Dimensional Stability, Aesthetic and Functional Properties of Cotton:Polyester Blended Knitted Fabrics with Different Structures

Najwa Ali Abu Nassif

Fashion Design Department, Design and Art College, Jeddah University, Jeddah, Saudi Arabia

Abstract:

Throughout this study, functional, aesthetic, and dimensional stability properties of knitted blended fabrics were experimentally presented. An experimental work was introduced to examine. In order to investigate the loop length of the knitted fabrics and the polyester blending ratio on bursting, air permeability, pilling resistance and shrinkage ratio of knitted fabrics, thirty fabric samples were knitted with three loop length, five levels of polyester ratios for single jersey and rib knit structures. Analysis of variance and regression analysis were used to detect the influence of loop length and polyester content on knitted fabric properties. The findings of this study revealed that independent variables under study have a massive influence on the functional and aesthetic properties of the knitted blended fabrics.

Introduction

Because of their high elasticity, low mass per unit area, low production cost and smooth surface and comfort, knitted fabrics acquired higher popularity and wider use compared to the other textile products [1]. Different patterns and various types of fabrics can be knitted on numerous of knitting machines with different sitting, different yarn linear densities and materials. These knitted fabrics are significantly by their structures and finishing methods [2]

Different research works have been conducted regarding the impact of finishing methods, yarn and constructional parameters on the physical characteristics of woven ad knitted fabrics [3-12]. Murugesh and selvadass investigated the influence of different wet processing methods, namely scouring, dyeing, mercerization and softening processes on knitted fabrics properties [3]. They found that mercerization improved knitted fabric properties more than scouring alone. Also, knitted fabric properties were changed significantly with dyeing and softening processes. In another study [1] it was found that increasing the stitch length reduced knitted fabric shrinkage and bursting strength; while increased spirality of single jersey fabrics. It was also found that fabric width, thiskness and abrasion resistance were all diminished with increasing stitch length [4].

In his study, to invistigate the impact of the content of micro fiber on the knitted fabric properties, Ramakrishnan and co-authors [5] found that fabrics knitted from micro denier fibers have a superior properties compared to their counterparts knitted from normal denier fibers in relation to drapeability, spirality and moisture vapor transmission properties. Physical properties of Single Jersey cotton/spandex plated fabric were examined [6]. It was revealed that loop length was reduced by approximately 2% to 5% in the case of platting cotton with spandex compared to cotton only.
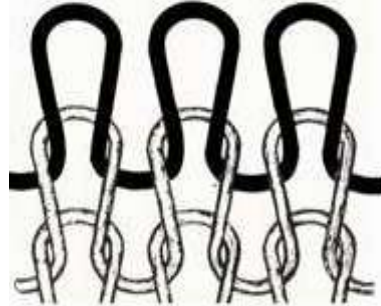
Levent O. and Cevza C. [7] investigated the shrinkage values of fabrics knitted from pure cotton and its blending with polyester fibers at different washing cycles. They stated that yarn type and fiber content have a significant impact on lengthwise and widthwise shrinkage of the knitted fabrics.

Although there are numerous researches deal with the influence of woven and knitted fabric parameters on their aesthetic and physical properties [8-22], there are a shortage in studying the aesthetic and functional characteristics of knitted blended fabrics in terms of blending ratio and loop length. Therefore, this study aimed at investigating the dimensional stability, aesthetic and physical characteristics of fabrics knitted from polyester and cotton fibers with different blending ratios and different structures.
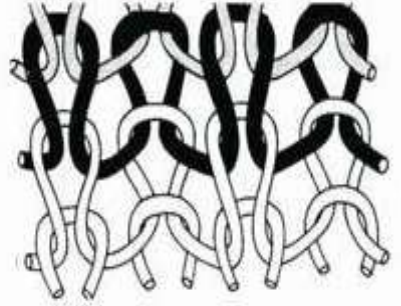
Materials

Throughout this study, thirty fabric samples were knitted from two different structures, five different blending ratios and three loop length values. These fabric samples were made from 100% Egyptian cotton, 100% polyester and cotton:polyester fibers with different blending ratios. They also were knitted from a yarn of the same counts, i.e. 30 Ne with twist multiplier 3.6.

The blending ratios of cotton and polyester fibers were 0%, 25%, 50%, 75% and 100% respectively of polyester weight. The blending ratio 0% means that fabrics were knitted completely from cotton fibers, whereas 100% signifies that fabric was knitted completely from polyester fibers.

