Journal of Design and Textiles (JDT)
Volume 2 Issue 1, Spring 2023
ISSN$_{(P)}$: 2959-0868 ISSN$_{(E)}$: 2959-0876
Homepage: https://journals.umt.edu.pk/index.php/jdt/index

Article QR

Title:	**Comparative Analysis of Structural Effect of Single Jersey and its Derivative Fabrics on Mechanical and Comfort Properties of Knitted Fabric**
Author (s):	Shehbaz Ahmad, Tanveer Hussain, Yasir Nawab, Habib Awais, Muzzamal Hussain, Waqas Ashraf
Affiliation (s):	National Textile University, Faisalabad, Pakistan
DOI:	https://doi.org/10.32350/jdt.21.03
History:	Received: April 25, 2023, Revised: May 18, 2023, Accepted: May 22, 2023, Published: June 20, 2023
Citation:	S. Ahmad, T. Hussain, Y. Nawab, H. Awais, M. Hussain, and W. Ashraf, "Comparative analysis of structural effect of single jersey and its derivative fabrics on mechanical and comfort properties of knitted fabric," *J. Des. Text.*, vol. 2, no. 1, pp. 36–47, June 2023, doi: https://doi.org/10.32350/jdt.21.03
Copyright:	© The Authors
Licensing:	This article is open access and is distributed under the terms of Creative Commons Attribution 4.0 International License
Conflict of Interest:	Author(s) declared no conflict of interest

A publication of
School of Design and Textiles
University of Management and Technology, Lahore, Pakistan

Comparative Analysis of Structural Effect of Single Jersey and its Derivative Fabrics on Mechanical and Comfort Properties of Knitted Fabric

Shehbaz Ahmad*, Tanveer Hussain, Yasir Nawab, Habib Awais, Muzzamal Hussain, and Waqas Ashraf

[1]School of Engineering & Technology, Department of Textile Engineering, National Textile University, Faisalabad, Pakistan

ABSTRACT The physical, mechanical, and comfort properties of knitted fabrics depend on the type, shape, and number of loops per unit area. Physical properties, namely areal density depend on the ratio of knit, tuck, and miss stitches. The higher the ratio of touch stitches, the higher would be the areal density of the knitted fabric. Double Lacoste had a higher ratio of touch stitches and single jerseys had a zero ratio of tuck stitches. Noticeably, the double Lacoste had the highest areal density, whereas the single jersey had the lowest areal density among all knitted fabrics. Therefore, areal density was inversely proportional to the loop length. Mechanical properties such as tensile strength and bursting strength also depend upon the type and length of the loop. The knit loop had the highest tensile and bursting strength, which decreased as the ratio of touch stitches increased. Air permeability increased with the increasing ratio of tuck stitches and reduced when the fabric contains 100% of the knit loops.

INDEX TERMS derivative fabrics, e-comfort properties, knitted fabrics, mechanical properties, single jersey

I. INTRODUCTION

Knitting is the second largest and oldest technology of fabric manufacturing [1]. The loop is the basic element of the knitting structure. The properties of knitted fabric largely depend on the size and shape of a knitted loop. Mechanical properties are directly linked with loop length by means of some knitting constants. The value of knitting constants is dependent upon the dry relaxed or wet relaxed states. For the same material and structure of the knitted fabric, the mechanical properties are governed by the knitted loop's size, shape, and state. Many researchers have developed relationships between loop length and knitted fabric structure, which are applicable to many fabrics irrespective of the type and count of yarn, machine gauge, and

* Corresponding Author: shahbazrnd@gmail.com

type of machine. This relationship may be expressed in the form of simple mathematical equations. The yarn used for a single loop is called stitch length or loop length, however, the configuration of the loop is different for different structures. The repeating pattern of stitches in a knitting structure is termed as Structural Knitted Cell (SKC), which describes the complete structure of the knitted fabric [2].

