INTERNATIONAL JOURNAL OF APPLIED RESEARCH ON TEXTILE
URL: http://atctex.org/ijartex
Volume 4, Issue 1, pp 62-75, September 2016

MODELING COTTON/ NATURAL BAST FIBERS BLENDS: GRAPHIC AND STATISTICAL ANALYSES OF COTTON-FLAX BLENDED YARNS PRODUCED ON RING AND ROTOR SPINNING MACHINES

BOUCHRAIET R. *, AZZOUZ B., BEN HASSEN M. AND SAKLI F.

TEXTILE ENGINEERING LABORATORY, UNIVERSITY OF MONASTIR, TUNISIA

Received 01 May 2016, Accepted 21 June 2016

ABSTRACT

In view of their physical properties and ultimate textile products quality, natural fibers have attracted attention to research workers and textiles experts. The modeling of blended fibers proportions of cotton-flax yarns produced on ring and rotor spinning machines are developed in the present study. Using experimental design method, the effect of blend proportions, setting parameters and spinning processes on physical properties of yarns are revealed and related. It was fund that the quality index of cotton flax blended yarn is largely influenced by the blended ratio of raw materials. However, three influencing factors, the metric yarn count, the twist coefficient value and the type of spinning system used are considered to be very critical to determinate the resistance and the elongation of the final blended yarns.

KEY WORDS

Yarn blends; fibers blended; spinning processes; cotton-flax blends; yarn physical properties; experimental design.

1. INTRODUCTION

Today, in the times of economics' globalization, it is required to produce textile product of required quality respecting the environment protection. Being an important renewable and recyclable resource, natural fibers will play a leading role in the global economy to gradually replace petrochemical textile products. For this purpose, the textile researchers are working on a more rational use of these fibers.

Due to their similar properties, like comfort and average rate of cellulose [Lewin, Pearce, 1998], Flax fiber and cotton fiber were used for several yarns in spinning industries [Jonn et al.,1991], and this mixture interest many researchers and industrialists around the word [Cierpucha at al.,2002, Sedelnik at al.,2006].

Flax fiber (Linumusitatissimum) is probably the earliest textile material and holds a great archaeological interest [Barber, 1991]. Flax is a source of industrial fibers and, as currently processed, provides long and short fibers. Long line fiber is used in manufacturing high value linen products, while short staple fiber has historically been the waste from long line fiber and used for lower value products [Jhala, Hall, 2010].

Cotton fiber is an important economic fiber, representing 45 percent (23.5 Million Tone) of the total fibers consumed in the textile industry in 2014 [Nana, 2015]. Cotton is the purest form of cellulose found in nature and is a fiber which originates from plants of the Gossypium species [Shore, 1995]. It is the most important cellulosic fiber and is also currently the most used of all textile fibers due to its availability and low price [Vasconcelos ,2005, Kavkler, Demšar 2011].Several studies have been reported in the literature on the cotton spinning OE yarns with a high proportion of flax fibers [Cierpucha et al.,2006, Kozlowski et al.,2008, Kozłowski et al.,2012]. Rungsima [Rungsima et al 2008], shown that the different blending processes, in the blow room (before carding), or in the drawing frame, affect the migratory behavior of the fibers.

---

* : Corresponding author. Email : romboufr@yahoo.fr

Regarding fiber properties, the differences among component length, fineness, shape of cross-section, coefficient of fiber friction and fiber chemical type, have important effects on fiber migration, as considered by several workers [Doraiswawy et al., 1993, Townend, Dewhirst , 1964].

In the case of coarser yarns, Mortan [Mortan , 1956] concluded that the migration tendencies of different fibers decrease because of the fibers' difficulties to migrate. But in the case of finer yarn counts, they may show more staple blends, because of the greater contribution of the fiber length [Ruppenenicker et al., 1989].

The investigation presented in this article is a continuation of our research work into modeling of natural fibers blending carried in a previous work of this study.