The two structures of knitted fabric samples were 1×1 Rib and single jersey respectively. Three different stitch length, i.e. 2.5, 2.8 and 3mm. were used to kint both structures. Figure 1 shows The knit structures utilized in this study .

Single Jersey   **Rib**

Figure 1: Knitted fabric structures used in this study

Laboratory testing

Before testing, all knitted fabrics were left in a conditioned room on its surface at 20±2 $^{\circ}$C and 605% ±2 relative humidity for on day. After that five samples each of dimension 30cm length and 30 cm width were cut from each knitted fabric sample. These cut fabrics were washed in a home laundering washing m/c at 40 $^{\circ}$C for 15 minutes sing 20g/l standard detergent. Then the fabric samples were washed using cold water and dried in a tumble dryer at 50 $^{\circ}$C. After that shrinkage in wales and courses direction were measured according to ASTM D2120-96 using the following function:

$$Shrinkage,\% = \frac{L_0 - L_w}{L_0} \times 100$$

where, L_0 = length of fabric sample before washing , L_w = length of fabric sample after washing. Hydraulic bursting tester was used to assess and evaluate the bursting strength of knitted fabric samples in accordance with ASTM D3786-96. In order to measure a pilling grade, a fabric sample of dimension 12.5cm×12.5cm sere cut. Each fabric sample was wrapped around a rubber tube with dimensions 5 inch × 1/8 inch × 1 ½ inch in the directions of length, inner and outer diameters respectively. Each fabric sample were sewn from each ends to be fixed on the rubber tube. After that a number of 5 rubber tube from each fabric sample were placed in a rotating box with dimension 9 inch × 9 inch × 9 inch. The box will the rotate for 3 hours with a speed 60 rpm. After that the samples were taken off the testing box, the pilling will be graded visually using a standard lens with standards from 1 to 5. The grade one denotes the worst pilling, namely maximum pilling grade, whereas the grade of five refers to the best or the minimum pilling value. In general, pilling grade test was accomplished using the standard ISO 12945:1-200. Air permeability which measures the flow rate of cubic centimeters of the air through one square centimeter of fabric in one second at differential pressure of one bar was measured using Shirley Air permeability tester in accordance with ASTM D737-96.

Statistical analysis

Since there are two different knitted structures, each of which has five different polyester ratios and three loop length, thus a 5 × 3 × 2 mixed factorial design was executed. This undertaken design was analyzed using Analysis of Variance (ANOVA) in order to detect the significance influence of fabric structure and the polyester content on weft knitted fabrics. The significance level was assessed at p-value, 0.05 (95% confidence) $\leq \alpha \leq 0.01$ (99% confidence).

In order to derive the regression relationship between polyester ratios and stitch length as independent variables and aesthetic and functional properties of knitted fabrics as dependent ones, a multiple regression analysis was also accomplished. The relationships between independent and dependent variable were in a non-linear form for the two knitted structures under study. These derived linear models were assessed using coefficient of determination, R^2 value which varies between zero and one. The higher values of R^2 mean the model represents the experimental data very well, and vice versa.

Results and Discussion

Effects on bursting strength

The values of knitted blended fabrics' bursting strength according to different values of polyester ratio and loop length were portrayed in figures 2 and 3. From tables 1 and 2, it can be seen that knitted fabrics' bursting strength was significantly affected by the independent variables under study.

Table 1: ANOVA results for bursting strength of single Jersey blended knitted fabrics

Variation source	SS	df	MS	F-calculated	P-value	Fcrit
Polyester, %	841.067	4	210.267	340.973	0.000	3.838
Loop length	260.4	2	130.2	211.135	0.000	4.459
Error	4.933	8	0.617			
Total	1106.4	14				

Table 2: ANOVA results for bursting strength of 1×1 Rib blended knitted fabrics

Variation source	SS	df	MS	F-calculated	P-value	Fcrit
Blending ratio	1202.267	4	300.567	419.395	0.000	3.838
Loop length	592.933	2	296.467	413.674	0.000	4.459
Error	5.733	8	0.717			
Total	1800.933	14				

