MedCrave
Step into the World of Research

Journal of Textile Engineering & Fashion Technology

Research Article

Open Access
CrossMark

Effects of knitted structures on the performance of cotton knitted fabrics

Abstract

In this study, ten different knitted structures of weft-knitted fabrics (including plain, 1X1 rib, interlock, purl, half cardigan, full cardigan, single lacoste, double lacoste, lace, and moss stitch) were manufactured utilizing Nm 15/1 cotton ring-spun yarn on Shima Seiki flat knitting machines. The samples underwent comprehensive testing for structural properties, bursting strength, air permeability, drapeability, abrasion and pilling resistance, as well as wrinkle recovery. The findings revealed that unit weight emerged as the most influential parameter affecting air permeability. Lace fabric exhibited the lowest bursting strength according to the test results. Air permeability of lacoste and cardigan fabrics are the lowest structure. Fabrics produced on double bed machines demonstrated enhanced resistance to abrasion, greater elasticity, and superior wrinkle recovery compared to others. Rib and interlock fabrics displayed the highest drapeability values. All fabrics exhibited a moderate level of pilling resistance. Both statistical and test results corroborated each other.

Keywords: cotton fabrics, flat knitted fabrics, knitted structures, performance

Volume 10 Issue 5 - 2024

Züleyha Değirmenci, Tuğba Can
Textile Engineering Department, Gaziantep University, Turkey

Correspondence: Prof. Dr. Züleyha Değirmenci, Textile Engineering Department, Gaziantep University, Turkey, Email degirmenci@gantep.edu.tr

Received: October 24, 2024 | **Published:** November 05, 2024

Introduction

The global textile market is projected to reach a size of USD 748 billion in 2024 and is anticipated to expand to USD 889.24 billion by 2029, reflecting a compound annual growth rate (CAGR) of 3.52% during the forecast period (2024-2029). This growth trajectory underscores the textile industry's continual expansion, driven by rapid industrialization in both developed and developing nations and advancements in technology. These developments facilitate the establishment of modern facilities capable of producing high-efficiency fabrics, thus contributing to increased revenue generation during the study period and projected continued growth.[1]

Weft knitting represents a swift, continuous, and highly versatile method for transforming yarns. Compared to warp-knitted and woven fabrics, weft-knitted fabrics exhibit superior properties such as stretchability, drapability, elasticity, wrinkle recovery, softness, and adaptability.[2] However, these advantageous characteristics can also result in easy deformation under stress and reduced dimensional stability post-laundering. Weft-knitted fabrics are produced by circular and flat knitting machines based on the shape of the knitting frame. Fabrics produced via flat knitting machines are being particularly popular due to the relative ease of producing new knitted structures and the capability of creating entire garments through flat knitting techniques.

Natural fibers derived from plants and animals, such as cotton, silk, linen, wool, hemp, jute, and cashmere, are extensively utilized in the production of garments, apparel, construction materials, medical dressings, and automotive interiors, among other applications. According to the National Cotton Council of America, cotton remains a versatile and indispensable fiber, contributing significantly to a wide range of products from apparel to personal care items, and supporting millions of jobs globally as it transitions from field to fabric (National Cotton Council of America, n.d.) Cotton, renowned for its versatility, appearance, performance, and natural comfort, exemplifies a fiber with numerous applications. From astronaut space suits to everyday apparel, bed linens, towels, tarpaulins, tents, and personal care products, cotton remains a fundamental material in today's fast-paced world. It not only contributes to the production of thousands of useful products but also supports millions of jobs from cultivation to fabric manufacturing. Currently, cotton holds a 64 percent market share in retail apparel and home products in the United States, highlighting its integral role in consumer lifestyles. Additionally, cotton and its byproducts enhance a wide range of products including plastics, high-quality paper, ice cream, cosmetics, futon and mattress padding, fertilizer, and livestock feed, demonstrating its extensive applicability and economic significance.[3]

