AIR PERMEABILITY AND STIFFNESS OF KNITTED FABRICS MADE FROM 100% COTTON AND COTTON/ELASTANE YARNS

Dereje Berihun Sitotaw
Ethiopian Institute of Textile and Fashion Technology, Bahir Dar University, Bahir Dar, Ethiopia
(*Author for correspondence: dere96@yahoo.com)

Abstract: The air permeability and stiffness of single jersey, 1x1rib, interlock, single pique and two thread fleece knitted fabrics made from 100% cotton and cotton/Lycra yarns (5% Lycra yarn content) investigated in this research. Air permeability and stiffness of knitted fabrics are important comfort property and determines the applications of different structures. The sample fabrics have been conditioned for 24 hours at 20±1°C temperature and 65±2% relative humidity. Ten specimens for air permeability and five specimens for stiffness were taken from each of the five knitted structures those made from 100% cotton and cotton/Elastane blended yarns. Together with the air permeability and stiffness; the loop length, wales per centimeter, thickness, shrinkage percent and tightness factor are also investigated since they are deciding factors of air transmission through the knitted fabrics and bending rigidity. As reported in this research, the air permeability and stiffness properties of single jersey, 1x1rib, interlock, single pique and two thread fleece knitted fabrics made from 100% cotton and cotton/Elastane yarns are significantly different from each other and all of the knitted fabrics made from cotton/Elastane blended yarn have lower air permeability and higher stiffness as compared to the same fabrics made from 100% cotton yarn.

Keywords: Air permeability; stiffness; 100% cotton; cotton/Elastane yarns; knitted fabrics

1. INTRODUCTION

Knitted fabrics are always popular for their excellent porosity, permeability, extensibility, soft feel, warming and body shape fitting. They do have high flexibility under low load and easily fit in any part it is pulled on to. Applying the interloping technology of yarns knit fabrics are constructed, and in this manner a large percentage of the total volume of a fabric is, usually, airspace (Burcak, 2004).

Air permeability is defined as volume of air in cm^3 passes through 1 cm of fabric in 1 second at a pressure difference of 10 mm head of water (ASTM-D737-04, 2004). Air permeability is deciding factor of comfort of a fabric, as it plays a role of transporting air and moisture vapor to the outside atmosphere from the skin and fresh air from the atmosphere to the skin of human body. The assumption is like that, the vapor travels mainly through the free spaces of fabric by diffusion in air from one side of the fabric to the other (Beceren, 2010, Elena Onofrei, 2011). Air permeability is normally measured on apparatus designed to force air through the test specimen, usually classified into two types. In one system, the pressure difference between the opposite faces of a test specimen is fixed and measurement is made of the resulting air flow through the material. In the other type, the rate of

movement of air through the fabric is adjusted to a fixed value and the pressure difference that must be developed across the fabric in order to maintain this air flow is then measured. The ASTM 737–96 procedure determines the volume rate of air flow per unit area of fabric in cubic centimeters per square centimeter per second. The British, European and International standard procedure determines the velocity of air of a standard area, pressure drop and time, in millimeters per second. The standard pressure specified in the ASTM standard procedure is 125 Pa (12.7 mm water gauge) whereas that specified in the British Standard procedure is 100 Pa for apparel fabrics and 200 Pa for industrial fabrics. Results obtained using the two procedures are, therefore, not comparable (HU, 2006).

Knitted fabrics have different air permeability at different states. For dry relaxed cotton 1×1 rib knitted fabrics, the thermal retaining property decreases with the increase of stitch length, porosity and air permeability (Ryuzo, 1990, Tasmaci, 1996, Haghi, 2002). It was found that air permeability, contrary to water vapor permeability, is a function of the thickness and surface porosity of knitted fabrics (BożenaWilbik-Hałgas, 2006, Kumar, 2013, Azim, 2014).

The air permeability of half plated and full plated single jersey knitted fabrics were investigated and it is found that the increase in the extension percent of the Lycra yarn decreases the air permeability of knitted fabrics (Sadek, 2012, Saber, 2009). The Lycra content in the cotton yarn and air permeability of single jersey is inversely proportional. The more the Lycra percent the more the single jersey shrinks and leads to low porosity. This in turn causes the single jersey knitted fabrics to have low air permeability (Bayazit, 2003, ASTM-D737-04, 2004).