The statistical analysis proved that polyester blending ratio and loop length accounted for 75% and 23% respectively of the effects on bursting strength for fabrics of single jersey structure. While, for rib knitted fabrics, it was found that both independent variables accounted for 65% and 32 % respectively of the effects on bursting strength.
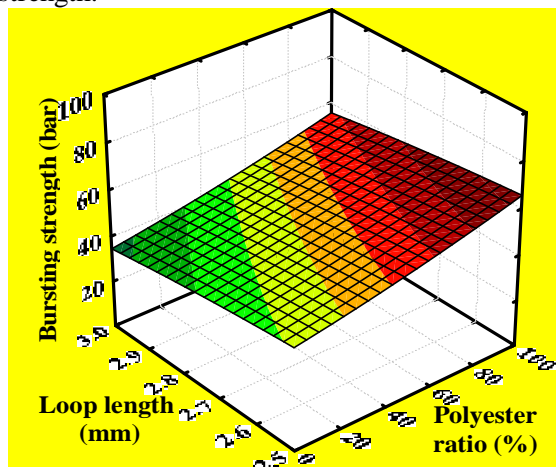
strength by 18% for single jersey and 21% for rib fabrics respectively.
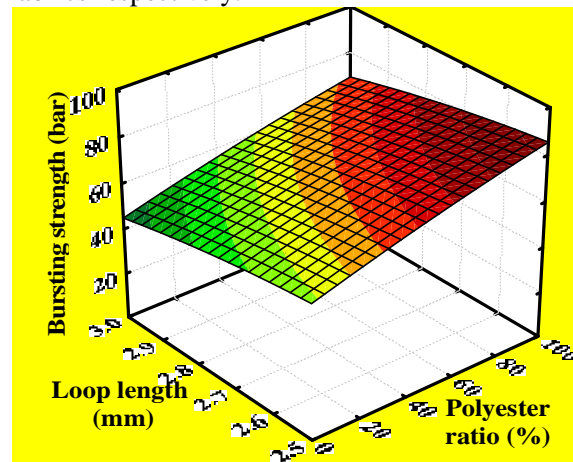
Figure 3: Response surface plot of bursting strength for 1×1 rib knitted fabric.

Figure 2: Response surface plot of bursting strength for single jersey knitted fabric.

From figures 2 and 3, it can be seen that polyester ratio has a positive influence on the bursting strength for both knitted structures. As the polyester ration in creases, the bursting strength reacts in the same manner. On the contrary, loop length has a negative significant impact on bursting strength of both structures. Bursting strength of single jersey and rib blended knitted fabrics increased by 52% and 47% respectively with increasing polyester ratio. While increasing the loop length results in decreasing the bursting

Multiple regression models which correlate bursting strength of blended knitted fabrics with polyester ratio and loop length have the following form:

Bursting strength, bar (single jersey) = $4.08 + 0.19 X + 46.13 Y - 0.0105 XY - 12 Y^2$

Bursting strength, bar (1 × 1 rib) = $-49.3 + 0.4 X + 103.4 Y - 0.0005 X^2 - 0.04 XY - 24 Y^2$

The values of R^2 were 0.99 for single Jersey model and 0.96 1× 1 model.

Effects on air permeability

Blended knitted fabrics' air permeability versus the values of polyester ratios and loop length for single-Jersey, and 1×1 rib structures were plotted in figures 4 and 5. The statistical analysis results were introduced in table 3 and 4. It was detected that both loop length and polyester ratio have a

significant impact on knitted fabrics 'air permeability.

It was also proved that polyester ratio accounted for 79% and 67% of the effects on the air permeability of both fabrics. It was also found that loop length accounted for 19% and 31 % of the effects on of both structures' air permeability.

Table 3: ANOVA results for air permeability of single Jersey fabrics

Variation source	SS	df	MS	F-calculated	P-value	Fcrit
Blending ratio	3552.4	4	888.1	206.535	0.000	3.838
Loop length	854.933	2	427.467	99.411	0.000	4.459
Error	34.4	8	4.3			
Total	4441.733	14				