Literature survey

The study of Choi, and Ashdown, focuses on the mechanical properties of weft knits for outerwear as a function of knit structure and density and the relationships between hand, structure, and density. Eighteen weft knits are produced with six different structures (1 × 1 rib, half-cardigan rib, half-milano rib, interlock, single-pique, and cross miss interlock) and three different densities (loose, medium, tight). The mechanical properties and hand values of the fabrics are measured using the KES-F method. Similar to tensile properties, bending and shear properties of the samples increase while compression values decrease rooted in increased stitch density. Surface properties such as softness and smoothness raise thanks to raised stitch density. Specific findings for tensile properties reveal that the single-pique and the cross miss interlock can not absorb external stress as much as the 1 × 1 rib and the interlock when stresses are applied in the course direction. Knits with tuck and miss stitches (half-cardigan rib, half-milano rib, single-pique, and cross miss interlock) have better dimensional stability than fabrics with only knit stitches (1x1 rib and interlock fabrics). Testing of primary hand values shows stiffness, fullness softness, and handle values increase and smoothness decreases while stitch density increases. Double knits show higher handle values than single knits. Half-milano rib and cross miss interlock structures have the highest total hand values. Based on the results of the test and an understanding of current market needs for dimensionally stable fabrics with a soft hand authors concluded that knit structures with combined miss and tuck stitches exhibit properties appropriate for outerwear fabrics for the winter season.[4] This paper investigates the effect of three weft knitted structures; plain, rib 1x1, and cardigan on some properties. Knitted fabrics from 100% wool yarn of 3.8 Nm on flat knitting machine are tested in the study. The influence of knit structure on the dimensional stability, density, resistance to pilling, fabric drape, fabric diameter, color fastness to washing, and to rubbing properties are investigated, and it is found that tuck stitch affected the properties of knitted Fabrics. It increased their areal density, made it more porous, increased their pilling resistance, their drape coefficient, and their width and kept their dimensional stability. However, the tuck stitch did not have a major influence on color fastness properties of knitted fabrics.[5] Gorea et al.[6] investigated the effects of tuck and float stitches on knitted fabrics. The results indicated that variations in moisture conditions have a significant effect on fabric thickness, and these variations differed by stitch knitted structure groups. Float knitted structures and tuck/rib knitted structures showed a continued relaxation of fabric thickness through all conditions, but tuck stitches and rib stitches showed a thickness recovery. The color switch of the wool and wool-nylon blend is different from each other in accordance with the air-drying time and conditions. In this paper, the thermal comfort properties of flat knitted acrylic fabrics differing in terms of knit structure, tightness, thickness, and porosity were investigated within the perspective of its usage in winter wear products. Measured and calculated thermal comfort properties by Permetest and Alambeta devices are handled in three aspects, namely thermoregulation characteristics, breathability, and thermo-physiological characteristics, and their relationship between fabric structural characteristics are investigated statistically. The results indicated that 2×2 rib structures provide the optimum condition in terms of thermoregulation, breathability, and thermo-physiological comfort, of which thickness and porosity values should be adjusted accordingly since the thickness improves thermal insulation and porosity improves breathability.[7] Knitting design is the foundation for woolen sweater making. Studies on the knit design for flat knitting machines are beneficial to opening up the innovative thinking of a designer. In the view of designing varied knits, the surface effect of the woolen sweater could be classified into the embossed, filet opening, and racked fabrics. The principle of forming these effects is discussed along with individual fabric styles. Knitting fabric performance is affected by yarns, color, and knitted structure.[8] The paper relates to the basic principles of creating 3D effects on the knitted fabrics produced by using electronic flat knitting machines. The research aims at outlining the technical potential of this technology, based on examples developed on CMS 330 E5 and CMS 530 E 6.2 Stoll machines and programs designed on M1 knitted structure stations. The selected examples emphasize the knitted structure's versatility for being used in different applications, from outerwear to technical end uses, by exploiting the unique capabilities of flat knitting machines to produce fabrics with a large variety of applications. The computer-controlled electronic flat knitting machines are capable of manufacturing shaped engineering structures using their modern and flexible technical features at low manufacturing costs. The fabrics with 3D forms or 3D effects can be used either for outerwear or for technical destinations, with the appropriate raw materials required by the destination.[9] In this study, flat knitting technology is exploited to fabricate auxetic fabrics which laterally expand when stretched. Three kinds of geometrical structures, i.e. foldable structure, rotating rectangle, and reentrant hexagon, are employed as basic reference structures for the development of these kinds of auxetic fabrics. The weft knitting processes based on these structures are specially developed and auxetic fabrics are fabricated using the computerized flat knitting machines. The Poisson's ratio-strain curves of the developed fabrics are plotted and compared with those calculated using existing models to demonstrate the variation trends of Poisson's ratio with the axial strain. The results reveal that except the folded fabric formed with the face loops and reverse loops in a rectangular arrangement, of which the auxetic effect firstly increases and then decreases with the axial strain, the auxetic effects of all other fabrics decrease with an increase of the axial strain. The study also shows that auxetic fabrics can be realized based on knitted structures and that flat knitting technology can provide a simple, but highly effective way of fabricating auxetic fabrics from conventional yarn.[10] The purpose of this study is to investigate the effect of different knitting structure elements and their position in the knit on the deformation properties of plain weft-knitted fabrics. An investigation is carried out with the fabrics knitted on a basis of rib 1×1, rib 2×2, and rib 1×2 on a flat V-bed knitting machine in a gauge 10E. It has been established that the extensibility and strength of the knitted fabrics are immediately concerned with knitting structure. In the case of transverse deformation, the maximum elongation and strength characterized knitted fabrics, which have in a structure just stitches or in different order ranged stitches and short floats. In the case of longitudinal deformation, the maximum elongation and strength are characterized by knitted fabrics that have in a structure tucks. It has been established that the extensibility and strength of the knitted fabrics are related to the knitting structure.[11] In this study, experimental study is presented to determine the effects of fourteen different knit structures of 80% Lambswool-20% Polyamide knitted outerwear fabrics, on the dimensional properties; pilling resistance, abrasion resistance, bursting strength, air permeability, and bending rigidity. The effect of the relaxation condition on the dimensional properties of the fabrics is also studied. From the analyses of variance, it is seen that the effects of knit structure on the properties of the knitted fabrics inspected are highly significant. Specifically, the effect of knit structure on the bursting strength, air permeability, and bending rigidity is highly significant in washed fabrics. Tuck stitch fabrics have the lowest resistance to abrasion. Links-links, seed stitch, and moss stitch fabrics have the highest resistance to pilling.[12] Bukhonka NP[13] examined the impact of rib set-out repeats and single miss stitches on the structural properties and dimensional stability of double weft knitted fabrics, compared to half Milano rib. Nine fabric variations were created, each with a different number of inactive needles. The fabrics were tested after dry relaxation and multiple washings. The results indicated that the number of miss stitches significantly affects the dimensional stability and structural properties of the fabrics. An increase in inactive needles led to greater length shrinkage and reduced width shrinkage. Overall, the study underscores the importance of stitch placement in designing double weft knitted fabrics for desired properties.

Optimizing fabric properties for outerwear is crucial in textile applications because outerwear is designed to protect against various environmental elements while providing comfort, durability, and aesthetic appeal. Outerwear often needs to be water-resistant, windproof, and sometimes insulated to withstand rain, snow, and wind. Optimizing fabric properties ensures that outerwear meets these requirements, keeping wearers dry, warm, and protected in harsh conditions. While protection from the elements is essential, outerwear must also be breathable to prevent overheating. Breathable fabrics allow moisture and excess heat to escape, enhancing wearer comfort, especially during physical activities. Outerwear fabrics are often exposed to rugged use and require resistance to abrasion, tearing, and UV exposure. Optimizing for durability ensures that the garment lasts longer and maintains its protective qualities, even with frequent wear. In colder environments, outerwear should provide effective thermal insulation to retain body heat. This requires selecting and optimizing materials that offer warmth without excessive bulk, allowing for lightweight and comfortable designs. Outerwear must allow freedom of movement, especially for outdoor activities or sports. Fabrics should have the right balance of stretch and structure to support flexibility and fit. Beyond technical properties, outerwear should look good and feel comfortable. Fabric properties like texture, weight, and drape contribute to the overall design and functionality of the garment, influencing consumer appeal and practicality. Increasingly, manufacturers are focused on sustainability. Optimizing fabric properties includes considering environmentally friendly materials, energy-efficient production methods, and recyclable or biodegradable options to minimize environmental impact. These considerations guide fabric engineers in selecting or developing textiles that enhance outerwear's performance, comfort, and durability for various environmental conditions and consumer needs.