The ultimate objectives for this work are to optimizing and modeling the properties (yarn evenness CVm%, tenacity, elongation % and yarn quality index) of the manufactured yarns with the use of a ring and rotor spinning machines from blended different natural fibers. Cotton and flax fibers were used as raw materials for the preparation of the yarns samples in a mill operated on the cotton system.

Physical properties of yarn blends that have relations by blend ratio, nature and parameters characterization of constituent fibers are analyzed through statistic and graphic method in order to modeling the yarn blends model.

2. MATERIALS AND METHODS

2.1. Preparation of Yarn Samples

In this study, Greek cotton and Flax are selected for the blending of the produced yarns. The properties of the used cotton and flax fibers are summarized in the table below.

Table 1 : The properties of used fibers

Fibre's properties	Flax fiber	Greek cotton
Maturity (%)		90
Fiber tenacity (cN/tex)	34.8	31.1
Fiber elongation (%)	7.2	8.7
Mean length by weight (mm)	34.3	24.6
CV. length by weight (%)	20.8	30.2
Short fiber content by weight (%)	8.2	6.4
Upper quartile length by weight (%) UQL	30.6	28.1
Mean length by number (mm)	24.6	21.8
C.V. length by number (%)	25.8	42.3
Short fiber content by number (%)	26.2	20.1

The cotton fibers which require different opening, cleaning and clearing are normally prepared in the mill operated on the cotton system as shown in a bloc scheme in Figure 1.

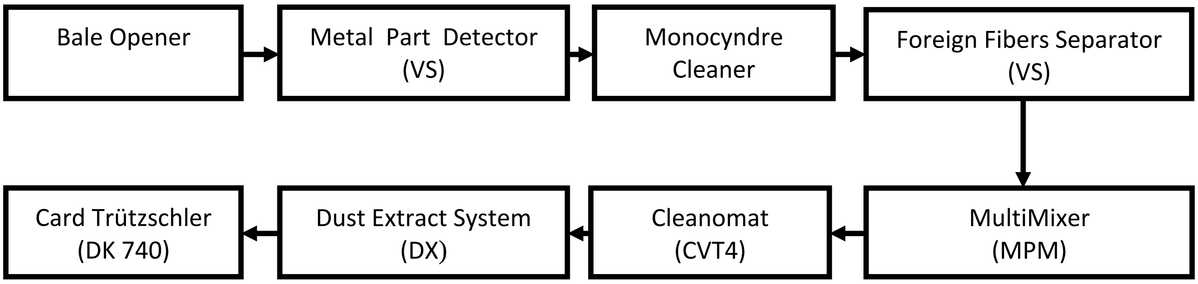

Figure 1: Processing of cotton opening and cleaning.

Flax carded sliver of 5 Ktex was prepared by using bale opener and then card machine (DK 740). For the blending of fibers, the carding machine slivers (six slivers) with the same linear density (5Ktex) were blended in the first passage in the drawing frame. A second passage is used to improve the homogeneity of the slivers blends.

Two different slivers were produced in different proportions of flax/cotton blends as 16.6/83.4, and 33.3/66.7 respectively (named -1 & 1 in the plots).

Different yarns tests in the present study were produced by using Schlafhorst Autocoro rotor spinning machine and Zinser ring spinning frame.

In this study we adopt the method of the design of experiments by using a full factorial set to get significant results. Some researchers used this method for different textile process [Ben Hassen ,Sakli, 2005,Halimi et al.,2008]. To statistically analyze the results, it's necessary to use the main effects and interaction plots and the analysis of variance (ANOVA) for each measured property of samples. This interpretations are made up of calculating statistic parameters that show whether the determinants significantly affiliated to the feedback data and every determinant's relative importance: the mean sum of squares (MS) , the F-statistic (F) and the p-value (P) in the interpretation add up to the relative importance of every determinant to the feedback.

Whenever the null hypothesis is absolutely true, the p-value expresses the probability of rejecting it. Since the P-value in the ANOVA table is less than 0.05, there is a statistically significant relationship between the variables at the 95% confidence level.