Knitted fabric's aesthetic and performance properties are directly linked to its mechanical properties. Mechanical properties such as tensile, bursting, shear strength, and flexural rigidity, are critically linked to knitted structure [3]. The current study was carried out to understand the mechanical behaviour of knitted fabric in a better way. Thereby, understanding the structure of the knitted fabric, the mechanical properties can be predicted, accordingly.

The mechanical properties of knitted fabrics depend upon the raw material of the fabric, stitch density, and structure of the fabric [4]. Synthetic materials usually have high mechanical properties as compared to the natural materials. Mechanical properties such as bursting strength and tensile strength decrease by introducing tuck and miss stitches. The decrease in the mechanical properties is higher for the tuck stitch as compared to the miss stitch. The mechanical properties of grey and finished fabrics are different. Usually, finished fabrics have higher mechanical properties as compared to the grey fabric because the Ks value for finished fabric is higher than that of the grey fabric. Lacoste fabrics show a higher bursting strength than the Pique fabrics [5]. Double-layered fabrics have better mechanical properties as compared to single-layered fabrics and in the same way, double, layered fabrics with all knit stitches have higher mechanical properties than double-layered fabrics with a tuck or miss stitches [6]. On the other hand, the dimensional stability of fabric consisting of only knit stitches is lower as compared to the fabric with tuck and miss stitches. To improve the dimensional stability, tuck and miss stitches are introduced in the fabric. The hand value is dependent on stitch density. By increasing the stitch density of the knitted fabric, hand value was improved. Hand value also depends upon the structure of the knitted fabric. Double-layered fabrics have a higher hand value than the single-layered fabrics [7]. Mechanical properties such as bending rigidity, fabric stiffness, pilling, and drapability also depend upon the tightness factor of the knitted fabric. The greater the tightness factor the more would these properties and vice versa

[8]. The mechanical qualities of knitted fabric are strongly influenced by the material. Since natural fiber strength is comparatively lower than the synthetic fibers, the mechanical properties are also poorer than synthetic fibers. Tomoko and Masaru studied the effect of different materials concerning the mechanical properties of plain knitted fabric. They found that by using filament yarn of polyurethane with cotton knitted fabric, the mechanical properties of plain knitted fabric increased almost thrice that of plain knitted fabric with 100 % of cotton yarn. The crimp of fabric with polyurethane fabric was also sharper than that of cotton fabric. The effect of the method of load on fabric mechanical properties was quite drastic. Gradual increment in load application on knitted fabric is attributed to the disappearance of creases, while drastic increment in load elongates the yarn itself [9].

The shape of yarn in fabric structure has an important role in the mechanical properties of knitted fabric. In different fabric structures, the shape of yarn is different. That is why each structure of knitted fabric with the same yarn type and with the same yarn count has different mechanical properties. The yarn becomes curved after knitting and has non-linear mechanical properties. The bending and torsion characteristics of the knitting yarn also affect the shape of the loop. The residual torque is considered to build a mechanical model of knitted cloth. The residual torque is affected by the tension and twist of the yarn, however, the slanting in the knitted loop would stop if the loop becomes trapped. A knitted loop's form is altered by slanting. This indicates that the tightness of the fabric affects the fabric's spirality [10]. Extensibility and strength are two significantly factors, which impact the knitting structure. The only difference between the wale spacing and course spacing in terms of their impact on knitting structure is their ratio. The link between the course spacing and wale spacing is reciprocal. Wale spacing is at its lowest when course spacing is at its highest [11]. The loop's shape is influenced by a variety of factors. The shape of the loop varies depending on several elements in the same fabric with the same stitch length. The fabric losing its tension, robbing back, and the swelling of the yarn following water absorption are three main elements, which determine the shape of the knitted loop [12]. The yarn friction and cam angle are the two main factors that influence the shape of the knitted loop. While yarn input tension is a small impact on the loop shape. This implies that the friction of the yarn significantly affects the formation of the loop shape [13]. Additionally, it was found that the knitting cam, cylinder walls, cam angle, coefficient of friction of the needle with the cam, and resistance of the needle movement against the cylinder walls affect the normal force acting on the needle. Cam angles significantly affect the overall tension of the yarn. The normal forces on the needle rise when the cam angle raises from 45-60 degrees, yet the overall tension of the yarn drops by 66%. This is due to a drop in yarn tension and elongation, as well as, a decrease in the needle force is required, drawing the yarn to make loops. A non-linear cam system has replaced the previously used leaner cam system, which has a net beneficial impact on the mechanical characteristics of the knitted loop [14].