Research problem

To what extent can the different properties of outwear be improved by using the weft knitting method in their production? - What is the best structural weft knitting suitable for the production of outwear fabrics?

Objectives

a) To study the production of outwear fabrics using the weft knitting method. Evaluate the characteristics of weft-knitted fabrics such as air permeability, bursting strength, drapeability, abrasion and pilling resistance, wrinkle recovery.

b) Identify the optimal performance of outwear produced by weft knitting.

Research hypotheses

a) The use of the weft knitting method in the production of outwear will contribute to:

b) To find out the effects of knitting structures on the characteristics and performances of weft knitted fabrics.

c) Analysing the knitted relation between knitted characteristics and performance of the samples statistically.

Material and method

In this study, a diverse range of ten weft-knitted fabrics including plain (single jersey), 1X1 rib (ribana), interlock, purl, half cardigan, full cardigan, single lacoste, double lacoste, lace, and moss stitch were meticulously crafted. These samples were expertly knitted utilizing a computerized Shima Seiki NSSG122 double-bed flat knitting machine produced with Nm 15/1 cotton ring yarn via Shima Seiki flat knitting machines as seen in Figure 1 and with the properties given in Table 1.

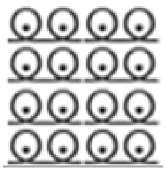
Figure 1 Machine schematic view of Shima Seiki NSSG122.

Table 1 Knitting machine and yarn properties used in this study

Machine properties		Yarn properties	
Type	Flat knitted weft knitting machine	Raw material	100 % cotton
Model	Shima Seiki NSSG122	Number	Nm 15/1
Dimensions	2370 * 826 * 1550 cm	Production method	Ring spun
Fineness	E-7 (There are 7 needles in 1 gauge)	Twist ratio	3.5 αe

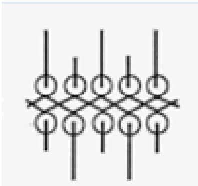
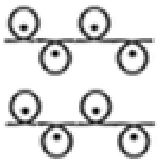
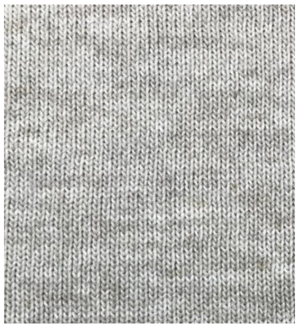
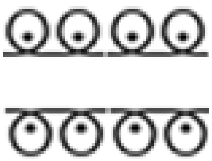
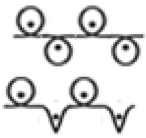
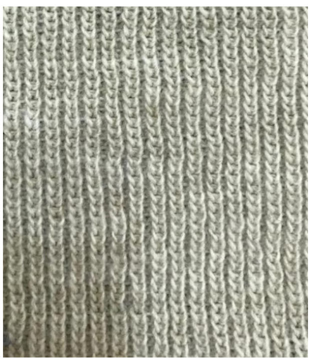
Needle diagrams and photographic views (original dimension with 1 X zoom by camera) of the samples are presented in Table 2.

Table 2 Needle diagrams and photographic views of the samples

Needle diagram of the samples	Face side of the sample	Back side of the sample
Plain (Single jersey) 		

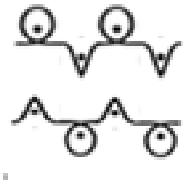
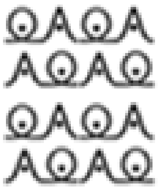
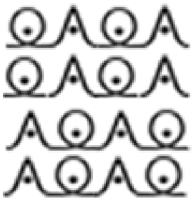
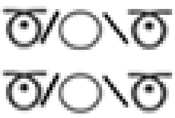
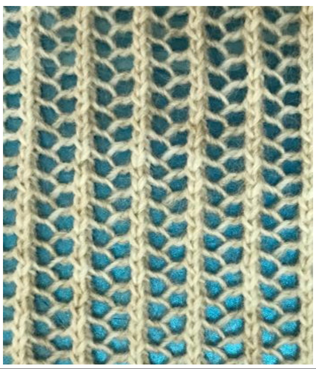
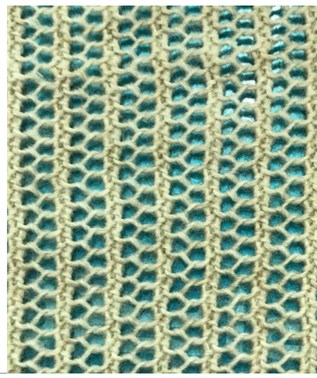
Citation: Değirmenci Z, Can T. Effects of knitted structures on the performance of cotton knitted fabrics. *J Textile Eng Fashion Technol.* 2024;10(5):213–224. DOI: 10.15406/jteft.2024.10.00390

Table 2 Continued...

Needle diagram of the samples	Face side of the sample	Back side of the sample
Rib 		
Interlock 		
Purl 		
Half cardigan 		

Citation: Değirmenci Z, Can T. Effects of knitted structures on the performance of cotton knitted fabrics. *J Textile Eng Fashion Technol.* 2024;10(5):213‒224. DOI: 10.15406/jteft.2024.10.00390

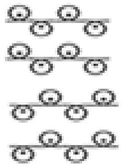
Table 2 Continued...

Needle diagram of the samples	Face side of the sample	Back side of the sample
Full cardigan 		
Single lacoste 		
Double lacoste 		
Lace 		

Citation: Değirmenci Z, Can T. Effects of knitted structures on the performance of cotton knitted fabrics. *J Textile Eng Fashion Technol.* 2024;10(5):213–224. DOI: 10.15406/jteft.2024.10.00390

Table 2 Continued...