A commonly used limit by rejecting value for the p-value is 0.05, such as, if the calculated p-value is less than 0.05 the null hypothesis is not any more true. So the determinant will have a major effect in the feedback.

Table 3 presents the combination of the spinning system, yarn count, twist factor and blend ratio of experiments.

Yarns are produced at different blend ration and two different metric counts with is used in different twist factors. The factors and levels used are shown in Table 2.

Table 2: Factors and levels used in fractional set

Factor **Level**	**Blend ratio (M)**	**Spinning system (P)**	**Yarn count (Ti)**	**Twist factor (To)**
-1	16,6/83,4	Ring	20	120
1	33,3/66,7	Open-End	34	140

Table 3: Design of trails for experiments

Test yarn	**Blend ratio (M)**	**Spinning system (P)**	**Yarn count (Ti)**	**Twist factor (To)**
1	-1	-1	-1	-1
2	-1	-1	-1	1
3	-1	-1	1	-1
4	-1	-1	1	1
5	-1	1	-1	-1
6	-1	1	-1	1
7	-1	1	1	-1
8	-1	1	1	1
9	1	-1	-1	-1
10	1	-1	-1	1
11	1	-1	1	-1
12	1	-1	1	1
13	1	1	-1	-1
14	1	1	-1	1
15	1	1	1	-1
16	1	1	1	1

2.2. Testing of Yarn Samples

All the samples were conditioned for 24 hours under standard atmospheric conditions of 21± 1 °C and a relative humidity of 65 ± 2%.

The breaking strength tests of cotton/flax blended yarns produced were carried out in Uster Tensiorapid 3 whereas unevenness and uniformity were measured using the Uster Tester 3.

3. RESULTS AND DISCUSSION

Different researchers have studied various aspects of spun yarns blends quality parameters in the last century. In textile engineering, quality index value has been considered to be the most important yarn quality index. On the other hand yarn, textile experts at the Uster Company concluded that the physical properties of spun yarn are the most important quality parameters of yarn [Uster, 2013]. In textile engineering, strength has been considered to be one of the most important yarn properties [Nurwaha, Wang, 2008]. Similarly Krifa [Krifa et al., 2001] who stated that many factors had an impact on yarn quality, which depends on both fiber quality parameters and spinning condition. Anindya [Anindya et al., 2005] stated that yarn strength is a principle component of yarn Quality. On the other hand yarn evenness (CVm %) and yarn elongation significantly affect the final yarn quality [Cheng, Adams, 1995, Azzouz et al., 2005].

It has been observed that researchers gave general statement about various quality parameters of blend yarn. There are various parameters during yarn production such as variation in mass per unit length and tensile properties of yarns have long been the most important characteristic in textile processing and quality control.

The present study has aimed analyzing the cotton/flax yarn blend with the combined effect of blend ratio, spinning system, linear density and twist factor on blended yarns properties, by studying the influence of following parameters:

- Yarn evenness CVm%
- Tenacity cN/tex
- Yarn elongation (%)
- Yarn Quality Index

The blend cotton/flax fibers is selected carefully to cover a wide knowledge domain of both fibers, whereas blend ratio, spinning system, yarn count and twist factor are also selected according to practical yarn spinning requirements ,which is vital for analyzing.

Table4. Table for optimization of yarn quality

Test yarn	CVm%	Tenacity cN/tex	Elongation (%)	Yarn Quality Index
1	27.28	9.35	6.16	2.11
2	28.71	11.45	7.17	2.86
3	31.54	7.96	5.71	1.44
4	36.88	8.03	5.61	1.22
5	21.60	8.42	5.02	1.96
6	22.40	9.17	6.26	2.56
7	20.02	8.9	5.9	2.62
8	20.24	8.46	5.15	2.15
9	31.20	8.5	5.8	1.58
10	30.74	10.17	6.37	2.11
11	32.61	7.94	5.28	1.29
12	36.01	8.12	4.51	1.02
13	23.10	8.05	4.1	1.43
14	24.40	7.9	3.9	1.26
15	25.60	7.7	4	1.2
16	26.20	7.8	3.8	1.13

5. GRAPHIC ANALYSIS

The graphical analyses were performed using Minitab 14 software package. Each chart shows the average effect of the factor corresponding to the answer studied when it passes from one level to another.

