Journal of Textiles and Polymers

Vol. 11, No. 3, 39-48, June 2023
https://www.itast.ir
DOI: 10.48302/JTP.2024.474533.1296

Effect of Number and Position of Tuck Stitches in the Pattern Repeat on the Quality of Rib Weft-Knitted Fabrics from the Point of Comfort

Azita Asayesh*[1], Maedeh Noori Moafrad[1]

[1] Department of Textile Engineering, Amirkabir University of Technology (Tehran Polytechnic), Tehran, Iran

Article Information

Article history:

Received: 2024-08-21

Accepted: 2024-12-03

***Keywords*:**

Comfort, weft-knitted fabric, fabric structure, tuck stitch, fabric quality.

Abstract

Consumers value knitted clothing that combines aesthetic appeal with comfort. Incorporating tuck or float stitches into basic weft-knitted fabrics creates a variety of new structures, each with distinct appearances and characteristics. This study examines the impact of the number and position of tuck stitches within the structure of rib-weft knitted fabrics on their comfort properties. The quality of the fabrics was assessed based on their ability to meet these comfort properties. The calculated values of the complex criterion for fabric quality revealed that all investigated fabric structures exhibited good to excellent quality. Among them, the fabric containing a single tuck stitch per pattern repeat demonstrated the best overall quality (Qk = 0.84). The Half Cardigan with tuck stitches on one side of the fabric achieved a quality score comparable to the Rib structure (Qk = 0.8). In contrast, the Full Cardigan, featuring tuck stitches on both sides, showed inferior quality (Qk = 0.76) relative to the other structures. In conclusion, the controlled use of tuck stitches within fabric structures enhances fabric quality concerning comfort properties.

1 INTRODUCTION

Clothing comfort is a multifaceted and subjective perception resulting from the interactions between fabric, climate, and human physiological and psychological factors. In essence, comfort represents a harmonious state of physiological, psychological, and physical balance between a person and their environment [1]. It is influenced by the sensory response to clothing materials and depends on various thermal, physiological, and mechanical properties [2].

Comfort can be classified into three main types: psychological, tactile, and thermal. Psychological comfort relates to societal acceptance and adherence to fashion trends, with minimal connection to fabric properties. Tactile comfort is influenced by the surface and mechanical properties of fabrics, while thermal comfort depends on a fabric's ability to regulate skin temperature by facilitating heat transfer and managing perspiration generated by the human body [3].

Numerous studies have highlighted factors affecting clothing comfort, including fiber type [4,5]; yarn-related parameters such as count and spinning system [4,6-9]; fabric-related parameters like thickness, tightness factor, and weight [5-12]; body activity levels; and environmental conditions.

The comfort of clothing produced from weft-knitted fabrics has been widely researched. Chidambaram et al. [13] demonstrated that increasing the proportion of bamboo fibers in cotton/bamboo knitted fabrics improves air and water vapor permeability while reducing thermal conductivity. Similarly, Oglakcioglu et al. [14] found that raising the percentage of Angora rabbit fibers in Angora rabbit/cotton knitted fabrics decreases thermal conduction, thermal absorption, and water vapor permeability while enhancing thermal resistance. Additionally, fabrics knitted from ring-spun yarns exhibit a warmer initial touch, greater thermal insulation, and lower water vapor permeability than those knitted from open-end yarns, primarily due to yarn hairiness.

Jhanji et al. [15] explored the impact of fiber type and yarn linear density on the comfort properties of single jersey-plated knitted fabrics. Their study revealed that plated fabrics with nylon as the inner layer provided the highest air and water vapor permeability, along with the coolest initial skin contact, owing to nylon's high thermal absorptivity. Conversely, coarser yarns in the outer layer are not recommended for warm conditions because they increase thermal resistance and reduce air and water vapor permeability.

Hassan et al. [16] studied the effect of sportswear fabric properties on the physiological responses and performance of athletes. The tested fabrics were made of 100% cotton, a 65/35 polyester/cotton blend, and 100% polyester fibers. The garment made of 100% polyester exhibited the best physiological responses and performance, which was attributed to better moisture management due to its relative water vapor permeability (68%) and lower thermal conductivity. Additionally, a high correlation was observed between fabric thickness, fabric porosity, fabric air

* Corresponding Author: a_asayesh@aut.ac.ir

permeability, relative water vapor permeability, fabric thermal properties, and athletes' physiological responses

Ozdil et al. [17] studied the effect of yarn features on the thermal properties of rib weft-knitted fabrics. The results revealed that fabrics produced from finer yarns exhibit lower thermal resistance and thermal conduction but higher water vapor permeability and lower thermal absorption compared to those made from coarser yarns. Additionally, increasing the yarn's twist leads to higher thermal absorption and water vapor permeability while reducing the thermal resistance of the fabric. Furthermore, the combing process enhances the thermal conduction, thermal absorption, and water vapor permeability of fabrics made from cotton yarn while decreasing their thermal resistance.

Yazdi et al. [18] investigated the heat and moisture transport properties of double-surface weft-knitted fabrics produced from different combinations of hydrophilic (cotton) and hydrophobic fibers (polyester and polypropylene). They observed that clothing made of hydrophobic fibers, such as polypropylene (PP) or polyethylene terephthalate (PET), in the inner layer and hydrophilic fibers, such as cotton, in the outer layer provides the best thermal and moisture comfort in hot environments with high body perspiration. The next-to-skin layer absorbs moisture from the skin surface and transfers it to the ambient atmosphere through surface evaporation.

In similar research, Long [19] studied water moisture transfer in double-layer weft-knitted fabrics made from various fiber combinations on each side. They demonstrated that the water vapor permeability of the fabric depends on its porosity, while water transfer from the inner to the outer layer is closely related to the water absorption properties of the fibers in the two layers and the difference in their absorption levels. More water can be transferred from the inner to the outer layer by capillary action, using absorbent fibers for the outer layer and hydrophobic fibers for the inner layer.

In another study, Bivainyte and Mikucioniene [20, 21] examined the effects of fabric structure, fiber type, and yarn features on the air permeability, water vapor permeability, and thermal properties of double-layered knitted fabrics. Their findings indicated that for fabrics with the same pattern, air permeability depends on the loop length, while for fabrics with different patterns, it can be predicted by the area linear filling rate. Moreover, the water vapor permeability of these fabrics is primarily influenced by the fiber type and its wetting and wicking properties. Fabrics knitted in combined patterns were found to have higher thermal resistance than plain-plated fabrics due to the increased thickness of combined structures. Furthermore, increasing the loop length of the fabric leads to an increase in the thermal conductivity coefficient. Consequently, knitted garments with low wale and course density provide a cooler sensation.