Stiffness is the measure of bending rigidity of fabrics (ASTM-D4032, 2001). The feasibility of using the torsional rigidity as a fabric stiffness measurement becomes more evident when the use of other measurement techniques is not possible. Such a case is the evaluation of stiffness of plain weft-knitted fabrics where variations in fabric stiffness can be engineered by purpose through varying their tightness levels or they can be purely a result of manufacturing process variations such as production on different machines by different knitters (Ayhan Haji Mohamad, 2012).

Most scholars studied the air permeability property of single jersey knitted fabric in relation to yarn types. Some tried to study the air permeability of plated knitted fabrics made from cotton, bamboo and cotton blends. Scholars not yet studied the comparative effect of Lycra yarn on single jersey, 1x1 rib and interlock knitted fabrics. In this research, the comparative effect of Lycra yarn on the air permeability of single jersey, 1x1 rib and interlock knitted fabrics will be investigated. Many of the possible factors those will affect the fabric air permeability such as loop length, wale per centimeter, fabric thickness and so are considered for analysis in this paper.

2. MATERIALS AND EXPERIMENTS

2.1. Materials

100% cotton and Cotton/Elastane blended yarns are used for this study. An Elastane accounts for about 5% contents (40 denier = 133Ne) while cotton accounts for 95% content (35Ne) in the 28Ne combed cotton/Elastane blended yarn (cotton/Elastane = 95/5%) and an Elastane is fed to the needles as naked filament with the cotton yarn in the same yarn feeder (carrier) which is neither plied nor core spun with cotton. Cotton fiber harvested from Upper Awash-Ethiopia has 28mm staple lengths, 12.8 short fiber index, 300 neps, 4.06% trash, 4.2 micronaire fineness. The yarns used for this study are produced from 100% cotton and cotton/Elastane blended fibers/filaments. The cotton yarn has 750m-1 twist, 28Ne count, 9.21% U% (irregularity), 11.70 CVM (coefficient of variation in mass), 0 thin-50%, 33.6 thick+50%, 29.8 Neps+200% and 63.4 total imperfection percent. The single jersey, single pique and two thread fleece are produced by the single bed circular knitting machine with 30rpm, 34" diameter, 2976 needles, 4 cam tracks and 108 feeders. 1x1 Rib/interlock is produced by double bed circular knitting machine with 20/14rpm, 30" diameter each, 2630 needles each, 94/112 feeders, 1/2 cam tracks respectively. The study was carried out by keeping these materials and their parameters constant except for the yarn's (type of raw material).

In the single jersey, 1x1rib, interlock, single pique and fleece knitted fabrics, the loop lengths were set equal in the knitting machine. But, during the knitting process the fabrics will have different loop lengths due to transferring of the loop and staying idles in the rib and interlock knitting machines and the floats at the technical back of fleece knitted fabrics. There are 28 needles per inch in a cylinder in single jersey, single pique and fleece. In 1x1 rib knitting machines, there are 18 needles per inch in cylinder and 18 needles per inch in dial. In interlock knitting machines there are 24 needles per inch in cylinder and 24 needles per inch in dial. The working principle and arrangement of needles in 1x1rib and interlock knitting machines is different in gaiting (Spencer, 2001).

2.2. Experiments

Air permeability, stiffness and thickness of single jersey, 1x1rib, interlock, single pique and fleece knitted fabrics made from 100% cotton and cotton/Elastane yarns have been designed for this study and the following tests are done.

i. Yarn properties

U% (irregularity), CVM (coefficient of variation in mass), Thin and Thick places and the amount of Neps in cotton yarn are the yarn properties tested for this study. This was done using Uster tester-5 machine and Uster testing standards.

ii. Air permeability

The air permeability of single jersey, 1x1rib, interlock, single pique and fleece knitted fabrics were tested using digital thickness tester as directed in ASTM D 737–04

Standard Test Method for Air Permeability of Textile Materials (ASTM-D737-04, 2004).

iii. Stiffness

The stiffness of single jersey, 1x1rib, interlock, single pique and fleece knitted fabrics were tested using Circular Bend Stiffness Tester as directed in ASTMD 4032 – 94 (Reapproved 2001) Standard Test Method for Stiffness of Fabric by the Circular Bend Procedure (ASTM-D4032, 2001).

iv. Thickness

The thickness of single jersey, 1x1rib, interlock, single pique and fleece knitted fabrics were tested using digital thickness tester as directed in ASTM D1777-02 Standard Test Method for Thickness of Textile Materials (ASTM-D1777, 2002).

v. Loop length and Wales per cm

The loop length and wpc of single jersey, 1x1rib, interlock, single pique and fleece knitted fabrics has been measured using crimp tester and pick glass, respectively.

