values were obtained in 95%viscose/5%elastane knitted fabrics and the lowest heat values were obtained in 100% cotton interlock knitted fabrics.

3.3. Wearing Test Results of Undershirts

30 people participated in the clothing trials for summer and winter undershirts. The participants gave the similar answers for the produced undershirts in this study. The age range of the participants is between 65 and 80. 60% of respondents are not employees. In the questionnaire, in which the clothing trial was conducted, the users were asked questions such as the ease of wearing the bra undershirt, whether it restricts their movements, as well as their demographic characteristics. All of the participants stated that it was easy to put on and take off the undershirts and did not restrict their movements. 63% of the participants said that they were different from their classic undershirts in terms of comfort and stated that this

difference was that they did not need to wear an extra bra. In addition, the produced undershirt is easy to put on, take off and also has the feeling of keeping warm. 20% of the participants stated that the velcro strip in the front made them itchy and that they would feel uncomfortable in their clothes because it was a little hard.

4. CONCLUSION

This study aimed to develop functional and comfortable summer and winter undershirt for elderly women. The results obtained from the physical and comfort tests of all the fabrics produced within the scope of this study are summarized below:

- Considering the antibacterial tests carried out with reference to the raw fabric, the result of cotton single jersey fabrics treated with microsiliconeand antibacterial substances are as follows. There was a reduction in the bacterial load of *Staphylococcus aureus* by 88.90% and in that of *Escherichia coli* by 99,53%, in the treated fabrics. These results indicate that the finishing processes with softener and antibacterial agent provided the fabrics with very high antibacterial properties.
- The fabric weight of 100% cotton interlock knitted fabric due to its knitting structure was the highest among the fabrics. The fabric weight values of the treated fabrics increased compared to the untreated fabrics. This is because the fabrics shrink in length and width after chemical and wet treatments. Considering these factors, the fabric with the lowest weight should be preferred for manufacturing summer undershirt. Therefore, untreated 95%bamboo/5%elastane and 95%cotton/5%elastane jersey knitted fabrics can be preferred for summer. The highest weight was obtained in 100% cotton interlock knitted fabric treated with macrosilicone and antibacterial agents. This fabric can be thought to be proper for winter undershirt.
- For the elasticity results, the highest elasticity value was obtained in the bamboo/cotton/elastane blended knitted fabric treated macrosilicone and antibacterial agents.
- The bursting strength of 100% cotton interlock knitted fabrics were the highest of all fabrics. Yarn strength, flexibility and fabric structure are effective factors when considering the bursting strength of fabrics. Since interlock knitted fabrics are thicker, the bursting strength values of these fabrics are higher than those of other fabrics. In single jersey fabrics produced for summer undershirts, the bamboo knitted fabric treated with cationic and antibacterial agents was the highest bursting strength value.
- The decreases in air permeability values in all treated fabrics were much more than those of untreated fabrics. The reason is shrinkage in length and width of the fabric after wet finishing treatments. The highest air permeability values among treated fabrics were observed in 95%cotton/5%elastane jersey and 95%viscose/5%elastane knitted fabrics.
- The highest water vapour permeability value was obtained in the cotton/bamboo/elastane blended knitted fabric among finished fabrics. 100% cotton interlock knitted had lowest water vapour permeability value. On the other hand, there were no remarkable differences between the treated fabrics.
- When the thermal conductivity results were examined, a decrease in thermal conductivity values was observed in the treated fabrics. As the thermal conductivity value increases, the comfort of the fabric value increases. Accordingly, 100% cotton interlock knitted fabric treated with cationic and antibacterial agents had the highest thermal conductivity value. For the winter undershirt this fabric can be proper. For the summer undershirt, 95%bamboo/5%elastane knitted fabric treated with macrosilicone and antibacterial agents can be preferred because this fabric has the highest thermal conductivity value.
- The thermal absorptivity value of a fabric means the warm-cool feeling. As the thermal absorptivity values increase, the cool feeling increases. Accordingly, 100% cotton interlock knitted fabric treated with macrosilicone and antibacterial chemicals had the lowest thermal absorbency value. So, this fabric can be suitable for winter undershirt. On the other hand, 95%viscose/5%elastane knitted fabric treated with macrosilicone and antibacterial chemicals had the highest thermal absorbency value. Thus, this fabric can be suitable for summer undershirt.
- Thermal resistance is the resistance of the fabric to heat. Fabrics with the highest heat resistance should be utilised for summer undershirt fabric. This is because an increase in thermal resistance increases the breathability of the fabric is high. Accordingly, the preferred fabric for winter undershirt was a treated 95%viscose/5%elastane knitted fabric with the lowest thermal resistance value. The fabric preferred for summer undershirt was a 95%cotton/5%elastane knitted fabric with the highest thermal resistance value, treated with cationic and antibacterial agents.
- When the maximum heat flow data was analyzed, a decrease was observed in the values of the interlock knitted fabrics among the fabrics. This is because the maximum heat flow decreases as the fabric structure’s porosity decreases. Since very porous fabrics can absorb more air, fabrics with the highest heat flow should be preferred for summer undershirt. Hence, the preferred fabric for winter undershirt was 100% cotton interlock knitted fabric with the lowest maximum heat flow value and treated with cationic and antibacterial agents. The fabric preferred for summer undershirt was 95%viscose/5%elastane knitted fabric treated with