Achour et al. [22] studied the effect of fabric structure and yarn type on the moisture management properties of knitted fabrics. They examined the wetting and transport characteristics of single jersey, Rib 1×1, and English Rib fabrics made from cotton and blended cotton/polyester yarns. The results showed that blending polyester into the yarn improved moisture transport performance. Among the knit structures considered, the English rib knitted fabric demonstrated the best moisture transport performance.

Knight et al. [23] investigated the comfort properties of plain jersey and 1×1 rib fabrics produced from cotton-nylon, cotton-polyester, and cotton-acrylic blends in various proportions. They observed that water vapor passes through single layers of plain jersey fabric faster than through equivalent rib fabrics. Additionally, significant increases in water vapor transmission and air permeability were noted as the synthetic fiber content in the blend increased. Conversely, moisture regain, moisture absorption, and shrinkage decreased as the proportion of synthetic fibers increased.

Oglakcioglu and Marmarali [24] examined the thermal comfort of weft-knitted fabrics with a focus on fabric structure. Their findings revealed that single jersey fabric exhibited significantly lower thermal resistance and higher water vapor permeability compared to rib and interlock fabrics. Interlock fabrics, on the other hand, showed higher thermal resistance and lower water vapor permeability than rib fabrics. They concluded that double jersey fabrics are a suitable choice for winter clothing due to their high thermal insulation properties, while single jersey fabrics are preferable for summer garments owing to their superior moisture management.

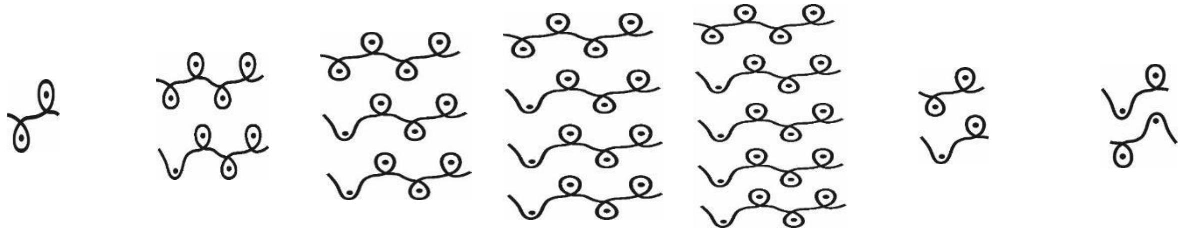
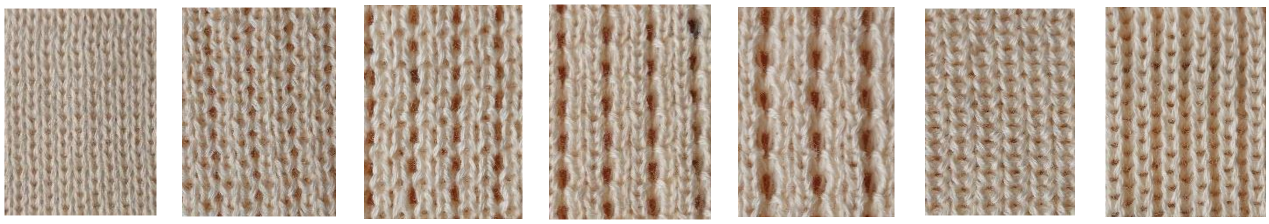
The rib structure is one of the fundamental weft-knitted patterns from which various derivatives can be developed by combining knit, tuck, and float stitches. These modifications are primarily used for design purposes and to enhance certain dimensional and physical properties of knitted fabrics. The knitting pattern is a key structural parameter that significantly influences the physical and mechanical characteristics of the fabric. This study aims to investigate the impact of the number and position of tuck stitches within the knit pattern on the comfort properties of rib weft-knitted fabrics, aiming to determine how fabric comfort is affected by its structural features.

2 MATERIALS AND METHODS

2-1 Fabric production

Rib fabrics with seven different knit patterns were fabricated on a 7-gauge STOLL CMS T330 computerized flat knitting machine. The fabrics consist of knit and tuck stitches and differ in the number of tuck stitches on successive courses. They produced using 30/3 metric cotton yarn under constant knitting conditions (cam setting, yarn input tension, and fabric take-down). After production, the fabrics were relaxed on a flat surface for 48h at 20º C and 65% relative humidity (RH). The fabric structures are illustrated in Table 1. In the fabric code, the number represents the number of tuck stitches in the knit repeat. Besides, the first and the two last fabric structures are Rib (R), Half Cardigan (HC), and Full Cardigan (FC), respectively. Samples R1 to R4 differ in the number of tuck stitches on successive courses, while Half Cardigan (HC), and Full Cardigan (FC) differ in both the number and position of tuck stitches. In Half Cardigan, the tuck stitches are on one side of the fabric, while in Full Cardigan the tuck stitches exist on both sides of the fabric.

Table 1 Fabric structures

Fabric code	R	R1	R2	R3	R4	HC	FC
Knit repeat							
Front side view							
Back side view							

2-2 Structural evaluation of the fabrics

2-2-1 Density

Due to the complex knit structure of the fabrics, the number of unit cells per unit length (C_uPC) and the number of unit cells per unit width (W_uPC) of the fabrics were counted. By multiplying these values by the number of courses and wales in the knit repeat, respectively (Table 1), the number of courses per centimeter (c.p.c) and the number of wales per centimeter (w.p.c) were obtained as follows:

$$c.p.c = \frac{Total\ number\ of\ courses}{Fabric\ length(cm)} = C_uPC \times Number\ of\ courses\ in\ the\ knit\ repeat \quad (1)$$

$$w.p.c = \frac{Total\ number\ of\ wales}{Fabric\ width(cm)} = W_uPC \times Number\ of\ wales\ in\ the\ knit\ repeat \quad (2)$$

These measurements were done at five different points of the fabrics at dimensions of 10×10 cm^2, and the average values are reported in Table 2.

2-2-2 Mass per unit area

According to ASTM D 3776 [25] standard test method, to measure the mass per unit area of the fabrics, from each fabric structure, four samples with a size of 10 × 10 cm^2 were weighted. By dividing the weight by the area of the sample, the mass per unit area of the fabric was calculated. The average results are presented in Table 2.

2-2-3 Thickness

The thickness of the fabrics was measured using the Shirley digital thickness tester based on ASTM D 1777-96 [26] standard test method. This measurement was done at ten different points of each fabric structure, under the pressure of 20 g.cm-2. The average results are shown in Table 2.