3. RESULTS AND DISCUSSION

3.1. Air permeability

The air permeability of single jersey, 1x1rib, interlock, single pique and fleece knitted fabrics were studied and the average test results are shown in Table 1 and Table 2. The air permeability of single jersey, 1×1rib, interlock, single pique and fleece knitted fabrics made from 100% cotton and cotton/Elastane (95/5%) blended yarns is different. As shown in Table 1, the air permeability of single jersey, 1x1rib, interlock, single pique and fleece knitted fabrics made from 100% cotton is higher as compared to the same fabrics made from cotton/Elastane blended yarn. This is because the fabrics made from cotton/Elastane yarns have greater width wise shrinkage and thickness, which leads to reduced air permeability of the fabrics. The air permeability of 1x1rib knitted fabric made from 100% cotton and cotton/Elastane yarns is the highest as compared to the other knitted fabrics made from the same materials because 1x1rib has high loop length, low stitch density and low shrinkage which allows the air to pass through the cords of the fabrics. Single jersey has the lowest air permeability in both 100% cotton and cotton/Elastane yarns as compared to the other fabrics made from the same materials because single jersey has more shrinkage, low loop length and dimensionally not stable.

As shown in Table 1, the thickness, wales per centimetre, shrinkage, and loop length of single jersey, 1x1rib and interlock knitted fabrics increased with cotton/Lycra blend yarn as compared to 100% cotton yarn. But the tightness factor of these fabrics is lower with Cotton/Lycra blend yarns than with 100% cotton. The following equation illustrates the calculation of shrinkage in percentage.

$$\%\text{shrinkage} = \frac{\text{Wales per inch} - \text{Gauge of the machine}}{\text{Wales per inch}} \text{x100}) \quad (1)$$

Table 1: Relationship of air permeability with some of dimensional properties of knitted fabrics

Type of Fabric	Loop length in mm	Wales per cm	Thickness in mm	Tightness factor	Shrinkage in %	Air permeability in $cm^3/cm^2/s$
100%cotton Single jersey	2.940	13.95	0.621	2.12	20.900	33.96
Cotton/Elastane Single jersey	3.030	22.90	0.750	1.77	33.190	119.86
100%cotton 1x1rib	3.090	15.50	0.835	1.67	28.880	85.69
Cotton/Elastane 1x1Rib	3.520	21.90	1.325	1.28	48.720	218.80
100%cotton Interlock	2.170	14.30	1.253	2.41	22.910	46.47
cotton/Elastane Interlock	2.603	19.60	1.495	1.77	43.750	101.20
100%cotton single pique	2.435	15.37	0.747	1.77	9.258	50.94
Cotton/Elastane single pique	2.990	12.15	1.032	2.17	28.264	131.50
100%cotton fleece	3.613	14.43	0.924	1.26	1.004	56.45
Cotton/Elastane fleece	4.200	11.14	1.430	1.67	23.575	127.60

As shown in Table 1, the thickness, wales per centimeter, shrinkage (see Equ. 1) and loop length of single jersey, 1x1rib and interlock knitted fabrics increased with cotton/Lycra blend yarn as compared to 100%cotton yarn. But the tightness factor of these fabrics is lower with Cotton/Lycra blend yarns than with 100% cotton. The air permeability property of knitted fabrics is inversely proportional to tightness factor, wales per centimeter, shrinkage percent and thickness; and directly proportional to loop length of knitted fabrics. As shown in Table 2, knitted fabrics made from cotton/Lycra yarns have higher shrinkage percent, thickness and wales per centimeter. Due to this, the air permeability property of single jersey, 1x1rib and interlock knitted fabrics is reduced. Though the loop length of knitted fabrics is high with cotton/Lycra yarn, the air permeability is reduced by the higher shrinkage percent of knitted fabrics due to the Lycra yarn. The increasing order of air permeability of knitted fabrics made from 100% cotton and cotton/Elastane blended yarns is single jersey, interlock, fleece, single pique and 1x1rib.

The air permeability of single jersey, 1x1rib, interlock, single pique and fleece knitted fabrics is reduced due to the presence of 5% Elastane yarns in the combed cotton yarn. This is due to the high shrinkage percent, wales per centimeter and thickness of these fabrics with the presence of naked filament yarns in the structure.