5.1. Analysis of CVm% of blended yarns

The main effects of factors and their interactions on the evenness CVm% of cotton/flax spun yarn are given respectively in Figures 2 and 3.

We note from the figure 2 that the optimum values of yarn evenness (CVm%) can be obtained with a mixture16.6/83.4 of flax/cotton fibers. The yarn count affects slightly the CVm%.The yarn evenness CVm% increases with a decrease in linear density due to variation of the cross sectional of the blended yarn. This finding remains consistent with the results of Klein W. [klein, 2011].We can note that the twist factor increases the CVm%. On the other hand, the yarn evenness is mainly affected by spinning system.

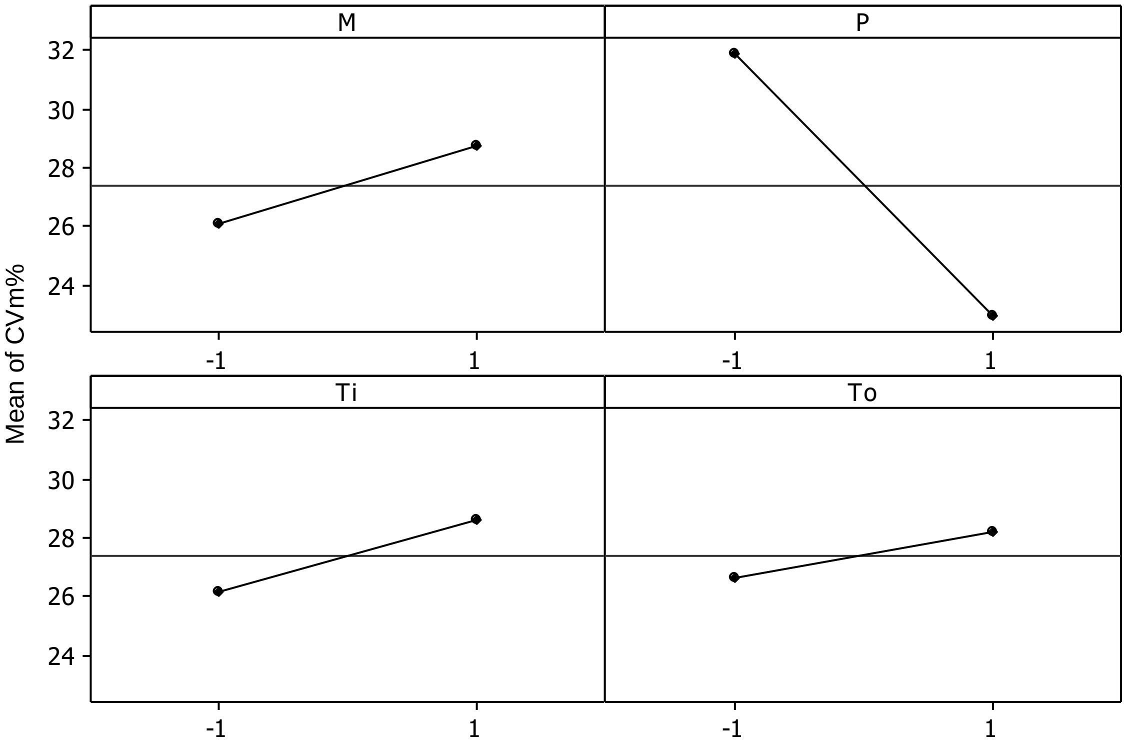

Figure 2: Main Effect Plot (data means) for CVm% of cotton/flax yarns

The deterioration of rotor-yarn evenness could be attributed to the sliver regularity because open-end methods enabling yarn to be spun direct from sliver. On the other hand, each drafting operation increase evenness considerably because the uniform arrangement of fibers mixed becomes more difficult. However, evenness values of ring yarns are lower because the fibers are well bound into the structure and exhibit a controlled movement during drafting resulting in lower evenness.

