The Influences of Loop Length and Raw Material on Bursting Strength Air Permeability and Physical Characteristics of Single Jersey Knitted Fabrics

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ABSTRACT
This paper reports the effect of loop length and raw material on the air permeability and the bursting strength of plain knitted fabrics. In this study, a series of plain knitted fabrics were produced on a circular knitting machine with cotton, polyester, acrylic and viscose by Ne 30/1 yarns. Each fabric type was produced with four different stitch lengths. All the fabrics were knitted at the same machine setting in order to determine the effect of their structure on the fabric properties. Their geometrical and physical properties were experimentally investigated. The influences of the loop length and the raw material on the number of the courses per cm, number of the wales per cm, loop shape factor, thickness, fabric unit weight, tightness factor, air permeability and bursting strength are analyzed. Statistical analysis indicates that raw material and loop length significantly parameters affect the air permeability and the bursting strength properties of the fabrics.

Keywords: single jersey fabric, loop length, raw material, bursting strength, air permeability

INTRODUCTION
Today, the production of high performance knitted goods has been expanded by changing the fibers, yarns, and knitting parameters to create new fabric designs as well as by the appropriate selection of post-knitting finishes to produce multifunctional knitwear, e.g., sportswear, high-tech active-wear, casual-wear, swimwear, outerwear, etc., with outstanding features, such as soft and smooth handle, air permeability, strength etc. [1]. The revolution in the fashion knitwear industry has become inevitable due to the frequent changes in fashion trends, leading to the production of knitted apparels using different yarn types, fabric types, designs and style variations. These elements play a significant role in fashion trends, especially in segments such as casual wear and sportswear. Plain knitting takes up about 90% of all knitted fabric consumption [2]. The knitted fabrics used for the production of underwear or any kind of next-to skin wear are in contact with human skin, therefore it is especially important for them to provide a sensation of comfort. Because of their looped structure, knitted fabrics have good stretch ability, an important element in optimal sensorial comfort [3]. The structural parameters and the majority of the mechanical and physical properties of knitted fabrics depend on the technical characteristics of knitting machines, the properties of yarns (such as the linear density) and the twist level of yarn, as well as the raw material used to produce the fibers [4].

In the literature, some researches describe the relationships between knitting parameters and mechanical properties of knitwear. Many previous studies [5-9] reported the effects of physical parameters such as yarn linear density, yarn twist, loop length, the tightness factor, finishing treatment and degree of washing on the dimensional properties of knitted fabrics. Many researchers [9,10] investigated the influence of the spinning system, yarn count, raw material and other parameters on the structural properties of knitted fabrics. According to these studies, the strength and the elongation of weft knitted fabrics increased with increasing density. By increasing the weight of the fabric and the loop length, the pilling resistance and bursting strength increased.

Chidambaram, Govind and Venkataraman [11], investigated the influence of loop lengths and yarn linear densities of 100 % bamboo knitted fabric on the thermal comfort properties. Single jersey structures were produced with yarns of three different linear densities and with three different loop lengths in the fabric, and their thermal comfort properties were evaluated and analyzed. The water vapor permeability and air permeability show concomitant increases as the linear density and loop length increases. Bivainytė and Mikučionienė [12] investigated the influence of knitting parameters and raw materials on the air and water vapor permeability of double layered knits used for leisure sports. The physical and dimensional properties of single jersey fabrics made from cotton / elastomeric core spun yarn were investigated by Kumar and Sampath [2]. The results clearly indicate that the resulting yarn was highly suitable for circular knitting and change in stitch length values did not have any significant impact on wale density values. Čiukas and Abramavičiūtė [13] in stated that the porosity of the knit was affected by the linear density of yarn and the length of the loop.