Table 4: ANOVA results for air permeability of Rib fabrics

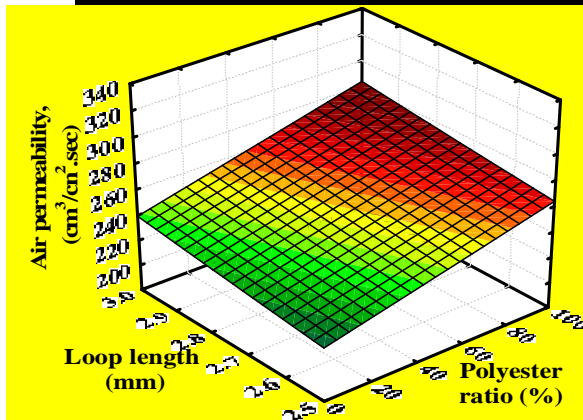| Variation source	SS	df	MS	F-calculated	P-value	Fcrit
Blending ratio	4012.933	4	1003.23	255.059	0.000	3.838
Loop length	1878.533	2	939.266	238.796	0.000	4.459
Error	31.46667	8	3.933			
Total	5922.933	14				

Figure 4: Response surface of air permeability values for single-jersey knitted fabric.
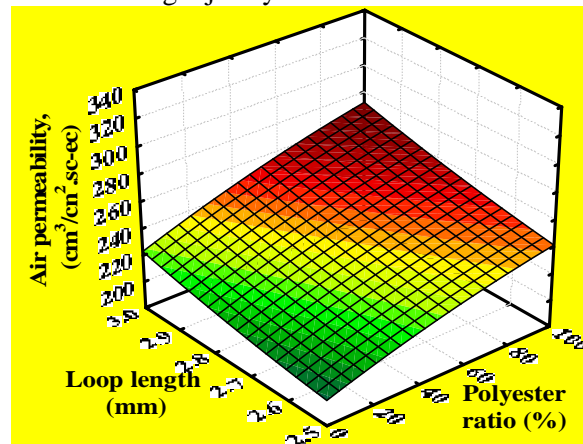

Figure 5: Response surface of air permeability values for 1×1 rib knitted fabric.

From figures 4 and 5, it can be seen that both independent variables have a profound influence on the blended knitted fabrics' air permeability. As the levels of polyester ratio and loop length increases, the blended knitted fabrics' air permeability increases. Increasing polyester ratio from 0% to 100% results in increasing the air permeability of blended knitted fabrics by 19% and 21% for single-jersey and rib structures respectively. While increasing loop length let to an increase in air permeability with 8% and 12 % respectively for single heresy and rib structures.

The regression models which correlate both polyester ratio and loop length with blended knitted fabrics' air permeability have the following non-linear formulas:

Air permeability, cm^3/cm^2.sec (single jersey) = $164.13 + 0.33 X + 13 Y - 0.036 XY - 4 Y^2$

Air permeability, cm^3/cm^2.sec ((1 × 1 rib) = $333.49 + 0.24 X - 138.83 Y - 0.0015 X^2 + 0.133 XY + 34 Y^2$

The values of R^2 were 0.0.96 for single Jersey model and 0.93 for 1× 1 rib model.

Effects on pilling resistance

In this study, pilling rate of the blended knitted fabrics was measured and evaluated. This grade ranges between 1 and 5, in which 5 denotes to high pilling resistance and 1 refers to low pilling resistance. The values of pilling resistance versus the levels of polyester ratio and loop length of knitted fabrics under study were illustrated in figures 6 and 7 respectively. The results of statistical analysis were listed in tables 5 and 6. It was determined that polyester ratio accounted for 90 of the effects on pilling resistance of the knitted fabrics under study. While loop length accounted for 7% and 9% of the effects on the pilling resistance on single jersey and rib knit structures respectively.

It was revealed that polyester ratio and loop length gave a significance influence on knitted fabrics' pilling resistance for both knitted structures at 0.01 significant level. From figures, a decreasing trend

can be observed confirming that as the levels of the polyester ratio and loop length increase the pilling resistance decreases. That is as the levels of the both variables increases the pilling tendency also increases. Increasing loop length leads to a reduction of pilling resistance of knitted fabrics from 3.5 to 0.7 and from 4 to 1.16 for single jersey and rib fabrics respectively. While increasing the loop length from 2.5 mm to 3 mm leads to a reduction of pilling resistance by about 32% for single-jersey and 28 % for rib structure.

The non-linear regression models which correlate both polyester ratio and loop length with pilling resistance f blended knitted fabrics have the following forms:

Pilling resistance (single-jersey) = $10.5 – 0.06 X – 3.03 13 Y + 0.07 XY +0.2 Y^2$

Pilling resistance ($(1 \times 1$ rib) = $4.5 – 0.06 X+ 1.7 Y +0.0082 XY – 0.7 Y^2$

The values of R^2 were found to equal 0.94 for single Jersey model and 0.0.92 for 1×1 rib model.