The interaction matrix (figure 3) show significant interaction between blend ratio and spinning system. The effect of M on the CVm% is more important on rotor-yarns than ring-yarns. With more proportion of flax fibers the evenness of open-end yarn becomes higher because the principle of draft system enabling yarn irregularity proportionally to those of sliver. However, slightly interaction shown between P and Ti. The interaction plot shows a non-significant interaction between M and Ti or (and) M and To.

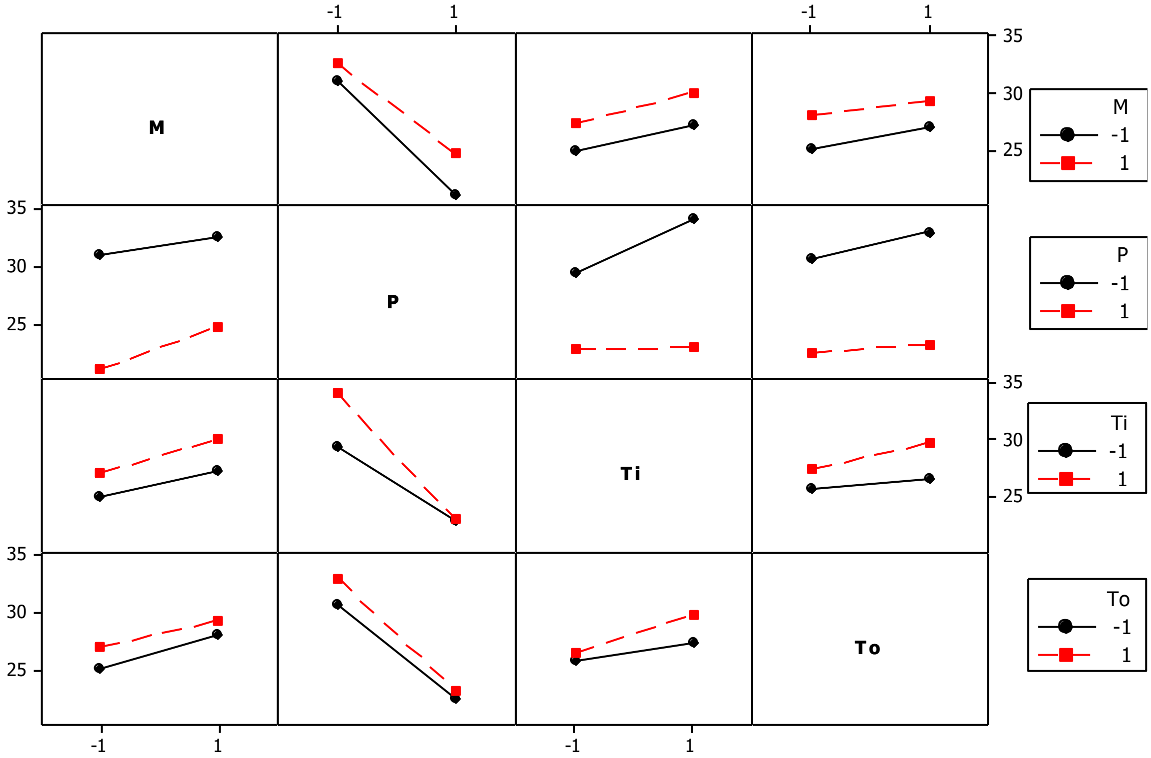

FIGURE 3: Interaction plot for CVm% of cotton/flax yarns

5.2. Analysis of Tenacity

Figure 4 illustrates results of the influence of four factors described above on the meaning yarn tenacity. While blend ratio of flax fibers in the raw material, the different count of the blended yarn and the spinning process influencing much of the tenacity. Yarn tenacity decreased with increasing the ratio of flax fiber. These results are in agreement with Krifa M. [Krifa et al., 2001] who stated that many factors had an impact on yarn strength, which depend on both fiber quality parameters and spinning condition. Also, higher percentage of flax fiber always decrease yarn strength. This is finding is consistent with the results of Sevkan A. [Sevkan, Kadoglu, 2012]. On the other hand, the effect of yarn linear density is significant on yarn tenacity. As the yarn linear density increase thin place, the number of thick and neps increase, tenacity and elongation values decrease. However, the twist has the least effect on the meaning tenacity due to the mechanical state of the constituent fibers (cotton & flax) will lead to different levels of torsional stress induced in the yarn blended [Bennet , Postle, 1979a).

From interaction matrix on blended yarn strength (Figure 5), the trend of strength has been decreased with the increase of blend ration of flax fibers any spinning system applied, but it is more higher on the open-end than ring spinning. Sight interaction between M and Ti on the yarn blended tenacity. This parameter decreased with the increase in the yarn count. From interaction matrix it is also seen a significant interaction between each other’s factors respectively: M and Ti, P and Ti also Ti and To. Negligible interaction between M and To can be observed. It is clear from the interaction plot for tenacity that higher interaction between independent variables indicating the significance effect on the yarn blended tenacity.