Fabric comfort properties have a significant effect on the human body. The most important among these all is the thermal comfort. Thermal insulation is largely related to the thickness of the fabric than the type of yarn. Noticeably, it was also observed that the twist level and spinning process also affected the thermal comfort [15]. Ozdil et al. found that by increasing the twist, the thermal insulation decreases and the thermal conductivity increases with it. As the twist increase, the yarn hairiness decrease, and as a result, thermal insulation decrease. They also found that carded yarn has more thermal resistance than combed yarn. This is because the carded yarn has more hairiness than the combed yarn. The fabric knitted with card yarn is thicker than that of combed yarn, which has a less contact area with the human body, thus, provides thermal insulation [16], [17].

II. MATERIAL AND METHOD

Purely, 100% cotton yarn was used to develop all knitted structures with a linear density of 20/1 Ne. All samples were knitted on a single jersey-knitting machine with a diameter of 30" and gauge 20 available in the knitting department of National Textile University. Fifteen samples of knitted fabric were produced with five different knitted structures and three different stitch lengths. In this way, three different tightness factors (high, medium, and low) were obtained. The derivatives of single jersey used were single Lacoste, double Lacoste, honeycomb, and plain pique having three different levels of stitch length 3.2, 3.6, and 4.0 mm.

A. CHARACTERIZATION

The physical, mechanical, and comfort properties of developed knitted structures were measured. For this purpose, different testing methods were used to find the mechanical properties and machinery used in the methods, which are explained briefly in this research. Following machinery and testing methods were used in this study. All the tests were performed under the standard laboratory condition, with at least three replicates of each test sample. These tests were performed after dry and wet conditions of knitted fabric. To obtain a reference state, fabrics were fully relaxed after ten-time tumble drying. The physical parameters of the developed samples are shown in Table I.

TABLE I

PHYSICAL PARAMETERS (GSM, COURSE PER INCH (CPI), WALES PER INCH (WPI), LENGTH AND WIDTH WISE SHRINKAGE AND TORQUEING OF ALL KNITTED SAMPLES

No	GSM	CPI	WPI	SHRINK.L	SHRINK.W	TORQUING
1	207	66	22	-0.4	-0.5	3.3
2	211	60	23	-2.4	-0.3	0.9
3	217	47	31	0.8	-2.7	0.6
4	207	62	20	-3.2	2.2	5.5
5	235	68	23	-4.3	0.5	2.1
6	265	80	24	-4.2	-1.3	4
7	254	72	25	-1.8	-1.1	2.1
8	230	72	20	0.9	-0.7	5
9	241	37	24	1	-2.7	0.5
10	197	41	30	-0.7	-1.4	1.6
11	281	90	22	0.2	-3.3	0.1
12	184	37	28	-1.9	0.4	0.2
13	228	68	22	-3.8	0.7	0.9
14	195	56	20	-1.7	1.9	1.5
15	255	52	21	-2.2	-2.2	0.3

III. RESULTS AND DISCUSSIONS

A. AREAL DENSITY

A number of variables influences areal density of knitted fabrics. The yarn linear density, loop length, shrinkage of the fabric, fabric structure, and finishing method are the most crucial variables. However, this paper focused on the yarn count, stitch length, and the fabric structure as the three most critical elements in this research. The number of yarns used determines the fabric's overall weight. When using the same yarn count, the fabric's stitch length and structure have a direct impact on the fabric's overall weight. For the same fabric structure, Figure 1 demonstrates an inverse relationship between areal density and loop length. The cloth grows looser and its mass per unit area falls as the loop length increases. Reduced loop length (tight-knit) results in a more compact fabric structure with an increase in the fabric mass per unit area.