Moss stitch



*(Knit, Skip decrease, yarn over, knit 2 stitches together, knit)

When analyzing the production methods of the samples used in the study, it is observed that plain, rib, Lacoste, and lace fabrics are knitted using a single bed, whereas the others are knitted using a double bed. Additionally, tuck stitches are present in the structures of lacoste and cardigan fabrics. The fabrics produced on double-bed machines (except for purl fabrics) exhibit higher elasticity and shrinkage behavior in the width direction. Among these fabrics, interlock fabric is heavier and thicker compared to others due to the two-thread feeding process during each row of production. Fabrics containing tuck stitches display embossing-like patterns on their surfaces and tend to gather at these points. However, if the tuck stitches are distributed homogeneously across the surface and positioned such that they do not align row by row, the fabric exhibits a balanced structure. The presence of tuck stitches within the fabric significantly alters various performance and structural characteristics. Consequently, it is anticipated that double Lacoste fabric will be more balanced than single Lacoste fabric, and double cardigan fabric will be more balanced than single cardigan fabric. Moss stitches are knitted with the industrial machines, instead of turning the knitting at the end of a row with a garter bar or forming purl stitches one-by-one as the garter carriage does, the machines make use of two needle beds and transfer operations automatically. Stitch transfers to the opposite bed are pre-programmed before the knitting begins. A row is knitted. Each stitch is then automatically transferred from one needle bed to the opposite needle bed. The next row is now ready to be knitted on the second bed. Transferring stitches to the opposite bed has the same effect as turning the knitting. The next knitted row will complete the garter stitch. The stitches are then transferred back to the first bed and the sequence begins again. Despite these predictions, the inherent loop structures of knitted fabrics lead to greater flexibility compared to other fabrics, resulting in varying properties depending on the raw material and pattern combinations used in their production. Therefore, it is crucial to test and analyze the structural and performance characteristics of the obtained samples. In this study, all the tests are applied according to the international standards in the university laboratory by the authors. The test standards and application procedures are given in Table 3.

Table 3 Applied tests and standards

Test name	Standard name	Test method
Wale and course number	ASTM D8007-15(2019) Standard Test Method for Wale and Course Count of Weft Knitted Fabrics	The number of loops was counted via a loupe from 5 different areas, and an average value was used.
Unit weight	The unit weight of the samples was measured according to standard TS EN 12127: 1999 Textile - Fabrics - Determination of mass per unit area using small samples standard	Five specimens were taken from each sample diagonally with a 10-cm diameter, and the weight was measured via precision balance and the average value was used.
Thickness	ASTM D1777 - 96(2019)	Five specimens were taken from each sample diagonally, and the thickness was measured via Schmidt thickness measuring apparatus, and an average value was used
	Standard Test Method for Thickness of Textile Materials	
Air permeability	ASTM D737-18 Standard Test Method for Air Permeability of Textile Fabrics	Air permeability of the samples was measured via SDL Atlas machine from ten different areas by 100 Pa pressure difference with 20-cm head, and the average value was used.
Bursting strength	ASTM D3786/D3786M-18 Standard Test Method for Bursting Strength of Textile Fabrics—Diaphragm Bursting Strength Tester Method	The bursting strength test was applied via Truburst test machine by 50-mm head from 5 samples with diaphragm correction and the average value was used.
Abrasion resistance	ISO 12947-2:2016	Abrasion resistance test was applied via Martindale test machine, and the assessment was done when the first hole was seen from 3 specimens and the average value was used.
	Textiles — Determination of the abrasion resistance of fabrics by the Martindale method — Part 2: Determination of specimen breakdown	
Pilling resistance	ISO 12945-2:2000	Pilling resistance test was applied via Martindale test machine, and the assessments were done by comparing the specimen with standard photographs up to 7000 cycles.

DOI: 10.15406/jteft.2024.10.00390

Table 3 Continued...

Test name	Standard name	Test method
	Textiles — Determination of fabric propensity to surface fuzzing and to pilling — Part 2: Modified Martindale method	
Drapeability	BS 5058:1973 Method For The Assessment	Drapeability test was done by Cusick test machine with two specimens and the average value was used.
	Of Drape Of Fabrics (British Standard)	
Wrinkle recovery	AATCC-128 Test Method for Wrinkle Recovery of Fabrics: Appearance	The wrinkle recovery test was done via AATCC wrinkle recovery tester, and the assessments were done by comparing the test results with standard photographs.

Results and discussion

Comparing of structural properties

According to Table 4, plain fabric is lightweight and has a moderate thickness with a relatively high wale and course count, contributing to its balanced loop shape factor. Rib fabric is heavier and thicker, with a high wale count and relatively low loop shape factor, indicating a compact structure. Interlock fabric is similar in weight to rib fabric but has a lower thickness and wale count, providing a balanced structure. Purl fabric is lighter with a lower stitch density, offering high loop shape flexibility. Half cardigan fabric is relatively heavy and thick, similar to purl fabric but with a higher mass per unit area. Full cardigan fabric has a moderate weight with high thickness and lower stitch density, providing a balanced loop structure. Single Lacoste fabric is lightweight with moderate thickness and balanced stitch density. Double Lacoste fabric is slightly heavier and thicker than single Lacoste, with a lower loop shape factor indicating a denser structure. Lace fabric is the lightest among the samples, with moderate thickness and lower stitch density, providing high flexibility. Moss stitch fabric is lightweight with moderate thickness and a balanced loop shape factor, offering flexibility. As a result, rib and half cardigan fabrics are the heaviest and thickest fabrics due to their high mass per unit area and thickness.

Table 4 Structural properties of the samples

Sample name	Structural properties						
	Mass per unit area, g/m^2	Thickness, mm	Wale per cm	Course per cm	Stitch density	Loop shape factor	Loop length, mm
Plain	185	0.85	9	14	126	1.56	5,0
Rib	250	1,78	17	11	187	0.65	5,2
Interlock	243	1.44	14	9	126	0.64	4,8
Purl	159	1,23	7	12	84	1.71	5,0
Half cardigan	213	2.38	7	12	84	1.71	5,1
Full cardigan	181	2.14	7	9	63	1.29	5,1
Single lacoste	154	1.09	10	11	110	1.1	4,8
Double lacoste	169	1.16	11	8	88	0.73	5,0
Lace	100	1.05	6	10	60	1.67	5,1
Moss stitch	149	1.37	9	8	72	0.89	5,2

Lace fabric is the lightest one with the lowest mass per unit area. Rib fabric, indicating a compact structure with the highest stitch density. Purl and lace fabrics are most flexible fabrics due to their high loop shape factors. Interlock, Double Lacoste, and Moss Stitch fabrics, offering a good balance between weight, thickness, and flexibility. Each fabric exhibits unique structural properties, impacting their performance and potential applications. Analyzing these characteristics is essential for understanding the suitability of each fabric for specific uses. The most significant result is that rib and half cardigan fabrics are the heaviest and thickest, attributed to their high mass per unit area and thickness, while lace fabric is the lightest with the lowest mass per unit area, demonstrating how varying structural properties like mass, thickness, and stitch density directly influence each fabric's flexibility, compactness, and suitability for different applications.