Table 5: ANOVA results for pilling rate of single Jersey fabrics

Variation source	SS	df	MS	F-calculated	P-value	Fcrit
Blending ratio	17.057	4	4.264	156.012	0.000	3.838
Loop length	1.548	2	0.774	28.317	0.000	4.459
Error	0.219	8	0.027			
Total	18.824	14				

Table 6: ANOVA results for pilling rate of 1×1 Rib fabrics

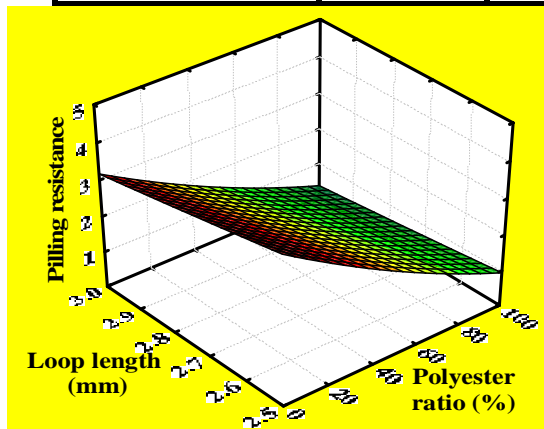| Variation source	SS	df	MS	F-calculated	P-value	Fcrit
Blending ratio	15.417	4	3.854	268.907	0.000	3.838
Loop length	1.6053	2	0.803	56	0.000	4.459
Error	0.11467	8	0.0143			
Total	17.1373	14				

Figure 6: Response surface plot of pilling rate for single jersey knitted fabric.
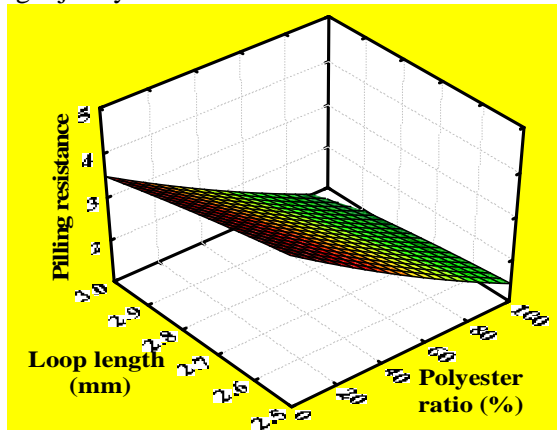

Figure 7: Response surface plot of pilling rate for 1×1 rib knitted fabric.

Effects on dimensional stability

Shrinkage in widthwise, i.e. in courses direction was used to characterize dimension stability of blended knitted fabrics under study. Shrinkage is an inseparable property of knitted fabrics that can not be neglected. This property occurs in many and different conditions especially after wet processing and home laundering. It has a detrimental effect on the appearance and fitting of the knitting cloths on the wearers.

The experimental values of blended knitted fabric shrinkage in widthwise versus both of blending ratio and loop length were presented in figures 8 and 9 for single jersey and rib fabrics. The ANOVA results that are shown in tables 7 and 8 revealed that the both independent variables have a huge impact on the shrinkage of knitted fabric in wale direction at 0.01 significance level. It was estimated that polyester content in the knitted fabrics accounted for 77% and 87% of the effects on shrinkage for single jersey and rib fabrics respectively; whereas the loop length accounted for 18% and 10% of the effects on knitted fabric shrinkage for the same knit structures.

From figures 8 and 9, a decreasing trend was detected concerning the impact of polyester ratio on knitted fabric shrinkage whether in the case of single jersey or rib structures. As the polyester ratio increases, the shrinkage ratio of blended knitted fabrics decreases. Increasing polyester ratio leads to a reduction of blended knitted fabric

from 6% to 2.5% and from 4% to 1.8 % for single heresy and rib structures respectively. It was also found that increasing loop length from 2.5 mm to 3 mm decreased the knitted fabric shrinkage from 5% to 3.25% and from 3.24% to 2.56% for the both knit structures.