Table 2 Structural features of the fabrics

Fabric code	C_uPC	C.P.C	W_uPC	W.P.C	Mass per unit area ($g.m^{-2}$)	Thickness (mm)	Tuck stitches in the knit repeat (%)
R	5.9	5.9	4.33	4.33	497	2.64	0
R1	3.54	7.08	1.77	3.54	474	3.01	12.5
R2	2.75	8.26	1.57	3.14	478	3.02	16.7
R3	2.16	8.66	1.57	3.14	498	3.22	18.8
R4	1.96	9.84	1.57	3.14	511	3.39	20
HM	4.72	4.72	2.75	2.75	494	3.35	25
FM	5.11	5.11	2.36	2.36	472	3.29	50

2-3 Evaluation of comfort properties

Some of the physical properties of the fabrics such as air permeability, water vapor permeability, and thermal conductivity as well as compressibility have been measured to evaluate the fabrics' comfort.

2-3-1 Air permeability

The air permeability test was done on a Shirley SDL-type air permeability tester based on ASTM D737 [27] standard test method. The test was performed under a water pressure difference of 25 Pa. From each fabric structure, ten specimens were tested and the average value was reported.

2-3-2 Water vapor permeability

The water vapor permeability (WVP) test was conducted using the cup method according to BS 7209 [28] at standard conditions (20±2 °C and relative humidity of 65±5%). From each fabric structure, four specimens were tested and the average result was recorded. By measuring the weight of the samples before and after the test (5 hours), the WVP was calculated according to the following equation:

$$WVP(kgm^{-2}h^{-1}) = \frac{M}{At} \quad (3)$$

Where M is a loss in mass (kg), t is the time between weighing (h) and A is the internal area of the cup (m2).

2-3-3 Thermal conductivity

The thermal conductivity of the fabrics was measured according to BS-4745 [29] standard test method using the two plates method. From each fabric structure, three specimens were tested and the average thermal conductivity(W.m-1.K-1) was calculated.

2-3-4 Compressional properties

The compressional properties of the fabrics were investigated by measuring the thickness of the fabric at various pressures (20, 50, 100, 200, 500, 1000, 1500, and 2000 g.cm-2) using a Shirley digital thickness tester. The first thickness recording was done after 30 s under the pressure of 20 g cm-2. The pressure was increased successively, and the corresponding thickness was registered. The first recovery recording was done by removing the pressure of 2000 g.cm-2 and allowing the fabric sample to recover for 30 seconds. The succeeding recovery readings were taken using the same method. For each fabric sample, ten tests were done and the compression and recovery readings were recorded. Finally, the average compression and recovery curves of the fabric were plotted. To evaluate the compressional properties of the fabrics, parameters such as the work of compression (area under compression curve (WC)), the work of recovery from compression (area under compression recovery curve (W′C)), the dissipated compression energy (E_m), the resilience of the fabric (RC), the relative compressibility (EMC), thickness change (ΔT), and the thickness recovery (TR) which was introduced by Kawabata [30] has been calculated as follows:

$$WC = \int_{T_{0c}}^{T_m} Pc\, dV = \int_{T_{0c}}^{T_m} Pc\, dt_c \quad (4)$$

$$W'C = \int_{T_m}^{T_{0r}} Pr\, Pr\, dV = \int_{T_m}^{T_{0r}} Pr\, Pr\, dt_r \quad (5)$$

$$E_m = WC - W'C \quad (6)$$

$$RC = \frac{W'C}{WC} \times 100 \quad (7)$$

$$EMC = (1 - \frac{T_m}{T_{0c}}) \times 100 \quad (8)$$

$$\Delta T = T_{0c} - T_m \quad (9)$$

$$TR = \frac{T_{0r}}{T_{0c}} \times 100 \quad (10)$$

In the above equations, suffixes c and r represent the compression and recovery state, respectively. P is the pressure, and T is the fabric thickness. T0c is the initial thickness of the fabric under the pressure of 20 g.cm-2, Tm is the thickness of the fabric under the pressure of 2000 g.cm-2, and T0r is the thickness of the fabric at the end of the compression recovery cycle.

2-4 Quality analysis

In the present research, quality means the quality of clothing fabrics in terms of comfort. In other words, quality is the degree to which the produced weft knitted fabrics satisfy better comfort performance. The quality of investigated fabrics was evaluated based on the results obtained for the fabrics' compression, and comfort. To this end, the complex criterion of fabrics' quality (Q_K) was established and calculated using the following equation [31]:

$$Q_K = \frac{\sum_{i=1}^{n} n_i}{\sum_{i=1}^{n} \frac{1}{Q_i}} = \frac{6}{\frac{1}{Q_{EMC}} + \frac{1}{Q_{TR}} + \frac{1}{Q_{RC}} + \frac{1}{Q_{AP}} + \frac{1}{Q_{WP}} + \frac{1}{Q_{TC}}} \quad (11)$$

where: n_i is the total number of investigated characteristics, Q_i is the dimensionless indicator of fabrics' quality expressed through the value of the investigated characteristic (Q_{EMC}– relative compressibility, Q_{TR} – thickness recovery, Q_{RC}– resilience, Q_{AP} – air permeability, Q_{WP} – water vapor permeability, Q_{TC} – thermal conductivity). The dimensionless indicator of fabrics' quality (Q_i) was calculated as follows:

$$Q_i = \frac{X_D}{X} \quad (for\ X > X_D)$$

or (12)

$$Q_i = \frac{X}{X_D} \quad (for\ X < X_D)$$

where X_D is the die value, and X is the average value of the measured characteristic. In the case of lack of die value, the minimal or maximal value of the tested characteristic, which means the best quality of the fabric, was used. In this research, the maximal value of all characteristics served as the die value. The fabric grading was done as follows:

When Q_k is in the interval 0.76–1.00, the fabric quality is excellent, when Q_k is in the interval 0.51–0.75, the fabric quality is good, when Q_k is in the interval 0.26–0.50, the fabric quality is satisfying and when Q_k is in the interval 0.00–0.25, the fabric quality is poor.

2-5 Statistical Analysis

To consider the effect of fabric structure on different fabric properties, the results were statistically analyzed by one-way analysis of variance (ANOVA) at a 95% significance level followed by Duncan's post-hoc tests, using SPSS software. A statistically significant difference was reported if $p < 0.05$.