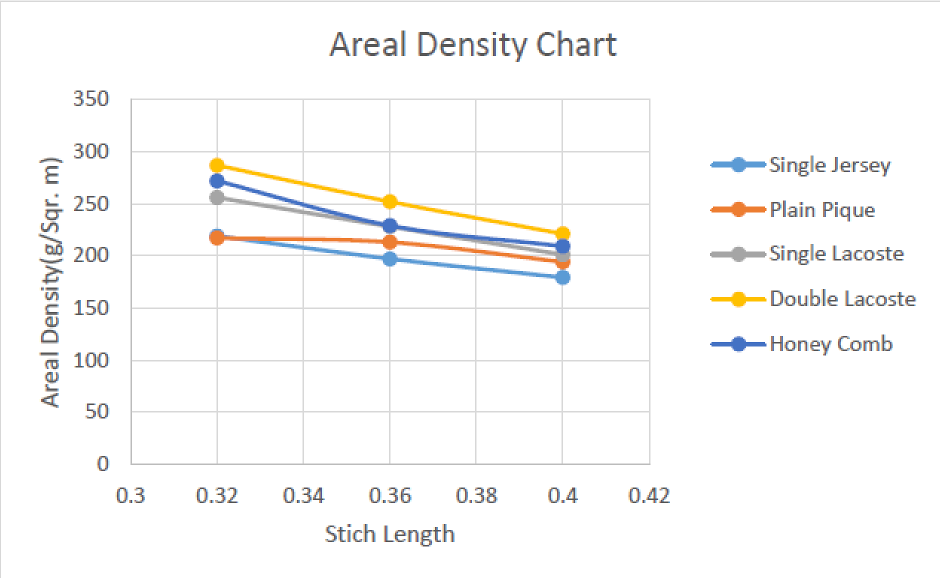

FIGURE 1. Effect of fabric structure and loop length on the areal density of the knitted fabric

B. TENSILE STRENGTH

It was noticed that the behaviour of tensile strength in the course-wise and wales-wise directions was different. The loops were attached to each other in wales and course direction. Nevertheless, when force was applied in wales' direction, the loops were entangled with each other and resisted the applied force. A higher force would be required to break the fabric if there are all knit loops. In the presence of tuck loops, this resistance was applied for the force reduction and ultimately, the tensile strength decreased in the wale's direction. As the ratio of tuck stitches increased, the value of tensile strength also decreased in comparison with 100% knit stitches. However, where the combination of knit and tuck stitch was used, an optimum value of tensile strength was obtained from it.

Tensile strength in course direction showed a different behaviour. Since the tuck loop lies in the course direction and on the application of the applied load tuck loop, it provided more resistance than a knit loop. Therefore, fabric like a single jersey, which had a good tensile strength in the wale's direction, did not have a good tensile strength in the course direction. The results indicated in Figure 2, explain that as number of tuck stitches of stitches increase in the course direction, the tensile strength also increases in the course direction; however, reducing in the wales direction. Honeycomb fabric is the combination of an equal number of tuck and knit stitches. That is why honeycomb fabric showed an optimum behaviour of tensile strength both in the course and wales direction.