The relation between blended knitted fabric shrinkage and both polyester ratio and loop length has the following non-linear forms:

Shrinkage, % (single jersey) = 6.3 - 0.1 X + 3.95 Y + 0.02 XY – 1.47 Y^2

Shrinkage, % (1 × 1 rib) = 6.03 - 0.06 X+ 0.58 Y + 0.013 XY – 0.474 Y^2

The values of R^2 were found to equal 0.94 for single Jersey model and 0.97 for 1× 1 rib model.

Table 7: Analysis of variance results for dimensional stability of single Jersey blended knitted fabrics

Variation source	SS	df	MS	F-calculated	P-value	Fcrit
Blending ratio	22.623	4	5.656	66.019	0.000	3.838
Loop length	5.488	2	2.744	32.031	0.000	4.459
Error	0.6853	8	0.086			
Total	28.796	14				

Table 8: Analysis of variance results for dimensional stability of 1×1 Rib blended knitted fabrics

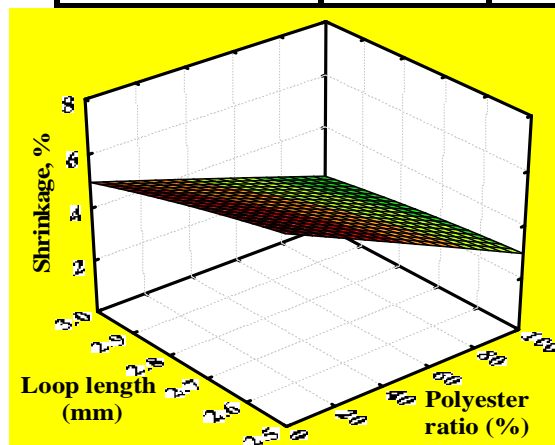| Variation source	SS	df	MS	F-calculated	P-value	Fcrit
Blending ratio	9.811	4	2.452	118.677	0.000	3.838
Loop length	1.161	2	0.581	28.097	0.000	4.459
Error	0.165	8	0.021			
Total	11.137	14				

Figure 8: Response surface plot of shrinkage in lengthwise for single jersey knitted fabric
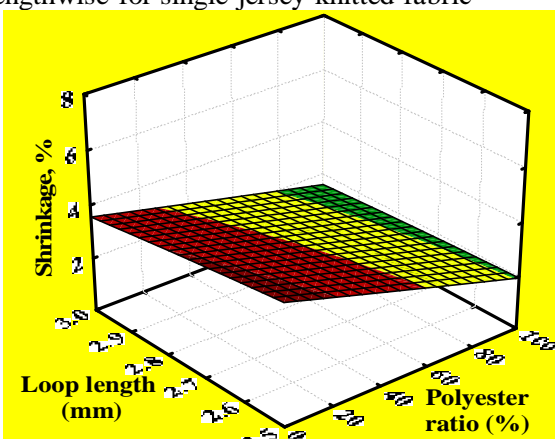

Figure 9: Response surface plot of shrinkage in lengthwise for 1×1 rib knitted fabric

Conclusion

The aesthetic and functional characteristics of knitted blended fabrics in terms of blending ratio and loop length were studied. The experimental outputs of this research can be abbreviated as following:

- The loop length and blending ratio were found to have a huge influence on the bursting strength of fabrics knitted from single-jersey or rib structures.

- As the polyester ratio increases, the bursting strength of both structures increases. By contrast, a reduction of bursting strength was noticeable as loop length increases.

- The values of air permeability were increased significantly with increasing the levels of the both independent variables for both knitted structures.

- The shrinkage in the wales direction was used as a measure to characterize the knitted fabrics' dimension stability. It was found that knitted fabric shrinkage was diminished significantly by the increase of loop length and polyester blending ratio.

- Pilling resistance of blended knitted fabrics was found to be reduced with increasing the polyester ratio and loop length values.

References

1- Sabina Yesmin, Modashar H asan, Md. Salam Miah, Farhana Momotaz, Mohammad Arafat Idris and Md. Rashedul Hasan. Effect of Stitch Length and Fabric Constructions on

Dimensional and Mechanical Properties of Knitted Fabrics. World Applied Sciences Journal 32 (9): 1991-1995, 2014

2- Mikuèionienë, D. and G. Laureckienë, 2009. The influence of drying conditions on dimensional stability of cotton weft knitted fabrics. Material Science, 15(1): 64-68.

3- Murugesh Babu. K and Selvadass. M. Influence of wet processing on properties of single jersey knitted fabrics. International Journal of Fiber and Textile Research, 3(1), 2013, 18-30.