3 RESULTS AND DISCUSSIONS

3-1 Air permeability

The air permeability of the fabrics is shown in Fig. 1. As seen, the Rib fabric (sample R) demonstrates the lowest air permeability compared to fabrics containing tuck stitches. This can be attributed to the fact that in fabrics containing tuck stitches, the held loops rob yarn from adjacent knitted loops. As a result, holes are created in the fabric structure in the place of held loops (Fig. 2). By increasing the number of tuck stitches from sample R1 to R4, the air permeability of the fabrics decreases. The reason is that tuck loops reduce the fabric length because the higher yarn tension on the held loops causes them to rob yarn from adjacent knitted loops, making them smaller (Fig. 2) [32]. Hence, increasing the number of tuck stitches leads to a higher yarn rob and smaller loop length. In other words, the coarse density of the fabric increases (Table 2), which in turn reduces the porosity of the fabric, and subsequently its air permeability. Due to the same reason, Full Cardigan (FC) and Half Cardigan (HC) structures have higher air permeability than rib fabric. In addition, Half Cardigan exhibits lower air permeability than Full Cardigan. In the Half Cardigan structure, in which tuck stitches exist on one side of the fabric, yarn is robbed from the stitches on the other side of the fabric. Consequently, the stitches on this side are smaller, which leads to higher stitch density and weight of the fabric compared to Full Cardigan (Table 2). Therefore, due to lower porosity, Half Cardigan has lower air permeability than Full Cardigan. Statistical results confirmed that fabric structure has a significant effect on the air permeability of the fabrics (P Value= 0).

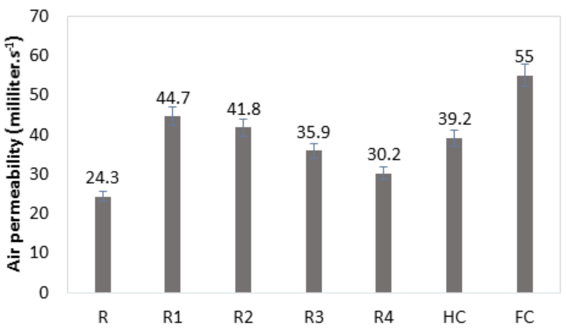


Fig. 1 The effect of fabric structure on the air permeability of the fabrics

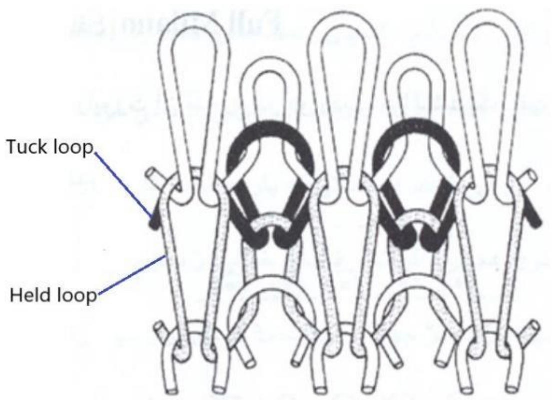


Fig. 2 Schematic of tuck stitch in a rib-knitted fabric

3-2 Water vapor permeability

The passage of water vapor from the fabric takes place through two mechanisms: one is through the fabric pores, and the other is through absorption by the fabric's structure and evaporation from the fabric's surface [33, 34].

Fig. 3 demonstrates the water vapor permeability of the fabrics. Although by increasing the number of tuck stitches from sample R1 to R4, the water vapor permeability of the fabrics decreases slightly, and Half Cardigan has a rather lower water vapor permeability than Full Cardigan, statistical results revealed that fabric structure has no significant effect on the water vapor permeability of the fabrics (P Value=0.44).

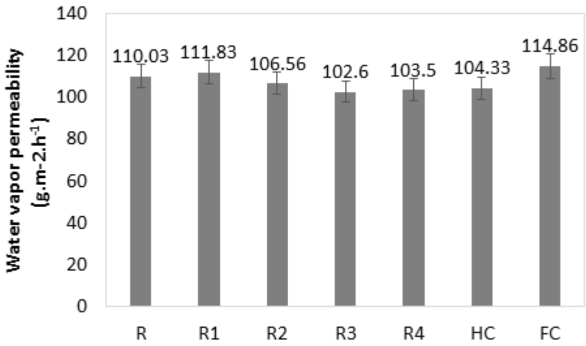


Fig. 3 The effect of fabric structure on the water vapor permeability of the fabrics

3-3 Thermal conductivity

The thermal conductivity of the fabrics is illustrated in Fig. 4. The Rib fabric has the highest thermal conductivity and by increasing the number of tuck stitches from sample R1 to R4, the thermal conductivity of the fabrics decreases. This is because the tuck stitches make the fabric bulky and puffy. Therefore, air entraps in the fabric structure, and leads to lower thermal conductivity of the fabric. Furthermore, Half Cardigan has higher thermal conductivity than Full Cardigan, which is due to the lower porosity of the Half Cardigan structure as mentioned previously. Statistical results showed that fabric structure has a significant influence on the thermal resistance of the fabrics (P_{value}= 0).

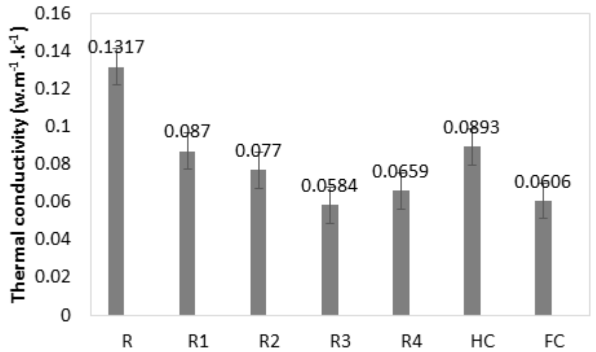


Fig. 4 The effect of fabric structure on the thermal conductivity of the fabrics

3-4 Compressional characteristics

The compression and recovery curves of different fabric structures were plotted. Typical compression and recovery curves of sample R1 are demonstrated in Fig. 5, and the average compressional parameters of the fabrics are presented in Table 3. The influence of fabric structure on the compressional parameters of the fabric has been discussed in the following.