Majumdar, Mukhopadhyay, and Yadav [14] examined the comfort properties of single jersey, interlock and rib knitted fabrics produced from cotton, regenerated bamboo and cotton/bamboo yarns. According to the results, the highest water vapor and air permeability values were obtained in single jersey knit structures. Kane, Patil and Sudhakar [15] focused on the effect of single jersey, single pique, double pique and honeycomb structures and structural cell stitch length (SCSL) on ring and compact yarn single jersey fabric properties. With increased SCSL, the dimensional properties such as CPI, WPI, SD, grams per square meter, thickness and tightness factor decreased for all the structures, while comfort properties such as air permeability and water absorbency increased. Mikučionienė, Arbataitis [4] researched the influence of different cellulose yarns on the structure and physical properties of knitted fabrics, such as loop length, wale and course spacing, the loop shape factor, the area density of knits, etc. Choi and Ashdown, [16] studied the mechanical properties of weft knits for outerwear as a function of knit structure and density, and the relationships between hand, structure and density.

In previous studies bursting strength and air permeability properties of fabric raw material and loop length were investigated separately. Therefore the combined effect of the factors cannot be determined. In this study the effect of four raw materials with four different loop lengths on air permeability and bursting strength were evaluated and compared.

MATERIALS

Sample knitted fabrics were produced from Cotton, Polyester, Acrylic and Viscose combed ring spun yarns of count Ne 30, possessing the same twist coefficient ($\alpha e = 3.6$) as single jersey fabric. The fabrics were produced by a Mayer and Cie Model MV4 single jersey knitting machine running at 30 rpm. Fabrics with gauge 28 GG and 30” diameter were knitted from each yarn. The knitting room atmosphere had a humidity of 65% and a temperature of 20 ± 2°C. Samples were produced with loop length values of 3.0, 2.9, 2.6 and 2.45 mm. The knitting process was carried out at constant machine settings and the samples were kept in a standard atmosphere for 24 hours to allow for relaxation and conditioning prior to testing.

TESTING

Bursting strength of samples was tested according to BS EN ISO 13938-2 by using a Truburst tester with diaphragm correction. Air permeability was measured according to ISO 9237 by using a SDL Atlas M021A tester at a test pressure drop of 100 Pa (20 cm^2 test area). All measurements were performed under standard atmospheric conditions (20 ± 2°C, 65 ± 2% relative humidity (RH) for 24 h according to ASTM D1776-08e1 (2009).

The experimental were statistically evaluated by using the Design Expert software programmed with the test method of Analysis of Variance (ANOVA). The correlations between structural characteristics and selected performance properties were analyzed by SPSS 17 statistical package program.

RESULTS AND DISCUSSION

The structural properties of sample knitted fabrics test results depending on raw material and loop length are presented in *Table I*.

TABLE I. Properties of single jersey knitted fabrics.

Raw Material	Loop Length (mm)	Course per cm	Wale per Cm	Stitch Density cpc*wpc	Loop Shape Factor cpc/wpc	Thickness (mm)	Fabric Weight (g/m^2)	Tightness Factor
Cotton	3.0	18	13	216	1.38	0.57	117	1.47
	2.9	21	13	273	1.61	0.58	124	1.53
	2.6	24	13	312	1.85	0.53	135	1.70
	2.45	23	13	299	1.77	0.53	140	1.81
Polyester	3.0	18	15	270	1.20	0.51	124	1.47
	2.9	19	15	285	1.27	0.54	131	1.53
	2.6	22	17	374	1.29	0.54	145	1.70
	2.45	23	16	368	1.44	0.50	152	1.81
Acrylic	3.0	19	12.5	237.5	1.52	0.61	132	1.47
	2.9	18	14	252	1.29	0.54	128	1.53
	2.6	19	13	247	1.46	0.55	141	1.70
	2.45	24	13	312	1.85	0.57	152	1.81
Viscose	3.0	17	13	221	1.31	0.43	118	1.47
	2.9	18	13	216	1.38	0.42	120	1.53
	2.6	21	13	273	1.62	0.42	134	1.70
	2.45	23	13	299	1.77	0.45	146	1.81

Loop length was the major factor affecting all the other properties i.e. wale per cm, course per cm, stitch density and tightness factor. When the loop length increased, the wales per inch, the course per inch, stitch density and tightness factor decreased correspondingly. The trend was the same for single jersey knitted fabrics. The thickness and weight of knitted fabrics are characteristic values related to the drape and fullness of clothing. The fabric thickness of a knitted fabric depends on the count, structure and relative closeness of the loops. The weight of knitted fabrics depends on the structure, yarn count and the dimensional properties of the knitted fabrics.