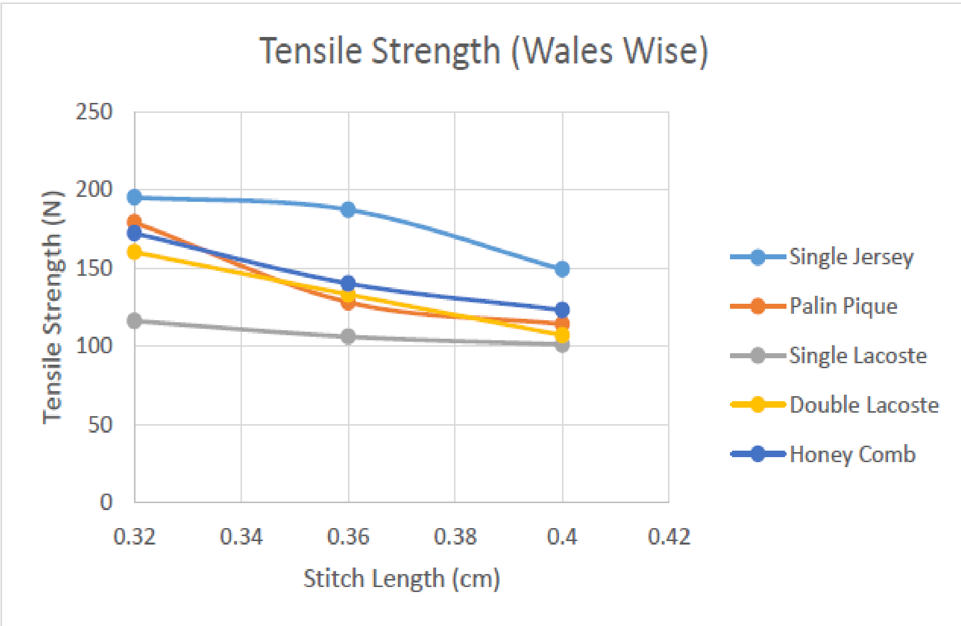

FIGURE 2. Effect of fabric structure and loop length on tensile strength of the knitted fabric

C. BURSTING STRENGTH

Figure 3 illustrates how fabric structure and loop length affect the knitted fabric's bursting strength. Despite the other numerous aspects, the knitted fabric's structure also affects its bursting strength. A fabric knit with full knit loops had a higher bursting strength than a fabric knit with a combination of knit and tuck stitches. Due to this, single jersey fabric had a higher bursting strength rating than fabric made of both knit and tuck stitches. The bursting strength of the fabric reduced as the number of tuck stitches rised and vice versa. As a result, honeycomb fabric had a lower value for bursting strength than double Lacoste because it contains fewer knit loops as a whole.

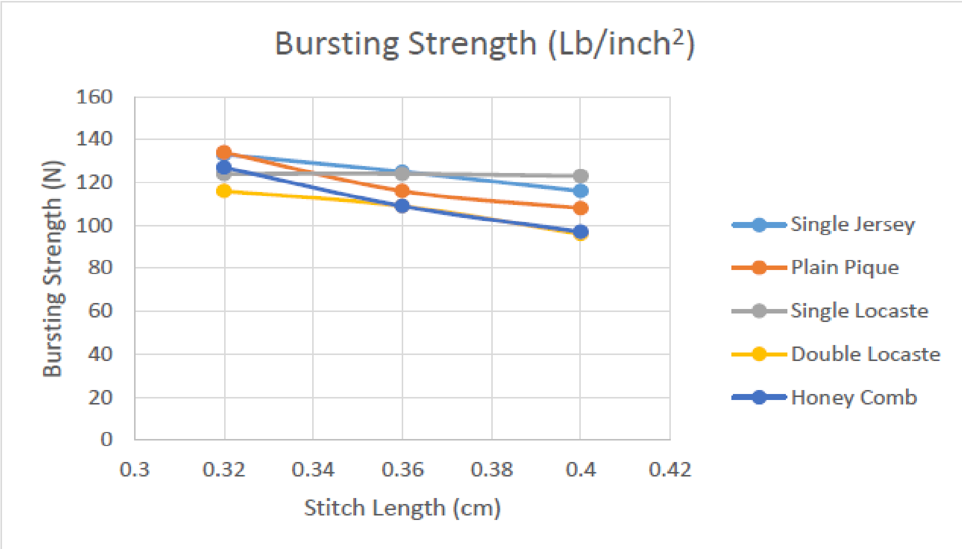

FIGURE 3. Effect of fabric structure and loop length on bursting strength of the knitted fabric

D. AIR PERMEABILITY

The result in Figure 4 shows that the air permeability of single jersey fabric has the lowest value and the plain pique fabric has the highest value. A knitted fabric consisting of 100% knit loops is compact in structure, ultimately reducing the air spaces and air permeability as compared to the fabric consisting of a combination of knit/tuck or knit/miss loops. On the other hand, adding the knitting and tuck stitch combination enhances the air permeability. Therefore, the plain pique has the highest value of air permeability due to this combination of tuck and knits stitch. Furthermore, if the tuck stitch is increased, the air permeability decreases simultaneously with it. The optimum option for air permeability is the alternate tuck and knit stitch combination. Hence, by increasing the value of tuck stitches and all knit stitches have the opposite effect on the air permeability of knitted fabrics.