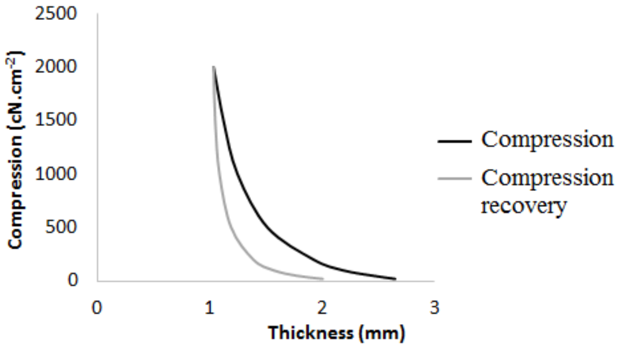


Fig. 5 Compression and recovery curves of sample R1

3-5 Energy absorption

Fig. 6 displays the influence of fabric structure on the absorbed energy (WC) by the fabric. As seen, the use of tuck stitches in the fabric structure increases the energy absorbed by the fabric, and by increasing the number of tuck stitches from sample R1 to R4, the amount of absorbed energy increases. As explained previously, the tuck stitch enhances the density and weight of the fabric. Consequently, the fabric resists more against compression and more energy is needed to compress the fabric. Similarly, the energy absorption of the Half Cardigan is greater than the Full Cardigan due to its heavier and tighter structure. Statistical results showed that fabric structure has an outstanding effect on the absorbed energy by the fabrics (P Value=0).

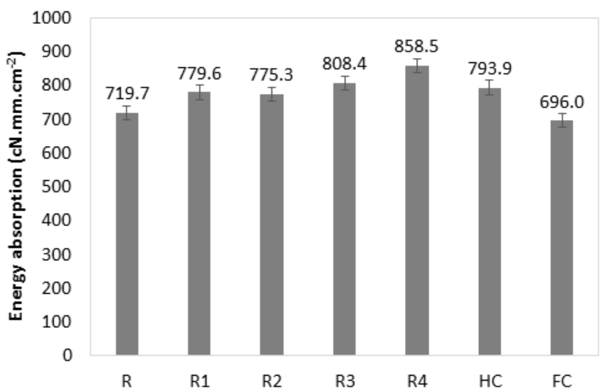


Fig. 6 The influence of fabric structure on the energy absorption of the fabric

3-6 Dissipated compression energy

Dissipated compression energy (E_m) represents the difference between work of compression and work of recovery from compression. Fig. 7 illustrates the dissipated compression energy of the produced fabrics. The Rib fabric has the lowest dissipated compression energy, and this value has been increased by increasing the number of tuck stitches from sample R1 to R4. Considering Table 3, by increasing the number of tuck stitches, the values of WC increase while no significant change in the values of W′C is observed. Therefore, their difference increases as well.

Besides, both values of WC and W′C for the Full Cardigan structure are less than those of the Half Cardigan structure, but due to a higher decrement of WC compared to W′C, the dissipated compression energy of the Full Cardigan is less than that of Half Cardigan. Based on the statistical results the difference between the dissipated compression energy of various fabrics was meaningful (P Value=0).

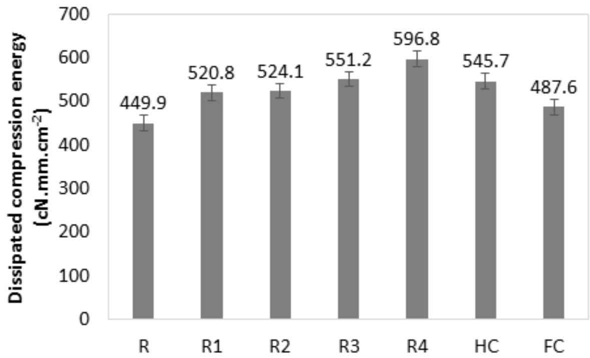


Fig. 7 The influence of fabric structure on the dissipated compression energy of the fabric

3-7 Resilience

Resilience is the ability of a material to return to its original form and shape after deformation. According to Fig. 8, the Rib fabric has the highest resilience, and by increasing the number of tuck stitches from sample R1 to R4 the resilience of the fabric decreases. As explained previously, by increasing the number of tuck stitches in the fabric structure, the value of WC increases which leads to a decrease in fabric resiliency. Furthermore, the Full Cardigan exhibits lower resilience than the Half Cardigan due to lower WC. Statistical results revealed that the effect of fabric structure on the fabric’s resiliency is significant (Pvalue=0).

Table 3 Compression parameters of the spacer fabrics

Fabric code	WC (cN.mm.cm-^{2})	$W'C$ (cN.mm.cm-^{2})	E_m (cN.mm.cm^{-2})	RC (%)	EMC (%)	ΔT (mm)	TR (%)
R	719.7	269.8	449.9	37.5	61	1.61	75.7
R1	779.6	258.8	520.8	33.2	67.1	2.02	67.8
R2	775.3	251.3	524.1	32.4	68.1	2.06	66.2
R3	808.4	257.2	551.2	31.8	68.6	2.2	64.7
R4	858.5	261.6	596.8	30.5	69.1	2.34	62.9
HC	793.9	248.2	545.7	31.3	71.1	2.38	61.2
FC	696	208.5	487.6	29.9	75.1	2.47	51.7

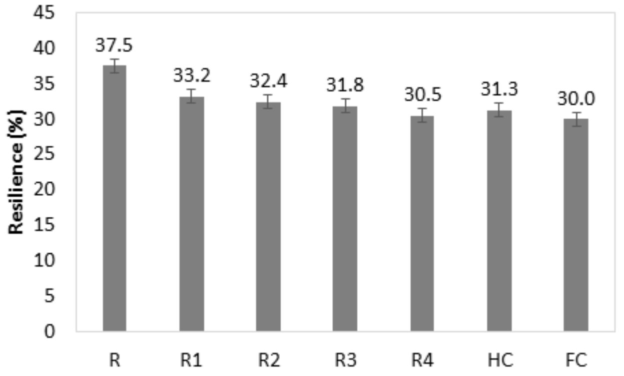


Fig. 8 The effect of fabric structure on the resilience of the fabric

3-8 Relative compressibility

The relative compressibility of the fabrics is shown in Fig. 9. As seen, Rib fabric has the lowest relative compressibility among the considered fabrics, and by increasing the number of tuck stitches from sample R1 to R4 the relative compressibility of the fabric increases. As mentioned previously, the use of tuck stitches in the fabric structure increases the thickness of the fabric and makes it bulky. Consequently, the thickness change of the fabric increases which leads to more relative compressibility. Also, the Full Cardigan exhibits more relative compressibility than the Half Cardigan due to its higher thickness change. Statistical results confirmed the significant influence of fabric structure on the relative compressibility of the fabrics (Pvalue=0).