- macrosilicone and antibacterial agents exhibiting the highest maximum heat flow value.
- After the tests, the functional and comfortable fabrics to be used in the production of summer and winter undershirts for elderly women were determined. While for summer undershirt 95%viscose/5%elastane knitted fabric treated with macrosilicone softener and antibacterial agents was choosen, for winter undershirt 100% cotton interlock knitted fabric treated with cationic softener and antibacterial agents was choosen. And then, the summer and winter undershirts for elderly women were produced from fabrics determined as a result of this study (Figure 13). Finally, the clothing trials were performed.

In the clothing trials, the participants generally liked the functional undershirts. Especially, the elderly and people with limited mobility expressed their satisfaction more. However, some people found the front velcro fastener hard and impractical. As a result of the clothing trials, it was concluded that the use of narrower and shorter velcro fastener to close the front of the undershirt can make the clothing much more comfortable. Dress trials were made by 30 women aged 65-80 years. In the questionnaire, in which the cloting trial was conducted, the users were asked questions about the ease of wearing the bra undershirt, whether it their movements, as well as their demographic characteristics. When the participants stated that it was easy to put on and take off the undershirt. Especially the elderly and people with limited mobility expressed their satisfaction with dressing easily. However, 20% of the users who participated in the clothing trials stated that they found the velcro fastening in front of bra undershirt hard and useless. As a result of the clothing trials, it was concluded that it would be more useful to use narrower and shorter Velcro fasteners for front closure in the design of undershirts. Considering the fact that the velcro tape is found to be uncomfortable for the front closure, it is also suggested that magnetic closure methods, which are thought to be more comfortable, can be used even if they increase the cost.

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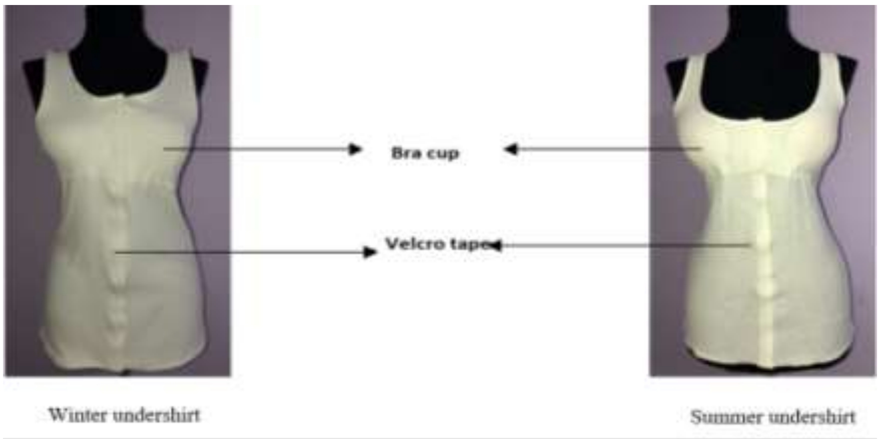

Figure 13. Winter and summer functional and comfortable undershirts for elderly women

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