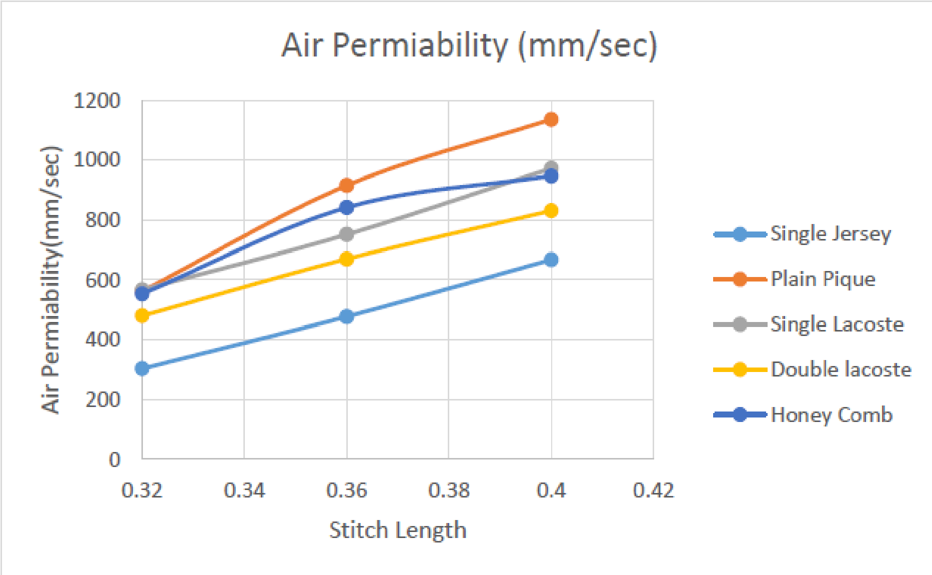

FIGURE 4. Effect of fabric structure and loop length on air permeability of the knitted fabric.

E. Conclusion

In this study, it was found that fabric areal density increases with the increased number of tuck stitches, which has a lower value with a knit stitch. Tensile strength changes in course and wale wise directions. In the wale's direction, higher tensile strength values were obtained with the knit stitch and lower with the tuck stitch. In course direction, a higher tensile strength value was also obtained with the tuck stitch and lower with the knit stitch. Notably, bursting strength was higher for all knit stitches, which decreased with the introduction of tuck stitches. The thickness of these fabrics also has a good relationship with the tuck stitches because yarn accumulated at that place where the thickness of the fabric increased. The single-knit fabric has a lower value of thickness than fabric with a combination of knit and tuck stitch. The air permeability of knitted fabric largely depends upon the fabric's structure. The fabric with all knit loops was compact, which provided resistance for the airflow. With the introduction of tuck loops, the fabric provided permeability for the airflow.

REFERENCES

[1] S. C. Ray, *Fundamentals and Advances in Knitting Technology*. Woodhead Publishing India Pvt. Limited, 2011.

[2] J. J. F. Knapton and D. L. Munden, "A Study of the mechanism of loop formation on weft-knitting machinery: Part II: The effect of input tension and cam setting on loop formation," *Text. Res. J.*, vol. 36, no. 12, pp. 1072–1080, Dec. 1966, doi: https://doi.org/10.1177/004051756603601208

[3] M. Rashed, "Effect of tuck loop in bursting strength of single jersey knitted fabrics," *Int. J. Res. Eng. Technol.*, vol. 3, no. 5, pp. 712–719, 2014.