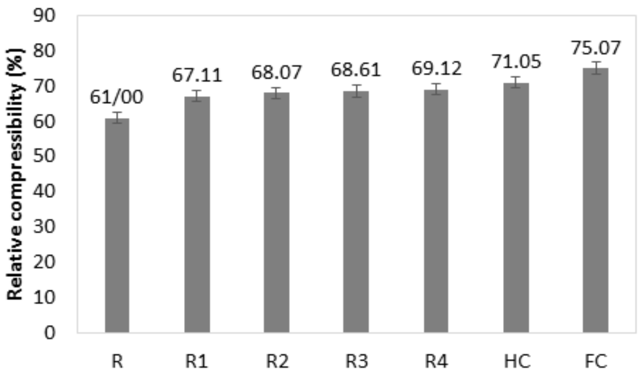


Fig. 9 The effect of fabric structure on the relative compressibility of the fabric

3-9 Thickness change

The effect of fabric structure on the thickness change of the fabrics is demonstrated in Fig. 10. Rib fabric has the lowest thickness change, and by increasing the number of tuck stitches from sample R1 to R4 the thickness change of the fabric increases. Also, the thickness change of the Full Cardigan is more than Half Cardigan. It is attributed to the increment of the fabric bulkiness as an increase of tuck stitches in the fabric structure. According to statistical results, the influence of fabric structure on the thickness change of the fabrics was significant (Pvalue=0).

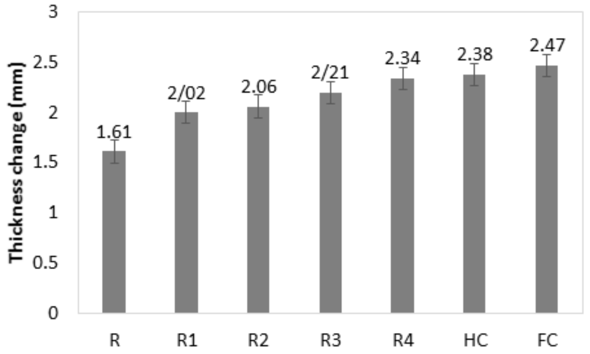


Fig. 10 The effect of fabric structure on the thickness change of the fabric

3-10 Thickness recovery

Thickness recovery represents the percentage of fabric thickness that recovers after eliminating compressional force. The influence of fabric structure on the thickness recovery of the fabric is shown in Fig. 11. Rib fabric has the highest thickness recovery than other fabric structures, and by increasing the number of tuck stitches from sample R1 to R4 a descending trend is observed in the thickness recovery of the fabrics. Moreover, the Full Cardigan demonstrates less thickness recovery than the Half Cardigan. There is an inverse relationship between the thickness recovery and dissipated energy of the fabrics. The less dissipated energy represents that the values of work of compression and work of recovery from compression are close to each other which means that the fabric recovers more after release of compression. As observed previously, the Rib fabric has the lowest dissipated compression energy, and this value has been increased by increasing the number of tuck stitches from sample R1 to R4. Based on statistical results, the difference between the thickness recovery of all samples was significant (Pvalue=0).

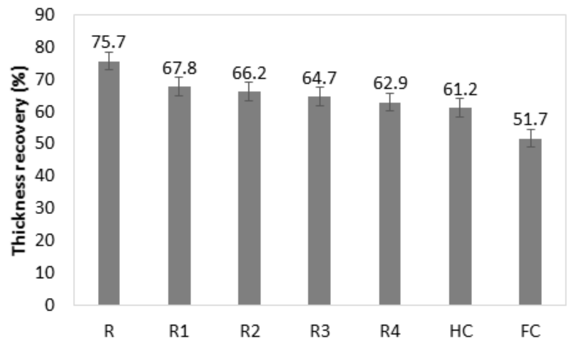


Fig. 11 The effect of fabric structure on the thickness recovery of the fabric

3-11 Quality of the fabrics

The dimensionless indicator of the quality of each fabric structure as well as all of them together is illustrated in Fig. 12 using radar charts. As seen, fabrics exhibit different radar charts. According to the results of dimensionless indicators, the complex criterion of fabrics' quality (Q_k) was calculated and is shown in Fig. 13. Except for samples R3 and R4 which have good quality, all the considered fabrics have excellent quality (Q_k higher than 0.76) regarding the investigated comfort characteristics.