Bursting Strength

The bursting strength of knitted fabric is important in several ways. The fabric should have sufficient strength against forces acting upon it during dying, finishing and use. However, it is very difficult to predict the bursting strength of knitted fabrics before performing strength tests [9]. Therefore, this was tested at ten different places per sample. The reading was noted in kPa. Results for all fabric samples are presented in *Figure 1* below.

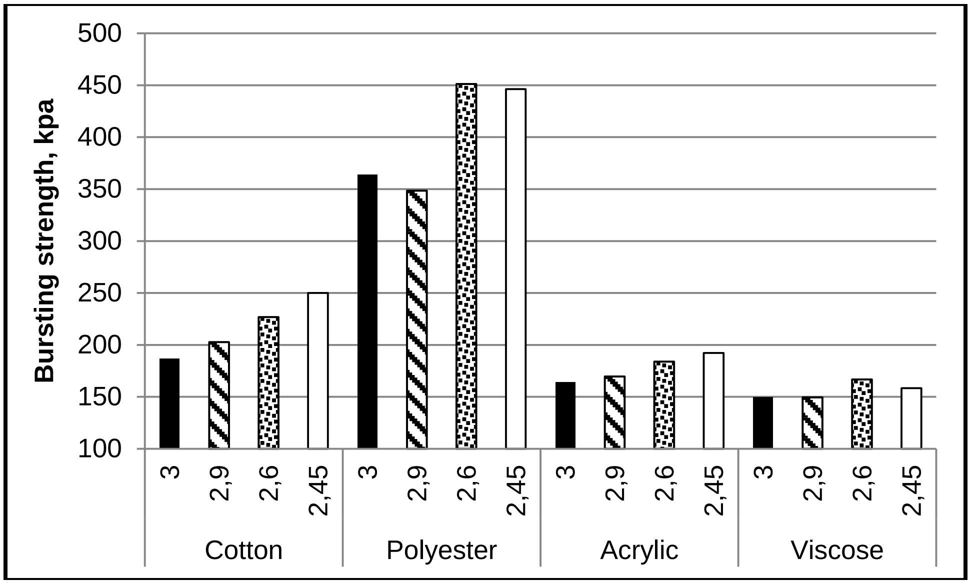

FIGURE 1. The influences of loop length and raw material on bursting strength.

According to the *Figure 1* polyester knitted fabrics are most resistant to bursting. The bursting strength of cotton is higher than acrylic and viscose knitted fabrics. Acrylic and viscose knitted fabrics present similar bursting strength values and are lowest of the samples tested. According to the literature the fiber tenacities are: viscose (0.21 N/tex) < acrylic (0.27 N/tex) < cotton (0.45 N/tex) < polyester (0.56 N/tex) [17]. Thus, the bursting strength of the fabrics correlates well with tenacity of the fiber used to produce them.

Figure 1 shows that bursting strength values at the loop lengths 3-2, 9 and loop lengths 2,6-2,45 are close to each other. Thus, as loop length of the fabric increases, the bursting strength decreases. An increase in loop length causes a decrease in the tightness factor (*Table I*) and so the fabrics become slack. The bursting strength of slack fabrics are lower than the tight ones. The results confirm those presented elsewhere in the literature [19].

Air Permeability

Air permeability of a textile material is closely related to the cover factor, density and thickness. Air permeability has a great influence on comfort because an air permeable material is also vapor or liquid permeable [18]. Airflow through textiles is mainly affected by the pore characteristics of fabrics. The pore dimension and distribution in a fabric is a function of fabric geometry. The yarn diameter, knitting structure, course and wale density, and yarn linear density are the main factors affecting the porosity of knitted fabrics [12].