4- Elias Khalil and Md. Solaiman. Effect of stitch length on physical and mechanical properties of single jersey cotton knitted fabric. International Journal of Science and Research, 3(9), 2014.

5- Ramakrishnan, G. et al. An investigation of the properties of knitted fabrics made from viscose microfibers. Journal of Textile and Apparel Technology and Management, 6(1), 2009.

6- Edin Fatkić, Jelka Geršak and Darko Ujević. Influence of knitting parameters on the mechanical properties of plain jersey weft knitted fabrics. FIBRES & TEXTILES in Eastern Europe 2011, 19(5), 87-91.

7- Levent O. and Cevza C. Contribution of fabric characteristics and laundering to shrinkage of weft knitted fabrics. Textile Research Journal, march, 2003.

8- Alsaid Ahmed Almetwally, M M Mourad. Effects of spandex drawing ratio and weave structure on the physical properties of cotton/spandex woven fabrics. The Journal of the Textile Institute, 105(3), 235-245, 2014

9- Alsaid Ahmed Almetwally, Hatim MF Idrees and Ali Ali Hebeish. Predicting the tensile properties of cotton/spandex core-spun yarns using artificial neural network and linear regression models. The Journal of the Textile Institute, 105(11), 1221-1229, 2014

10- Nergiz Emirhanova, Yasemin Kavusturan. Effects of knit structure on the dimensional and physical properties of winter outerwear knitted fabrics. FIBRES & TEXTILES in Eastern Europe April / June 2008, Vol. 16, No. 2 (67)

11- Prakash C., et al. The effect of loop length and yarn linear density on the thermal properties of bamboo knitted fabrics. AUTEX Research Journal, Vol. 11, No4, December 2011

12- Y M E Hassan, A El-Salmawy and Alsaid Ahmed Almetwally. Performance of woven fabrics containing spandex. Indian Textile Journal, 120, 22-27, 2010.

13- Sabina Y., et al. Effect of stitch length and fabric constructions on dimensional and mechanical properties of knitted fabrics. World Applied Sciences Journal 32 (9): 1991-1995, 2014.

14- N. A. Ibrahim, A. Amr, B. M. Eid, A. A. Almetwally, M. M. Mourad. Functional finishes of stretch cotton fabrics. Journal of Carbohydrate Polymers, 98, 2013, 1603– 1609.

15- Elias Khalil and Md. Solaiman. Effect of stitch length on physical and mechanical properties of single jersey cotton knitted fabric. International Journal of Science and Research (IJSR), 3(9), 2014.

16- Nabil A. Ibrahim, Basma M. Eid, Heba M. Khalil, Alsaid A. Almetwally. A new approach for durable multifunctional coating of PET fabric. Applied Surface Science, Vol. 448, 2018, 95-103. https://doi.org/10.1016/j.apsusc.2018.04.022.

17- Alsaid Ahmed Almetwally. Multiobjective optimization of woven fabric parameters using Taguchi – Grey relational analysis. Journal of Natural fibers, 2019.

18- M. M. Mourad, Ahmed El-Salmawy, and Alsaid Ahmed Almetwally. Core spun yarn and the secret behind its popular appeal. Textile Asia, 2011, November, 42, 41-43

19- - Alsaid Ahmed Almetwally, H. F. Idrees and Ali Ali Hebeish. Predicting the Tensile Properies of cotton/ spandex core-spun yarns using Artificial Neural networks and regression models. The Journal of the Textile Institute, 2014, 105(11), 1221-1229

20- Alsaid Ahmed Almetwally, M. M. Mourad , Ali Ali Hebeish and Mohamed A. Ramadan. Comparison Between Physical Properties of Ring-Spun Yarn and Compact Yarns Spun from Different Pneumatic Compacting systems. Indian Journal of Fibers and Textile Research, 40, March 2015, 43-50

21- Alsaid Ahmed Almetwally, M. M. Mourad and Ali Ali Hebeish. Some handle Properties of Cotton fabrics woven from Ring Spun Yarn and Compact Yarns Spun from Different Pneumatic Compacting Systems. Textile Association journal, 76 (4), November-December, 222-228, 2015

22- Alsaid Ahmed Almetwally. Dynamic stresses measurement of Warp yarns on Sulzer weaving machine using strain gauge.Journal of the Textile Association, 2019,