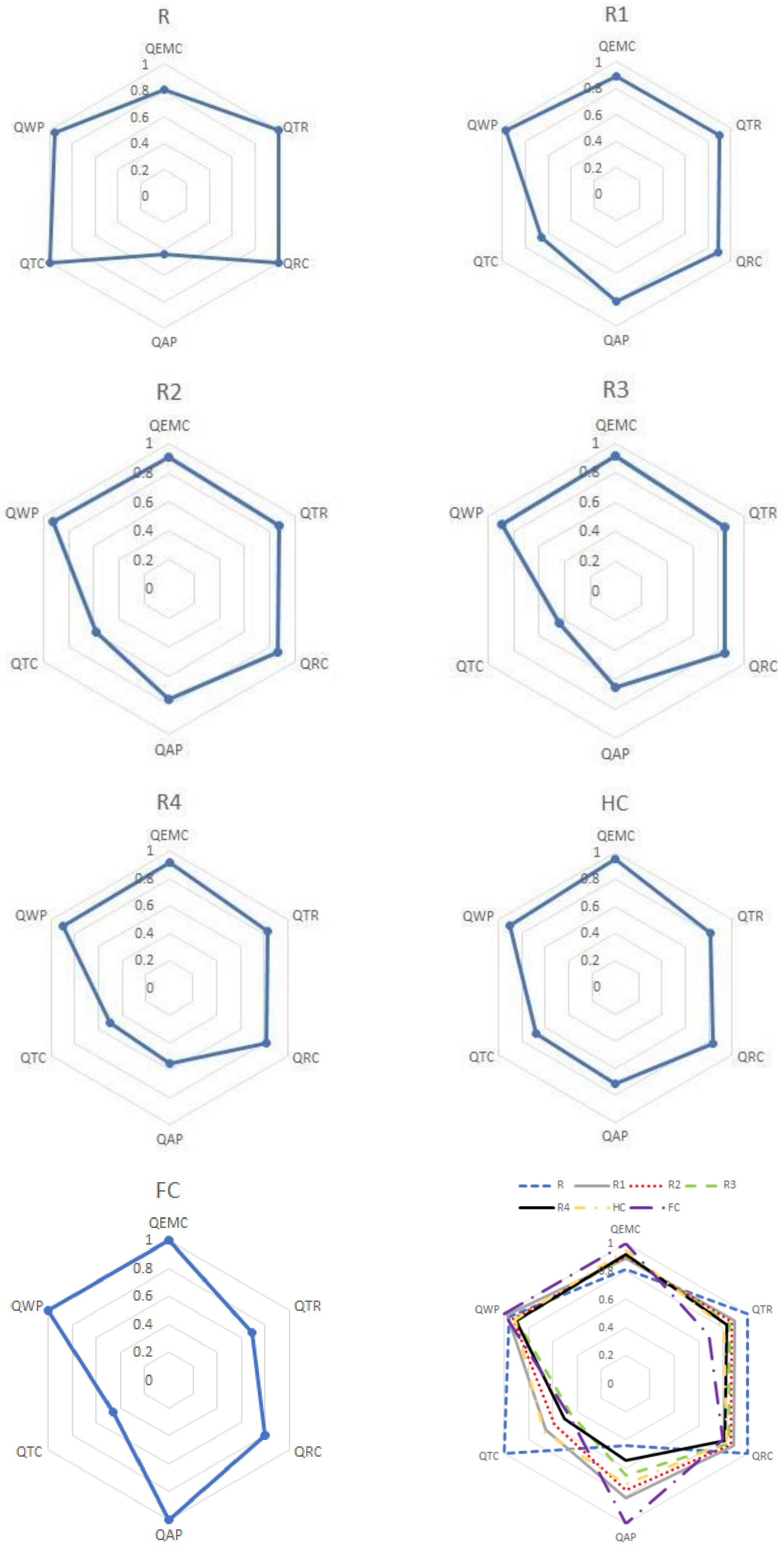


Fig. 12 Dimensionless indicator of fabrics' quality

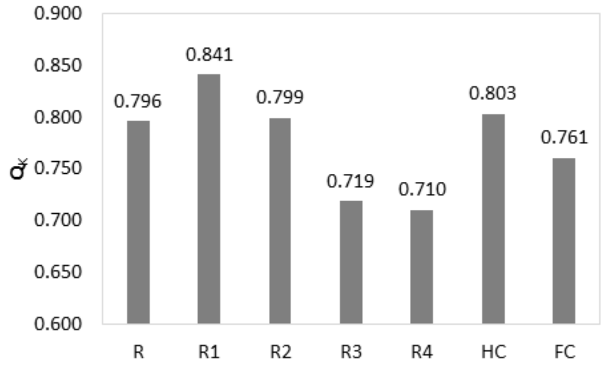


Fig. 13 The complex criterion of fabrics' quality (Qk)

According to Table 2, by increasing the number of tuck stitches in the fabric structure from sample R1 to R4, the percentage of tuck stitches increases. Furthermore, the Full Cardigan structure has the highest percentage of tuck stitches among the considered fabric structures. The relation between the percentage of tuck stitches and the complex criterion of fabrics' quality (Q_k) is displayed in Fig. 14. This figure confirms that fabric containing one tuck stitch in the pattern repeat (R1) possesses the best quality, and by increasing the percentage of tuck stitches in the structure of the fabric, the fabric's quality index decreases. Also, the Full Cardigan structure containing tuck stitches on both sides of the fabric exhibits inferior quality compared to the Rib, while the Half Cardigan structure containing tuck stitches on one side of the fabric shows almost similar quality as the Rib structure. In other words, the number and position of tuck stitches within the pattern repeatedly influence the quality of the fabric, and the use of tuck stitches in the fabric structure in a controlled way could lead to a better quality of the fabric from the point of comfort properties.

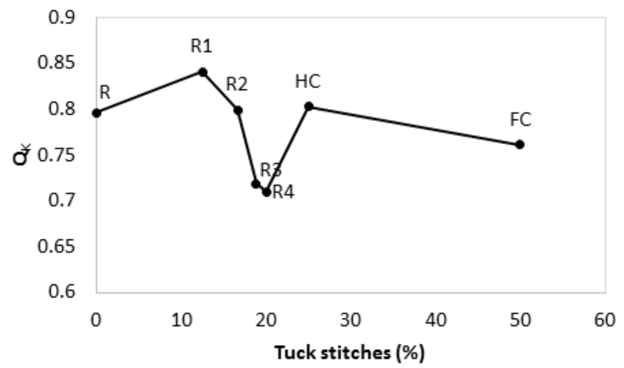


Fig. 14 The relation between the percentage of tuck stitches and the complex criterion of fabrics' quality (Qk)

4 CONCLUSIONS

In this research, rib weft-knitted fabrics with various knit patterns differing in the number and position of tuck stitches were produced, and the influence of fabric structure on the comfort properties of the fabrics was studied. The results indicate that incorporating tuck stitches in the fabric structure enhances air permeability by 24% to 126%, while reducing thermal conductivity by 32% to 56%. Furthermore, increasing the number of tuck stitches in successive courses decreases air permeability by 32% and reduces thermal conductivity by 24%.

The Half Cardigan structure exhibits lower air permeability (40%) but higher thermal conductivity (32%) compared to the Full Cardigan structure. Regarding compressional characteristics, fabrics with tuck stitches absorb more energy (from 3% to 19%) and show higher relative compressibility (from 10% to 23%) and thickness change (from 25% to 53%). However, these fabrics have lower resiliency (from 11% to 20%) and thickness recovery (from 10% to 32%). Increasing the number of tuck stitches in successive courses enhances all compressional features, except for resiliency and thickness recovery.

The Half Cardigan structure demonstrates higher energy absorption (12%), resiliency (4%), and thickness recovery (15%) but lower relative compressibility (6%) and thickness change (4%) compared to the Full Cardigan structure. Despite all investigated fabric structures showing good to excellent quality in terms of analyzed comfort properties, sample R1, containing one tuck stitch in the pattern repeat, exhibited the best overall quality among the considered fabrics (Qk=0.84).

The findings of this research could assist designers in selecting an optimal combination of knit and tuck stitches in fabric structures to achieve desirable comfort properties for everyday use.

Conflict of Interest

The authors confirm that there are no known conflicts of interest associated with this publication.

Data Availability Statement

The datasets generated and analyzed during the current study are not publicly available, as research on this subject is ongoing and will be used in future publications.

REFERENCES

[1] Wang, S.X. and Li, Y.I., 2006. Coupled heat and moisture transfer, in *Clothing Biosensory Engineering*, Woodhead Publishing.

[2] Das, A. and Alagirusamy, R., 2011. Improving tactile comfort in fabrics and clothing, in *Improving Comfort in Clothing*, Woodhead Publishing.

[3] Pamuk, O., 2008. Determination of Clothing Comfort for Textile Industry. *Engineering Sciences*, *3*(1), pp. 69-74.

[4] Mohapatra, S., Vidya, T., Kumar, D.V., Rajwin, A.J., Babu, V.R., Prakash, C., Shah, B.A. and Roy, R., 2021. Study of Thermal Comfort Properties of Different Kinds of Polyester Knitted Fabrics. *Fibres & Textiles in Eastern Europe*, 29(5), pp. 50-55.