In Table 1, the mean, standard deviation, coefficient of variations (CV %) standard error, minimum and maximum values of the test specimens are shown. The standard deviations of all sampled fabrics made from 100% cotton and cotton/Elastane are similar with slight deviations from their mean. This shows that the values in a statistical data set are closest to the mean of the data set, on average.

Table 2: Results of air permeability of knitted fabrics made from 100% cotton and cotton/Lycra (95/5%)

		N	Mean	Std. deviation	CV%	Std. Error	Minimum	Maximum
Air permeability of single jersey	95.00	10	33.9600	3.00636	8.85265	.95070	29.00	38.70
	100.00	10	119.8600	10.21635	8.523569	3.23069	96.60	132.00
Air permeability of 1x1rib	95.00	10	85.6900	5.56266	6.491609	1.75907	75.80	95.80
	100.00	10	218.8000	19.00760	8.687203	6.01073	185.00	250.00
Air permeability of interlock	95.00	10	46.4700	2.24749	4.836432	.71072	43.80	49.80
	100.00	10	101.2000	4.86598	4.808281	1.53876	95.50	109.00
Air permeability of pique	95.00	10	56.4500	4.13179	7.31938	1.30659	48.00	62.00
	100.00	10	127.6000	4.92612	3.860596	1.55778	120.00	134.00
Air permeability of fleece	95.00	10	50.9400	2.24063	4.398567	.70855	48.00	54.80
	100.00	10	131.5000	4.74342	3.607163	1.50000	124.00	141.00

The air permeability of single jersey, single pique, 1x1rib, interlock and fleece knitted fabrics mean differences are significant at 0.05 levels. As shown in Table 3, the thickness of single jersey is significantly influenced by the presence of 5% Elastane in the Upper Awash combed cotton yarn (F = 650.620; Sig. = 0.000). 1x1Rib (F = 451.729; Sig. = 0.000), interlock (F = 1042.630; Sig. = 0.000), single pique (F = 1224.607; Sig. = 0.000) and fleece (F = 2358.215; Sig. = 0.000) knitted fabrics are significantly influenced by the types of yarns (100% cotton and Cotton/Elastane-95/5%). Fleece knitted fabrics have the highest F-Value as compared to other knitted fabrics which shows that fleece has a high dispersion rate as compared to other knitted fabrics.

Table 3: Analysis of variance air permeability of knitted fabrics

		Sum of Squares	df	Mean Square	F	Sig.
Air permeability of single jersey	Between Groups	36894.050	1	36894.050	650.620	.000
	Within Groups	1020.708	18	56.706		
Air permeability of 1x1rib	Between Groups	88591.361	1	88591.361	451.729	.000
	Within Groups	3530.089	18	196.116		
Air permeability of interlock	Between Groups	14976.865	1	14976.865	1042.630	.000
	Within Groups	258.561	18	14.365		
Air permeability of pique	Between Groups	25311.612	1	25311.612	1224.607	.000
	Within Groups	372.045	18	20.669		
Air permeability of fleece	Between Groups	32449.568	1	32449.568	2358.215	.000
	Within Groups	247.684	18	13.760		

3.2. Stiffness

Stiffness is the resistance to bending and with regard to the circular bending of textiles, resistance to multi-directional bending. The stiffness of single jersey, 1x1rib, interlock, single pique and fleece knitted fabrics were studied and the average test results are shown in Table 4. The stiffness of single jersey, 1×1rib, interlock, single pique and fleece

knitted fabrics made from 100% cotton and cotton/Elastane (95/5%) blended yarns is different.

The stiffness of single jersey, 1x1rib, interlock, single pique and fleece knitted fabrics made from 100% cotton are lower as compared to the same fabrics made from cotton/Elastane blended yarn. This is because the fabrics made from cotton/Elastane yarns have greater width wise shrinkage which leads to higher bending rigidity of the fabrics.

The stiffness of interlock knitted fabric made from 100% cotton and cotton/Elastane yarns is highest as compared to the other knitted fabrics made from the same yarns, because interlock is made when two 1x1rib loops are locked together and appears in the technical face of loops which becomes more stable and thicker fabric in addition to its shrinkage. Single jersey has the lowest bending rigidity in both 100% cotton and cotton/Elastane yarns as compared to the other fabrics made from the same types of yarns in two reasons. Firstly, single jersey is made on one needle bed with one set of needles and has single faced appearance as compared to interlock and 1x1rib knitted fabrics. Later, in single jersey only one yarn is fed to needles and one loop is formed at each needle continuously while in single pique knitted fabric each stitch is formed from one tuck loop, one held loop and one knit loop; and in fleece knitted fabric two yarns floating at the technical back of the fabric, which gives more stiffness as compared to single jersey made from the same yarns. The increasing order of bending rigidity of knitted fabrics made from 100% cotton and cotton/Elastane blended yarns is single jersey, single pique, 1x1rib, fleece and interlock.