The air permeability of a fabric is a very sensitive indicator of the fabric construction and type of fibers and yarn used. The air permeability of the fabrics is presented in *Figure 2*. It can be seen that the polyester knitted fabric with 3.0 mm loop length is the most permeable fabric. The same yarn fineness in combination with the large loop length means an open structure so the permeability of air is high.

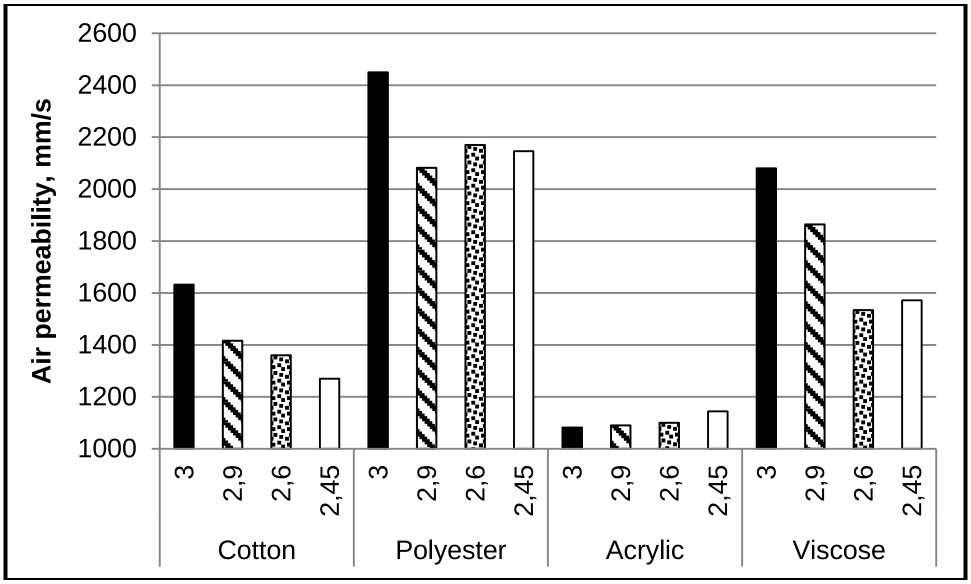

FIGURE 2. The influences of loop length and raw material on air permeability.

The maximum air permeability values are obtained in the fabric manufactured from polyester fibers. Since the polyester fiber is synthetic the cross section of the polyester yarn is more regular than cotton and viscose. Thus, the unevenness of polyester yarn is better so the fabrics made by polyester yarns allow highest air flow. The data in *Figure 2* shows that the fabrics made of viscose fiber pass air more than those made of cotton fibers. The results are identical to the literature [20]. The fabrics made from acrylic fibers have lowest air permeability values due to the hairy structure of acrylic fibers.

Statistical Significance Analysis

The experimental results have been statistically evaluated by using the Design Expert statistical package program. To analyze the test results Analysis of Variance (ANOVA) method is used and the significance level is selected as p=0,005. The results were evaluated based on the F ratio and the probability of the F-ratio (prob>F). The lower the probability of the F-ratio, the more significant the variable. *Table II* summarizes the statistical significance analysis for all the data obtained in the study.

TABLE II. Statistical analysis-design expert.

Responses	R^2	Raw Material			Loop Length			Interaction		
		P-Value	F-Value	%C	P-Value	F-Value	%C	P-Value	F-Value	%C
Cpc	0.82	0.3645	1.22	8.10	0.0004	32.86	74.45	0.9038	0.18	17.44
Wpc	0.96	<0.0001	68.83	95.18	0.6590	0.21	1.07	0.5535	0.75	3.74
Stitch density	0.92	0.0009	16.45	47.36	0.0002	44.38	43.27	0.5158	0.83	9.37
Loop Shape Factor	0,83	0.0239	5.51	34.94	0.0015	22.13	49.11	0.8773	0.22	15.95
Thickness	0.92	0.0001	27.27	85.95	0.2227	1.75	2.10	0.3671	1.21	11.95
Fabric Weight	0.97	0.0010	15.74	14.81	<0.0001	260.05	81.94	0.3731	1.19	3.25
Tightness Factor	0.99	0.000	1.000	0	3083.67	<0.0001	100	0.000	1.000	0
Bursting Strength	0.99	<0.0001	286.23	92.85	0.0002	39.40	4.47	0.0172	6.25	2.69
Air Permeability	0.97	<0.0001	75.75	88.48	0.0080	12.28	6.57	0.0891	3.10	4.95