[5] Santhanam, S. and Selvaraj, S.K., 2022. Moisture and Thermal Comfort Properties of Heat Resistance Protective WorkWear Using Cotton and Cotton/Polyester Blended Weft Knitted Fabrics. *Journal of Textile & Apparel Technology & Management (JTATM)*, 12(3), PP. 1-13.

[6] Gedilu, M., Santhanam, S., Bogale, M. and Selvaraj, S.K., 2022. Experimental analysis on the effect of ring and rotor spun yarns for comfort characteristics of weft knitted fabric structures. *Journal of Engineered Fibers and Fabrics*, 17, pp.1-8.

[7] Ajmeri, J.R. and Bhattacharya, S.S., 2013. Comparative analysis of the thermal comfort properties of knitted fabrics made of cotton and modal fibres. *International Journal of Textile and Fashion Technology*, *3*(1), pp.1-10.

[8] Sundaresan, S., Sivanganam, K.J. and Kumar, A.S., 2019. Detailed Investigation of Weft Knitted Interlock Fabrics for Comfort Properties to Suit for Active and Sportswear Application. *International Journal* of *Engineering* &Technology, 8(5), PP. 712-721.

[9] Vadicherla, T. and Saravanan, D., 2017. Thermal comfort properties of single jersey fabrics made from recycled polyester and cotton blended yarns. *Indian Journal* of *Fibre* & Textile Research, 42(3), PP. 318-324.

[10] E Ozkan, E.T. and Binnaz, M., 2015. Thermophysiological comfort properties of different knitted fabrics used in cycling clothes. *Textile Research Journal*, 85(1), PP. 62-70.

[11] Mansor, A., Ghani, S.A. and Yahya, M.F., 2016. Knitted fabric parameters in relation to comfort properties. *American Journal of Materials Science*, *6*(6), pp.147-151.

[12] Chen, Q., Fan, J. and Sun, C., 2015. The comfort evaluation of weft knitted plant structured fabrics and garment. II. Sweating manikin and wearer trial test on polo shirt. *Fibers and Polymers*, *16*(9), pp.2077-2085.

[13] Chidambaram, P., Govindan, R. and Venkatraman, K.C., 2012. Study of thermal comfort properties of cotton/regenerated bamboo knitted fabrics. *African Journal of Basic & Applied Sciences*, *4*(2), pp.60-66.

[14] Oglakcioglu, N., Celik, P., Ute, T.B., Marmarali, A. and Kadoglu, H., 2009. Thermal comfort properties of angora rabbit/cotton fiber blended knitted fabrics. *Textile Research Journal*, *79*(10), pp.888-894.

[15] Jhanji, Y., Gupta, D. and Kothari, V.K., 2015. Comfort properties of plated knitted fabrics with varying fibre type. *Indian Journal of Fibre & Textile Research (IJFTR)*, *40*(1), pp.11-18.

[16] Hassan, M., Qashqary, K., Hassan, H.A., Shady, E. and Alansary, M., 2012. Influence of sportswear fabric properties on the health and performance of athletes. *Fibres & Textiles in Eastern Europe*, *20*(4), pp. 82-88.

[17] Ozdil, N., Marmaralı, A. and Kretzschmar, S.D., 2007. Effect of yarn properties on thermal comfort of knitted fabrics. *International Journal of Thermal Sciences*, *46*(12), pp.1318-1322.

[18] Yazdi, M.M., Semnani, D. and Sheikhzadeh, M., 2009. Moisture and heat transfer in hybrid weft knitted fabric with artificial intelligence. *Journal of Applied Polymer Science*, *114*(3), pp.1731-1737.

[19] Long, H.R., 1999. Water transfer properties of two-layer weft knitted fabric. *International Journal of Clothing Science and Technology*, *11*(4), pp.198-205.

[20] Bivainyte, A. and Mikucioniene, D., 2011. Investigation on the air and water vapour permeability of double-layered weft knitted fabrics, *Fibres and textiles in Eastern Europe*, 19(3), pp.69-73.

[21] Bivainytė, A., Mikučionienė, D. and Kerpauskas, P., 2012. Investigation on thermal properties of double-layered weft knitted fabrics. *Materials Science*, 18(2), pp.167-171.

[22] Achour, N.S., Hamdaoui, M., Nasrallah, S.B. and Perwuelz, A., 2015. Investigation of moisture management properties of cotton and blended knitted fabrics. *International Journal of Materials and Metallurgical Engineering*, *9*(7), pp.891-895.

[23] Knight, B.A., Hersh, S.P. and Brown, P., 1970. moisture characteristics of some knit fabrics made from blend yarns. *Textile research journal*, *40*(9), pp.843-851.

[24] Oglakcioglu, N. and Marmarali, A., 2010. Thermal comfort properties of cotton knitted fabrics in dry and wet states. *Tekstil ve Konfeksiyon*, *20*, pp. 213-217.

[25] ASTM D3776, 2020. Standard test methods for mass per unit area (weight) of fabric.

[26] ASTM D1777- 96, 2019. Standard Test Method for Thickness of Textile Materials.

[27] ASTM D737, 2018. Standard Test Method for Air Permeability of Textile Fabrics.

[28] BS 7209, 1990. British Standard Specification for Water Vapour Permeable apparel fabrics.

[29] BS 4745, 1990. British Standard Test method for Determination of thermal resistance of textiles.

[30] Kawabata, S., 1975. The standardization and analysis of hand evaluation, 2nd ed., Hand Evaluation and Standardization Committee, Textile Machinery Society of Japan.

[31] Asanovic, K. A., Mihailovic, T. V., and Cerovic, D. D., 2017. Evaluation of the quality of clothing fabrics in terms of their compression behaviour before and after abrasion. *Fibers and Polymers*, *18*, pp.1393-1400.

[32] Spencer, D.J., 2001. Knitting Technology-A comprehensive handbook and practical guide: Technology and Engineering, Cambridge: Woodhead Publishing.

[33] Bagherzadeh, R., Gorji, M., Latifi, M., Payvandy, P. and Kong, L.X., 2012. Evolution of moisture management behavior of high-wicking 3D warp knitted spacer fabrics. *Fibers and Polymers*, *13*(4), pp.529-534.

[34] Bagherzadeh, R., Montazer, M., Latifi, M., Sheikhzadeh, M. and Sattari, M., 2007. Evaluation of comfort properties of polyester knitted spacer fabrics finished with water-repellent and antimicrobial agents. *Fibers and Polymers*, *8*(4), pp.386-392.