Comparing the air permeability of samples

Air permeability is the rate of airflow perpendicularly between the two surfaces of the fabric.

Air permeability is a crucial parameter in the textile industry, defining the fabric's ability to allow air to flow through it under specified conditions of pressure, direction, and time. This property holds significant technical relevance, especially in assessing the functional performance of textile products. Notably, air-permeable fabrics possess the capacity to facilitate the passage of water in both vapor and liquid states. Consequently, the circulation of air and water vapor within a garment plays a pivotal role in ensuring the comfort of the wearer.[14] The determination of air permeability is gaining prominence, tailored to the specific application of the knitted fabric. Consequently, this parameter holds substantial weight in the selection process of knitted fabrics. Figure 2 graphically illustrates the results of the air permeability tests conducted on the knitted fabric.

Air permeability is intricately linked to structural attributes like thickness, weight, and loop density of knitted fabrics. Altering the knitted structure of the fabric induces corresponding changes in its characteristics. A crucial parameter in this context is porosity, where the lace knitted structure emerges as the most permeable. This is attributed to the abundance of holes in this design. Notably, apart from variations in mass per unit area, the stitch density also differs among the samples. As indicated in Table 4, there exists an inverse relationship between stitch density and air permeability. Additionally, the presence of tuck stitches exerts a discernible influence on air permeability. Lacoste and cardigan fabrics exemplify this, showcasing a proportional relationship between the number of tuck stitches and air permeability. It can be inferred that if the mass per unit area of all samples were equal, the relationship between air permeability and knitted structures would remain consistent. The interaction between air permeability and structural attributes is further underscored by the role of stitch density, where an increase in stitch density leads to a decrease in air permeability due to reduced porosity; this effect is notably modulated by tuck stitches, which enhance permeability in proportion to their frequency, as demonstrated in lacoste and cardigan fabrics.

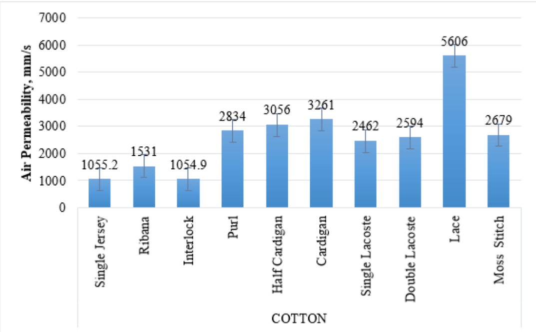


Figure 2 Air permeability test results of samples.

Comparing the bursting strength of samples

Bursting strength test is applied to measure the multidimensional strength of the fabric. Bursting strength test results were shown as a graphic in Figure 3.

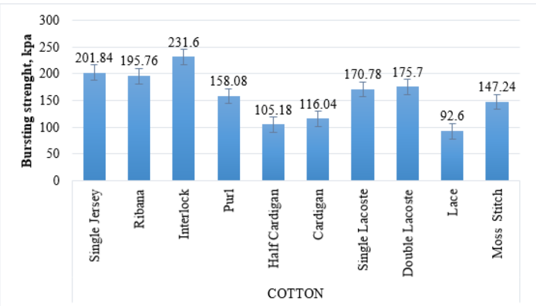


Figure 3 Bursting strength test results of samples.

In general, there is a common assumption that the bursting strength of fabric samples is primarily related to the strength of the yarn used. However, this may not always hold true, as it's not necessarily the weaker yarns that break first. Stronger yarns, although more robust, tend to be less flexible and can reach their flexing limits more easily, potentially leading to earlier breakage. Similarly, yarns with lower crimp can reach their flexing limits faster, resulting in earlier failure.

In this context, it's worth noting that the bursting strength results cannot be solely attributed to yarn strength, as the raw material used in all samples is the same. Upon closer examination of the knitted structures, it becomes evident that the weakest fabric is lace. This is likely due to the elongated stitches in this knitted structure, coupled with a low stitch density value.

Cardigan fabrics, being knitted on double beds with tuck stitches, exhibit reduced bursting resistance. The presence of both tuck stitches and loop transfers between beds contributes to the fabric's stiffness. In comparison, the full-cardigan sample demonstrates a more balanced structure than the half cardigan, resulting in higher bursting resistance.

In the moss knitted structure, the absence of tuck and miss stitches, along with lower weight, thickness, and stitch density values, leads to a notably loose structure. Lacoste fabrics, incorporating tuck stitches, experience a reduction in strength. The lengthwise elasticity of the purl fabric is low, correlating with its lower bursting strength.

Interlock, rib, and plain fabrics boast the highest mass per unit area, which translates to the highest bursting strength values among the samples. To summarize, no single parameter directly determines bursting strength. Rather, a combination of factors influencing fabric tightness and elasticity collectively contribute to this property.

Comparing abrasion resistance

Abrasion is defined as the wearing down of a fabric due to rubbing against another surface. Fabrics are subject to wear over their lifespan, which can lead to deterioration, damage, and diminished performance. Factors like abrasion resistance, performance, and durability are crucial considerations in assessing wear. Wear can manifest in various ways, including fabric-to-fabric friction, contact with surfaces during use, and inter-fabric rubbing. It's challenging to directly correlate real-world wear conditions with laboratory tests, which accounts for the diversity in abrasion testing methodologies and interpretations.

In this study, the number of cycles until a single hole is observed is used to determine abrasion resistance. The test results are graphically presented in Figure 4.

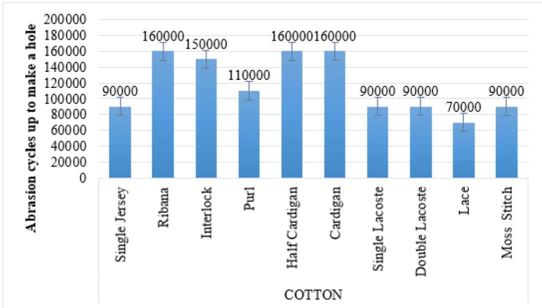


Figure 4 Abrasion resistance test results of samples.