The statistical analysis indicates that the raw material has a significant influence with a 93 % contribution to the bursting strength values of sample knitted fabrics. The contributions of loop length and their interactions to the bursting strength values of the knitted fabrics are under 5 percent. In the case of air permeability of the fabrics the contributions of loop length and their interactions are around 5 %, while the raw material has a significant influence with an 89 % contribution. According to *Table II* raw material has a significant influence on the wpc, stitch density, thickness, fabric weight, bursting strength and air permeability because the p values are found smaller than 0,005=α. The loop length factor is significantly effective on the cpc, stitch density, fabric weight, bursting strength and air permeability values because the p values are found smaller than 0.005=α. Therefore, it is concluded that when the raw material and loop length are changed the stitch density, fabric weight, bursting strength and air permeability properties of the fabrics are changed significantly. Because this table does not show the effect of structural parameters, (i.e. fabric weight, stitch density, loop shape factor, cpc, wpc and thickness) correlation analyses were performed using the SPSS 17 statistical package program. *Table III* summarizes the correlation analysis for all data obtained in the study.

TABLE III. Correlation between structural parameters and selected performance properties.

	Fabric Weight, g/m^2	Stitch Density, cpc*wpc	Loop Shape factor, cpc/wpc	Course per cm	Wale per cm	Thickness, mm	Tightness factor
Bursting Strength, kpa	.394**	.750**	-.292**	.291**	.821**	.146	.218
Air Permeability, mm/s	-.139	.304**	-.505**	-.145	.615**	-.413**	-.095

** Correlation is significant at the 0.01 level

According to the *Table III* there is a positive correlation between fabric weight, stitch density, cpc, wpc and bursting strength of the fabrics. Thus, as the weight of the fabric increases, bursting strength of the fabric increases 39 percent. As the value cpc increases, bursting strength of the fabric increases 29 percent. As the value of loop shape factor rises, bursting strength of the fabric decreases 29 percent. As the value of stitch density increases, bursting strength of the fabric increases 75 percent. Finally, as the number of wales per cm rises, bursting strength of the fabric rises 82 percent. Therefore, changes in wale per cm and stitch density have the highest effect on bursting strength of the fabrics.

According to the table there is a positive correlation between stitch density, loop shape factor, wpc, thickness and air permeability of the sample knitted fabrics. As the value of stitch density rises, air permeability of the fabric rises 30 percent. As the value of loop shape factor increases, air permeability of the fabric decreases 50 percent. As the number of wales per cm rises, air permeability of the fabric rises 61 percent. Finally, as the thickness of the fabric increases, air permeability of the fabric decreases 41 percent. Therefore, in designing more permeable single jersey fabrics, the thickness and loop shape factor are important characteristics. Furthermore, it is known that the thickness is related to loop shape factor of knitted fabrics.

CONCLUSION

The investigations show that an increase in the loop length of the fabric increases their permeability to air and the correlation between the thickness of the knit and its permeability to air is strong. Experimental test results and statistical analysis indicated a strong correlation between bursting strength of knitted fabrics and raw material fiber tenacity. Since bursting strength of a fabric is the resistance of many loops simultaneously, more loops results in higher resistance. Since loop length is related to the tightness factor of the fabric, for a given raw material high loop length translates to lower bursting strength.

Fabric weight was found to significantly affect bursting strength. In this study all the fabrics were manufactured with same knitting parameters and the count of all was the same. Therefore the weight difference of the fabrics is related to the density of the raw material and the loop length of the fabrics.

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