The bending rigidity of single jersey, 1x1rib, interlock, single pique and two thread fleece knitted fabrics has been increased due to the presence of 5% Elastane in 95% cotton yarns. This is because the width wise shrinkage of all knitted fabrics is higher in cotton/Elastane yarn than 100% cotton yarn. The mean, standard deviation, coefficient of variations (CV %), standard error, minimum and maximum values of the test specimens are depicted as shown in Table below. The standard deviations of all sampled fabrics made from 100% cotton and cotton/Elastane are similar with slight deviations from their mean. This shows that the values in a statistical data set are closest to the mean of the data set, on average.

The stiffness of single jersey, single pique, 1x1rib, interlock and fleece knitted fabrics mean differences are significant at 0.05 levels. As shown in Table 5, the stiffness of single jersey significantly influenced because of the presence of 5% Elastane in the Upper Awash combed cotton yarn ($F = 146.602$; Sig. = 0.000). 1x1Rib ($F = 167.232$; Sig. = 0.000), interlock ($F = 444.035$; Sig. = 0.000), single pique ($F = 288.300$; Sig. = 0.000) and fleece ($F = 332.645$; Sig. = 0.000) knitted fabrics are significantly influenced by the types of yarns (100% cotton and Cotton/Elastane-95/5%). Two thread fleece knitted fabric has the highest F-Value as compared to other knitted fabrics which shows that fleece has a high dispersion rate as compared to other knitted fabrics.

Table 4: Description for thicknesses of knitted fabrics made from 100% cotton and cotton/Elastane yarns

		N	Mean	Std. Deviation	CV (%)	Std. Error	Minimum	Maximum
Stiffness (N) of single jersey	95.00	5	1.5800	.08367	5.29557	.03742	1.45	1.65
	100.00	5	.8000	.11726	14.6575	.05244	.60	.90
Stiffness (N) of 1x1rib	95.00	5	2.4700	.25642	10.38138	.11467	2.05	2.70
	100.00	5	.8600	.10840	12.60465	.04848	.70	1.00
Stiffness (N) of interlock	95.00	5	3.4700	.17536	5.053602	.07842	3.25	3.70
	100.00	5	1.2300	.16047	13.04634	.07176	1.10	1.50
Stiffness (N) of single pique	95.00	5	1.8600	.07416	3.987097	.03317	1.75	1.95
	100.00	5	.9300	.09747	10.48065	.04359	.80	1.05
Stiffness (N) of fleece	95.00	5	2.7900	.09618	3.447312	.04301	2.70	2.95
	100.00	5	1.2000	.16956	14.13	.07583	1.00	1.40

Table 5: Analysis of variance of stiffness of knitted fabrics made from 100% cotton and cotton/Elastane yarns

		Sum of Squares	df	Mean Square	F	Sig.
Stiffness (N) of single jersey	Between Groups	1.521	1	1.521	146.602	.000
	Within Groups	.083	8	.010		
Stiffness (N) of 1x1rib	Between Groups	6.480	1	6.480	167.232	.000
	Within Groups	.310	8	.039		
Stiffness (N) of interlock	Between Groups	12.544	1	12.544	444.035	.000
	Within Groups	.226	8	.028		
Stiffness (N) of single pique	Between Groups	2.162	1	2.162	288.300	.000
	Within Groups	.060	8	.008		
Stiffness (N) of fleece	Between Groups	6.320	1	6.320	332.645	.000
	Within Groups	.152	8	.019		

4. CONCLUSION

The air permeability and bending rigidity of single jersey, 1x1rib, interlock; single pique and two thread fleece knitted fabrics made from 100% cotton and cotton/Elastane (95/5%) yarns are studied. The air permeability of knitted fabrics reduces while the stiffness is increased because of the presence of 5% Elastane in the cotton yarn. This is because of Elastane content in the yarn causes high shrinkage percent, thickness and wales per centimeter to the fabrics. 1x1 Rib knitted fabric has better air permeability as compared to other knitted fabrics in both 100% cotton yarn and cotton/Elastane blended yarn due to the high loop length and low tightness factor as compared to single jersey, single pique, and two thread fleece and interlock knitted fabrics. The increasing order of air permeability of knitted fabrics made from 100% cotton and cotton/Elastane blended yarns is single jersey, interlock, fleece, single pique and 1x1rib. The stiffness of interlock knitted fabric made from 100% cotton and cotton/Elastane yarns is highest as compared to the other knitted fabrics made from the same yarns, because interlock is made when two 1x1rib loops are locked together and appears in the technical face of loops which becomes more stable and thicker fabric in addition to its shrinkage. The