Absolutely, when it comes to evaluating abrasion resistance for garments, the formation of a hole is a crucial parameter. Both abrasion and bursting resistances are closely tied to the material's strength and elongation. However, during an abrasion resistance test, the presence of a friction force on the sample, along with surface characteristics, plays a significant role in determining resistance levels. Notably, fabrics knitted on double beds tend to exhibit higher resistance, while there's generally no significant difference observed among the other samples, except for the lace knitted structure. In assessing abrasion resistance in textiles, hole formation is a critical parameter, as both abrasion and bursting resistance are strongly influenced by fabric strength and elongation, with double-bed knitted fabrics showing higher resistance levels, unlike other samples, except for lace structures.

Comparing pilling resistance

Research on the mechanics of pilling has revealed that the propensity for pilling is governed by the rates of fuzz formation, entanglement, and eventual pill wear-off. Pilling occurs swiftly as fuzz density reaches a critical level. Fibers become twisted and entangled, progressively involving nearby fibers. As the abrasive action continues, pills eventually move away from the fabric surface.[15] In this study, test evaluations were conducted at intervals of 125, 500, 1000, 2000, and 7000 cycles. However, assessments were made only after 7000 cycles, as the primary focus of the study was not to compare samples based on cycle count. Evaluations were carried out through a comparison with standard photographs, assigning ratings between 1 and 5 (where 5 signifies no change). The results of the pilling resistance tests are graphically depicted in Figure 5.

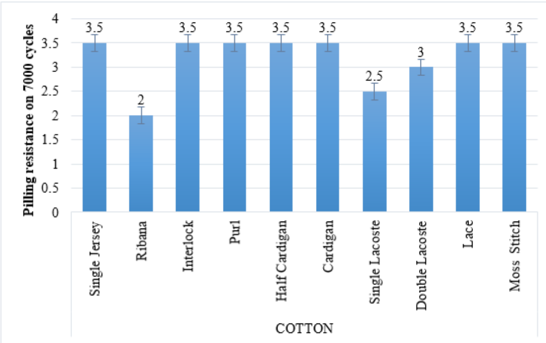


Figure 5 Pilling resistance test results of samples.

Figure 4 illustrates that all the samples exhibit a moderate level of resistance to pilling. Given the similarity in results, it can be inferred that the knitted structure is not the primary determinant of pilling resistance. Pilling is a critical quality factor in textiles, as it affects both the aesthetic appeal and durability of fabrics by influencing surface appearance, fabric texture, and wear resistance, thus impacting consumer satisfaction and product longevity. In accordance with the moderate test results of samples any one can be used.

Comparing drapeability

Drapeability stands out as a crucial characteristic influencing the visual appeal of a fabric, defined by its deformation behavior under its own weight. This property proves significant in anticipating how the fabric will appear in actual use. In recent times, with an increased emphasis on comfort, the drapeability and bending properties of fabrics have gained prominence.

The drapeability test involves using a mirror to observe and trace the shadow of the sample. Subsequently, the traced area is cut, and the difference between the undrawn and drawn paper is calculated and expressed as a percentage. The results of the drapeability tests are graphically depicted in Figure 6.

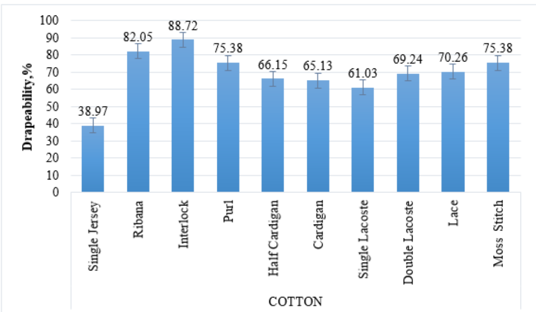


Figure 6 Drapeability test results of samples.

When examining the drapeability of cotton fabrics, it's evident that rib and interlock fabrics exhibit the highest values. This can be attributed to their elevated stitch density. While the mass per unit area of a fabric contributes to its drapeability, stiffness introduces resistance. Consequently, a stiff and heavy fabric may possess a similar drapeability value to a loose and lightweight one. The drapeability of a fabric hinges not only on its tightness but also on factors like yarn resistance to angle change, fabric resistance to distortion, and ease of elongation. Fabrics with greater elasticity tend to be more drapeable compared to those with lower elasticity.[16] Therefore, it can be concluded that the use of tuck stitches diminishes elasticity, resulting in low drapeability for both cardigan and lacoste fabrics. The plain fabric exhibits the lowest drapeability due to its stabilization in the longitudinal direction and the tendency of fabric edges to curl. In conclusion, fabric drapeability is influenced by a combination of structural factors, including stitch density, elasticity, yarn resistance, and fabric stiffness, with tuck stitches and stabilization techniques reducing elasticity and resulting in lower drapeability, as observed in cardigan, lacoste, and plain fabrics.

Comparing wrinkle recovery

Wrinkle recovery pertains to a fabric's capacity to revert to its original state, free from wrinkles, under the influence of its own weight and gravity after experiencing a certain load. Evaluation is conducted by comparing standard photographs, assigning ratings ranging from 1 to 5. On this scale, 5 indicates no wrinkles visible on the fabric, while 1 denotes a fabric with slightly high wrinkles.

The results of the wrinkle recovery tests are presented graphically in Figure 7.

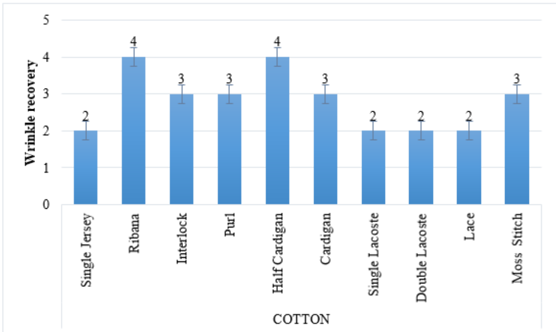


Figure 7 Wrinkle recovery test results of samples.

The wrinkle recovery of knitted fabrics made from cotton is generally not very effective, and some of them exhibited poor performance in this aspect. This is indeed linked to the elasticity of the fabrics. As noted, fabrics like lacoste, which have low elasticity, also showed low wrinkle recovery. On the contrary, fabrics knitted by double beds tended to be more elastic, leading to better wrinkle recovery properties. This aligns with what we observed in terms of abrasion resistance as well. Fabrics produced with a double bed tend to be more elastic and therefore exhibit better wrinkle recovery characteristics**.** The wrinkle recovery of cotton-based knitted fabrics is generally limited, with some fabrics performing poorly in this regard. This characteristic is closely associated with fabric elasticity. Fabrics with lower elasticity, such as those with a lacoste knit, demonstrate reduced wrinkle recovery, whereas fabrics knitted with double beds, which tend to have greater elasticity, show improved wrinkle recovery. These findings are consistent with observations on abrasion resistance, as double-bed fabrics exhibit both enhanced elasticity and better wrinkle recovery properties.