[4] El-Shiekh and S. Backer, "The mechanics of snagging in plain-knitted structures", *Text. Res. J.*, vol. 43, no. 5, pp. 262–271, May 1973, doi: https://doi.org/10.1177/004051757304300504

[5] M. W. Suh, "A study of the shrinkage of plain knitted cotton fabric, based on the structural changes of the loop geometry due to yarn swelling and deswelling," *Text. Res. J.*, vol. 37, no. 5, pp. 417–431, May 1967, doi: https://doi.org/10.1177/004051756703700513

[6] H. M. Fletcher and S. H. Roberts, "The relationship of the geometry of plain knit cotton fabric to its dimensional change and elastic properties," *Text. Res. J.*, vol. 24, no. 8, pp. 729–737, Aug. 1954, doi: https://doi.org/10.1177/004051755402400806

[7] M. Karimian, H. Hasani, and S. Ajeli, "Analyzing the effect of fiber, yarn and fabric variables on bagging behavior of single jersey weft knitted fabrics," *J. Eng. Fibers Fabr.*, vol. 8, no. 3, Sep. 2013, doi: https://doi.org/10.1177/155892501300800301

[8] N. Oglakcioglu, P. Celik, T. B. Ute, A. Marmarali, and H. Kadoglu, "Thermal comfort properties of angora rabbit/cotton fiber blended knitted fabrics," *Text. Res. J.*, vol. 79, no. 10, pp. 888–894, June 2009, doi: https://doi.org/10.1177/0040517508099396

[9] W. E. Shinn, "An engineering approach to jersey fabric construction," *Text. Res. J.*, vol. 25, no. 3, pp. 270–277, Mar. 1955, doi: https://doi.org/10.1177/004051755502500314

[10] M. S. Choi and S. P. Ashdown, "Effect of changes in knit structure and density on the mechanical and hand properties of weft-knitted fabrics for

outerwear," *Text. Res. J.*, vol. 70, no. 12, Dec. 2000, doi: https://doi.org/10.1177/004051750007001201

[11] S. Tornaletti, D. Rozek, and G. P. Pfeifer, "The distribution of UV photoproducts along the human p53 gene and its relation to mutations in skin cancer," *Oncogene*., vol. 8, no. Oct. 2015, pp. 2051–2057, Sep. 1993.

[12] A. Bivainyte and D. Mikucioniene, "Investigation on the dynamic water absorption of double-layered weft knitted fabrics," *Fibres Text. East. Eur*., vol. 19, no. 6, pp. 64–70, 2011.

[13] C. D. Kane, U. J. Patil, and P. Sudhakar, "Studies on the influence of knit structure and stitch length on ring and compact yarn single jersey fabric properties," *Text. Res. J.*, vol. 77, no. 8, pp. 572–582, Aug. 2007, doi: https://doi.org/10.1177/0040517507078023

[14] N. A. Ibrahim, T. F. Khalifa, M. B. El-Hossamy, and T. M. Tawfik, "Effect of knit structure and finishing treatments on functional and comfort properties of cotton knitted fabrics," *J. Ind. Text*., vol. 40, no. 1, pp. 49–64, Apr. 2010, doi: https://doi.org/10.1177/1528083709357975

[15] P. Chidambaram, R. Govindan, and K. C. Venkatraman, "Study of thermal comfort properties of cotton/regenerated bamboo knitted fabrics," *African J. Basic. Appl. Sci*., vol. 4, no. 2, pp. 60–66, 2012, doi: https://doi.org/10.5829/idosi.ajbas.2012.4.2.1032

[16] C. D. Kane, U. J. Patil, and P. Sudhakar, "Studies on the Influence of knit structure and stitch length on ring and compact yarn single jersey fabric properties," *Text. Res. J.*, vol. 77, no. 8, pp. 572–582, Aug. 2007, doi: https://doi.org/10.1177/0040517507078023

[17] N. Özdil, A. Marmarali, and S. D. Kretzschmar, "Effect of yarn properties on thermal comfort of knitted fabrics," *Int. J. Therm. Sci*., vol. 46, no. 12, pp. 1318–1322, Dec. 2007, doi: https://doi.org/10.1016/j.ijthermalsci.2006.12.002