increasing order of bending rigidity of knitted fabrics made from 100% cotton and cotton/Elastane blended yarns is single jersey, single pique, 1x1rib, fleece and interlock. So, this comparative study has novelty, because the effect of yarn types on different knitted fabrics has been investigated.

5. ACKNOWLEDGEMENT

I would like to thank the Ethiopian Institute of Textile and Fashion Technology in Bahir Dar University (one of the technology institute in Ethiopia) and MAA garment and Textile Factory (produces knitted fabrics and located in Mekele, Ethiopia) for helping me in accomplishing this research effectively and efficiently.

6. REFERENCES

Burcak, K., *Characterization and Role of Porosity in Knitted Fabrics. M.Sc thesis.* Department of Textile Engineering, Chemistry and science, North Carolina State University., 2004.

ASTM-D737-04, *Standard Test Method for Air Permeability of Textile Fabrics.* 2004.

Y. Beceren, C.C., S. Cimilli, K. Ülger, *Properties of Plain Knits from Siro-SpunViscose/Spandex Yarns.* FIBRES & TEXTILES in Eastern Europe 2010. **18** (1): p. (78).

Elena Onofrei, A.M.R.a.A.C., *Investigating the effect of moisture on the thermal comfort properties of functional elastic fabrics.* Journal of Textiles, 2011. **0**(00): p. 1-18.

J.Y. HU, Y.LI, & K.W. YEUNG, *Clothing biosensory engineering: Air permeability*, 2006: Woodhead Publishing Limited and CRC Press LLC.

Ryuzo, O., *Effect of Stitch Length on Some Properties of Cotton 1×1 Rib Knitted Fabrics.* Journal of the Textile Machinery Society of Japan, 1990. **36**(3): p. 91-95.

Tasmaci, M., *Effects of Spandex Yarn on Single Jersey Fabrics Knitted with Naked Lycra Yarn.* Tekstil ve Konfeksiyon, 1996. **6**: p. 422-426.

Haghi, A., *Mechanism of heat and mass transfer in moist porous materials.* Jurnal Teknologi 2002. **36**(F): p. 1-14.

BożenaWilbik-Hałgas, R.D., Air and Water Vapour Permeability in Double-Layered Knitted Fabrics with Different Raw Materials. Fibres & Textiles in Eastern Europe, 2006. 14(3): p. 77-80.

Kumar V, S.V., Investigation on the Physical and Dimensional Properties of Single Jersey Fabrics made from Cotton Sheath - Elastomeric Core Spun. FIBRES & TEXTILES in Eastern Europe, 2013. 21(3(99)): p. 73-75.

Azim, A.Y.M.A., Effect of Elastane on Single Jersey Knit Fabric Properties - Physical & Dimensional Properties. International Journal of Textile Science, 2014. 3(1): p. 12-16.

Sadek R. , E.-H.A.M., Eldeeb A. S. ,Yassen A.A. , Effect of Lycra Extension Percent on Single Jersey Knitted Fabric Properties. Journal of Engineered Fibers and Fabrics, 2012. 7(2).

Saber B., A.S., Influence Of Elastane Consumption On Plated Plain Knitted Fabric Characteristics. Journal of Engineered Fibers and Fabrics, 2009. 4: p. 30-35.

Bayazit, A., Dimensional and Physical Properties of Cotton/Spandex Single Jersey Fabrics. Textile Research Journal, 2003. 73: p. 11-14.

ASTM-D4032, Standard Test Method for Stiffness of Fabric by the Circular Bend Procedure. 2001.

Ayhan Haji Mohamad, T.C., Alan Brydon; and Dave Halley, The measurement of plain weft-knitted fabric stiffness. Measurement Science and Technology, 2012. 23: p. 10.

Spencer, D.J., KNITTING TECHNOLOGY: A comprehensive handbook and practical guide. 3rd ed2001, Abington Hall, Abington Cambridge CB1 6AH, England: Woodhead Publishing Limited.

ASTM-D1777, Standard Test Method for Thickness of Textile Materials. 2002.