Statistical analyses of performance properties

To discern the interrelationships between the test results, statistical analyses were conducted. Specifically, a one-way ANOVA test was employed to assess the significance of differences in any response

Citation: Değirmenci Z, Can T. Effects of knitted structures on the performance of cotton knitted fabrics. *J Textile Eng Fashion Technol.* 2024;10(5):213‒224. DOI: 10.15406/jteft.2024.10.00390

based on design or knitted structure. The analyses were carried out using the SPSS software package with a confidence interval of 0.05. The results are presented in Table 5.

Table 5 indicates that the only significant difference among the test results lies in the air permeability values. This implies that altering the knitted structure has a notable impact on air permeability. However, the one-way ANOVA test results do not provide a comprehensive explanation regarding the effects of various parameters on the performance of the samples. To delve deeper into this, a correlation analysis was conducted, and the outcomes are highlighted in Table 6.

Table 5 One-way ANOVA test results of samples

	Sum of squares	Df	Mean square	F	Sig.
Mass per unit area	39550	43	919.767	3.246	0.071
Thickness	34303.333	35	980.095	1.975	0.087
Air permeability	765.333	73	10.484	4.568	0
Bursting strength	401.333	46	8.725	2.344	0.265

Table 6 Correlation analysis of responses and structural characteristics

	M	T	AP	BS	AR	WR	D	PR
Mass per unit area, M	1	0.513	-.755*	0.584	0.584	.671*	0.311	-0.325
Thickness. T	0.513	1	0.033	-0.354	.642*	.820**	0.308	-0.017
Air permeability. AP	-.755*	0.033	1	-.887**	-0.345	-0.203	0.031	0.28
Bursting strength. BS	0.584	-0.354	-.887**	1	-0.031	-0.066	0.127	-0.34
Abrasion Resistance. AR	0.584	.642*	-0.345	-0.031	1	0.599	-0.301	-0.137
Wrinkle Recovery. WR	.671*	.820**	-0.203	-0.066	0.599	1	0.494	-0.157
Drapeability. D	0.311	0.308	0.031	0.127	-0.301	0.494	1	-0.169
Pilling Resistance. PR	-0.325	-0.017	0.28	-0.34	-0.137	-0.157	-0.169	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 6 provides insightful correlations between various parameters and performance characteristics of the samples:

1) There is a strong negative relationship between mass per unit area and air permeability, indicating that as the mass per unit area increases, air permeability decreases.

2) A positive and moderate correlation exists between mass per unit area and wrinkle recovery, suggesting that higher mass per unit area is associated with improved wrinkle recovery.

3) A moderate positive correlation is observed between thickness and abrasion resistance, indicating that as thickness increases, abrasion resistance also tends to increase.

4) There is a strong positive correlation between thickness and wrinkle recovery, signifying that higher thickness is linked to better wrinkle recovery.

5) A strong negative correlation between air permeability and bursting strength implies that fabrics with lower bursting strength tend to have higher air permeability.

These correlations provide valuable insights into how different factors interact and influence the performance characteristics of the samples, independent of the knitted structure. These findings offer valuable insights for the textile industry, directing the development of high-performance outerwear fabrics specifically tailored to distinct applications and consumer requirements. The results indicate that knitting structures significantly impact fabric properties such as air permeability, bursting strength, and abrasion resistance. These findings underscore the substantial influence of knitting structures on performance characteristics, aligning closely with existing literature.[4] Additionally, the observed effects of various knitting structures on fabric attributes—including weight, thickness, and air permeability—are consistent with previous research findings, mirroring those reported in similar studies.[12] Overall, the literature supports our findings, demonstrating that our results are in agreement with established research within the field of textile engineering and fabric performance.[7,17–27]

Conclusion

This study aimed to investigate the production and performance characteristics of outwear fabrics utilizing the weft knitting method. By meticulously crafting ten diverse weft-knitted fabrics and evaluating them through a comprehensive array of standardized tests, several significant insights were gained.

Selection criteria of consumers for outerwear are fashion, price and performance. To support the sustainability and slow fashion, producing and selecting the most durable outerwear is necessary for us and for our world. Results of this study showed that by changing only the structure the performances of the samples changed. Therefore selecting the correct structure to target end use can lessen the payment to the clothes and the waste. It means instead of maximizing any property, producers should optimize the each property according to target using are is better.

Firstly, the structural properties of the fabrics varied widely, influenced primarily by their knitting structures. Plain, rib, and interlock fabrics demonstrated balanced structures with the highest mass per unit area, which translated to superior bursting strength. Conversely, lace fabric, characterized by elongated stitches and low stitch density, exhibited the weakest performance in terms of bursting strength.

Air permeability emerged as a crucial parameter, intricately linked to the fabric's structural attributes such as thickness, weight, and

Citation: Değirmenci Z, Can T. Effects of knitted structures on the performance of cotton knitted fabrics. *J Textile Eng Fashion Technol.* 2024;10(5):213–224. DOI: 10.15406/jteft.2024.10.00390

loop density. Lace fabric, with its highly porous structure, showed the highest air permeability, while fabrics with higher stitch densities, such as rib and interlock, displayed lower permeability. The presence of tuck stitches in fabrics like lacoste and cardigan significantly influenced their air permeability, underscoring the importance of knitted structure on this property.

In terms of abrasion resistance, double-bed knitted fabrics generally exhibited higher resistance, with no significant differences observed among other samples except for lace. The pilling resistance of all samples was moderate, indicating that the knitted structure was not a primary determinant of this property. However, the drapeability of fabrics varied, with rib and interlock fabrics showing the highest values due to their elevated stitch density. The use of tuck stitches diminished elasticity, resulting in low drapeability for both cardigan and lacoste fabrics.

Wrinkle recovery was another critical performance characteristic, closely tied to the fabric's elasticity. Fabrics knitted on double beds demonstrated better wrinkle recovery due to their higher elasticity, while less elastic fabrics like lacoste showed lower recovery.

Statistical analyses, including one-way ANOVA and correlation analysis, revealed significant relationships between various structural characteristics and performance properties. Notably, air permeability was significantly affected by the knitted structure. Additionally, mass per unit area, thickness, and stitch density were found to correlate with properties such as wrinkle recovery, abrasion resistance, and bursting strength.

In conclusion, the study highlights the potential of weft knitting in enhancing the properties of outwear fabrics. By selecting appropriate knitting structures, manufacturers can optimize key performance characteristics such as air permeability, bursting strength, drapeability, abrasion resistance, and wrinkle recovery. These findings provide valuable insights for the textile industry, guiding the production of high-performance outwear fabrics tailored to specific applications and consumer needs. As a result, it is concluded that knitting structures affect fabric properties such as air permeability, bursting strength, and abrasion resistance. The findings highlight the significant influence of knitting structures on performance characteristics and these results are similar to the literature.[4] The impact of various knitting structures on fabric properties, including weight, thickness, and air permeability. It provides insights similar to those found in your study regarding the effects of knitting structures on performance and these are identical to the literature.[12] Briefly literature supports for our findings, it demonstrates that our results are consistent with established research in the field of textile engineering and fabric performance.[8]

At the end of the study, it is proved that if the consumer needs a cloth for summer wear; lace, plain and lacoste structures should be preferred. If the consumer needs elastic and durable clothes, he should prefer rib, interlock and cardigan structures. While wrinkle recovery and elastic behaviors of structures are parallel, bursting strength and abrasion resistance of structures are similar to each other. Finally, in accordance with test results the performance necessity of the outerwear is related to the fitting to using purpose.

Acknowledgments

None.

Funding

None.

Conflicts of interest

The author declares that there is no conflict of interest.

References

1. https://www.mordorintelligence.com/industry-reports/global-textile-industry---growth-trends-and-forecast-2019---
2. Pamuk G, Çeken F. Manufacturing of weft-knitted fabric reinforced composite materials: a review. *Materials and Manufacturing Processes*. 2008;23(7):635–640.
3. Cotton: from field to fabric introduction.
4. Choi MS, Ashdown SP. Effect of changes in knit structure and density on the mechanical and hand properties of weft-knitted fabrics for outerwear. *Textile Research Journal*, 2000;70(12):1033–1045.
5. Bouagga T, Harizi T, Sakli F. The effect of tuck stitch on the properties of weft knitted fabric. *Journal of Natural Fibers*. 2021:1–12.
6. Gorea A, Baytar F, Sanders E. Effect of stitch patterns on moisture responsiveness of seamless knitted wool fabrics for activewear. *International Journal of Clothing Science and Technology*. 2020;33(2):175–187.
7. Erdumlu N, Saricam C.. Investigating the effect of some fabric parameters on the thermal comfort properties of flat knitted acrylic fabrics for winter wear. *Textile Research Journal*. 2017;87(11):1349–1359.
8. Jing-hong YUAN, Yi HU. Design and making of varied weaves of computerized flat knitted fabric. *Wool Textile Journal*. 2014;42(7).
9. Penciuc M, Blaga M, Ciobanu R. Principle of creating 3D effects on knitted fabrics developed on electronic flat knitting machines. *Buletinul Institutului Politechnic DIN IASI Publicat de Universitatea Tehnică, Gheorghe Asachi din Iasi Tomul LVI (LX), Fasc, 4*. 2010.
10. Hu H, Wang Z, Liu S. Development of auxetic fabrics using flat knitting technology. *Textile Research Journal*. 2011;81(14):1493–1502.
11. Mikučionienė D, Čiukas R, Mickevičienė A. The influence of knitting structure on mechanical properties of weft knitted fabrics. *Materials Science (Medžiagotyra)*. 2010;16(3):221–225.
12. Emirhanova N, Kavusturan Y. Effects of knit structure on the dimensional and physical properties of winter outerwear knitted fabrics. *Fibres & Textiles in Eastern Europe*. 2008;16(2):67.
13. Bukhonka NP. The impact of miss stitch on the dimensional properties and stability of double weft knitted fabrics after dry and washing relaxations. *AATCC Journal of Research*. 2024.
14. Wilbik-Halgas B, Danych R, Wiecek B, et al. Air and water vapour permeability in double-layered knitted fabrics with different raw materials. *FIBRES and TEXTILES in Eastern Europe*. 2006;14(3):77.
15. Gintis D, Mead EJ. The mechanism of pilling. *Textile Research Journal*. 1959;29(7):578–585.
16. Değirmenci Z, Çoruh E. The influences of loop length and raw material on bursting strength air permeability and physical characteristics of single Jersey knitted fabrics. *Journal of Engineered Fibers and Fabrics*. 20117;12(1).
17. Can T. Performance properties of flat knitted fabrics produced by different designs and raw materials. Gaziantep University, Textile Engineering, Master Thesis, Turkey. 2019.
18. Instruction Manual Operation/Maintenance. Wakayama, Japan. 2010.
19. ASTM International - ASTM D8007-15(2019), Standard test method for wale and course count of weft knitted fabrics. 2019.
20. EN 12127:1997, (MAIN) Textiles - Fabrics - Determination of mass per unit area using small samples.

21. ASTM D1777-96 (2019), Standard test method for thickness of textile materials. 2019.
22. ASTM D737-18, Standard test method for air permeability of textile fabrics. 2023.
23. ASTM D3786/D3786M-18, Standard test method for bursting strength of textile fabrics—diaphragm bursting strength tester method. 2023.
24. ISO 12947-2:2016, Textiles — Determination of the abrasion resistance of fabrics by the Martindale method, Part 2: Determination of specimen breakdown.
25. ISO 12945-2:2020, Textiles — Determination of fabric propensity to surface pilling, fuzzing or matting, Part 2: Modified Martindale method.
26. British Standards Document, BS 5058, Method for the assessment of drape of fabrics.
27. AATCC TM128-2017e2, Test method for wrinkle recovery of fabrics: Appearance.

Citation: Değirmenci Z, Can T. Effects of knitted structures on the performance of cotton knitted fabrics. *J Textile Eng Fashion Technol.* 2024;10(5):213–224. DOI: 10.15406/jteft.2024.10.00390