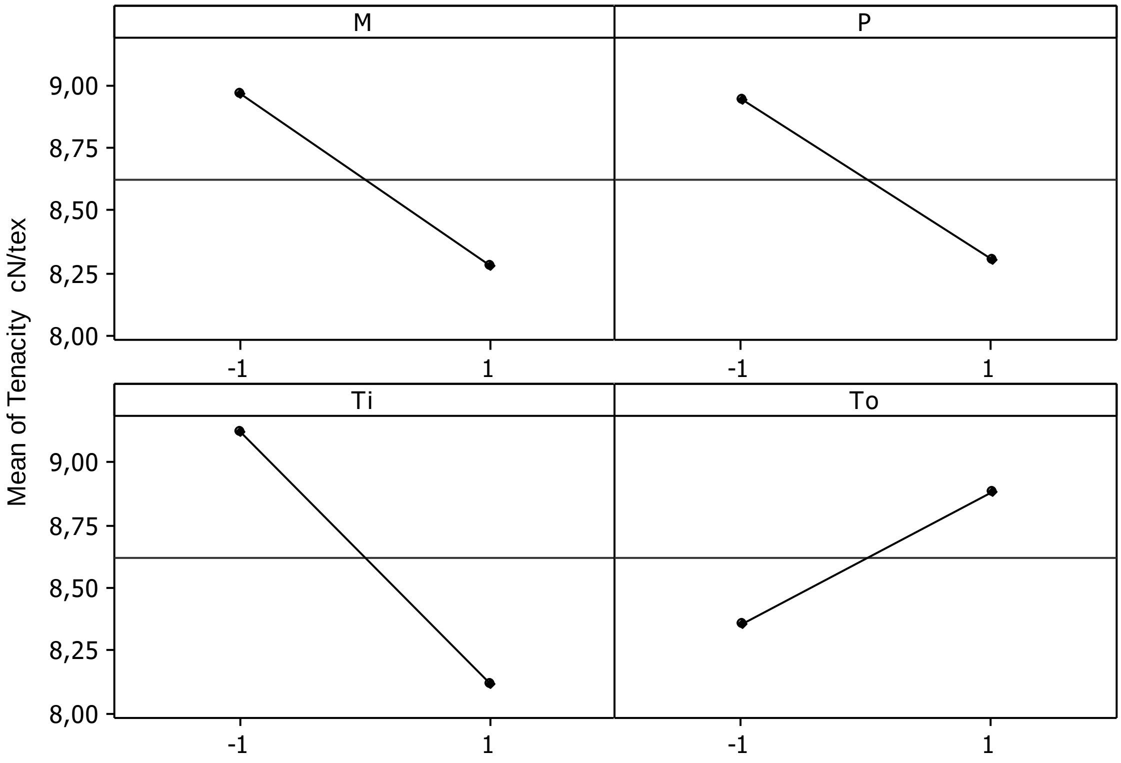

Figure 4: Main Effect Plot (data means) for tenacity of cotton/flax yarns

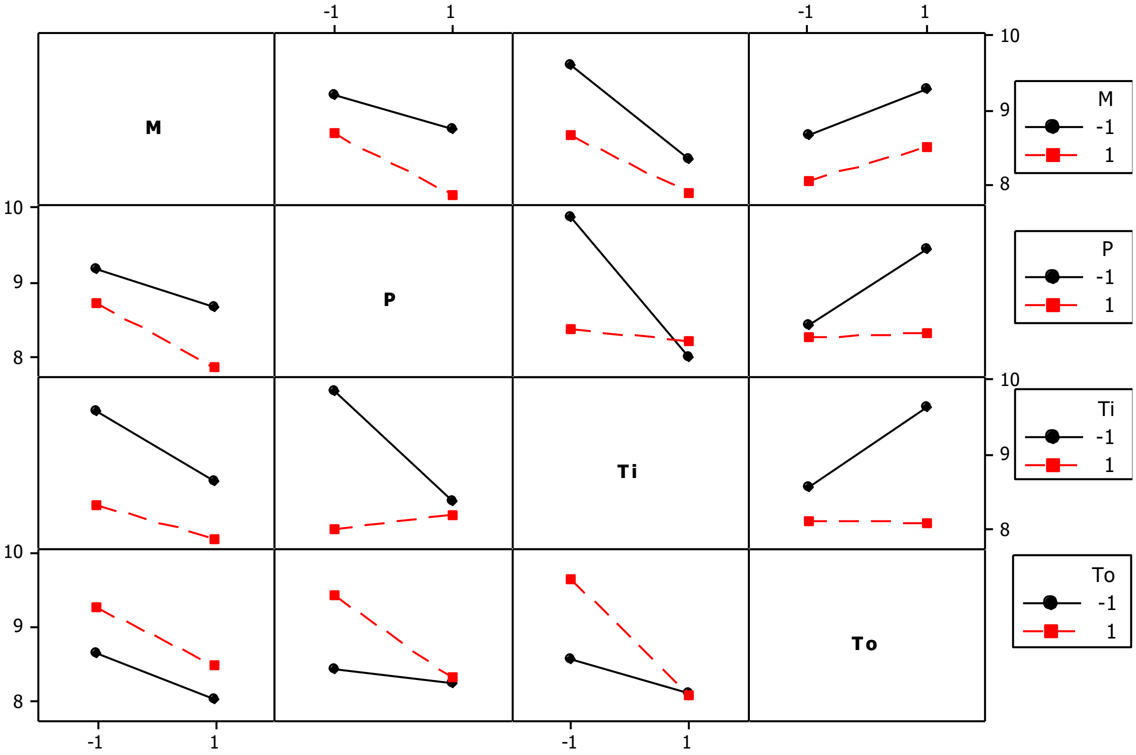

Figure 5: Interaction plot for tenacity of cotton/flax yarns

5.3. Analysis of blended yarns elongation

From Figure 6, it is obvious that the raw material blended ratio(M), spinning process (P) and yarn count (Ti) present the most significant effect on the elongation percentage of the blended yarn.

The higher the ratio of flax fiber in the mix the lower is the yarn elongation (%)“. We note that the Open-End blended yarn over elongation is significantly lower than that produced in ring spinning. This finding is consistent with the results of Klein W. [Klein,2011]. The elongation (%) is mostly influenced by yarn count. While all factors have positive effect except twist factor, who no consistent trend was observed.

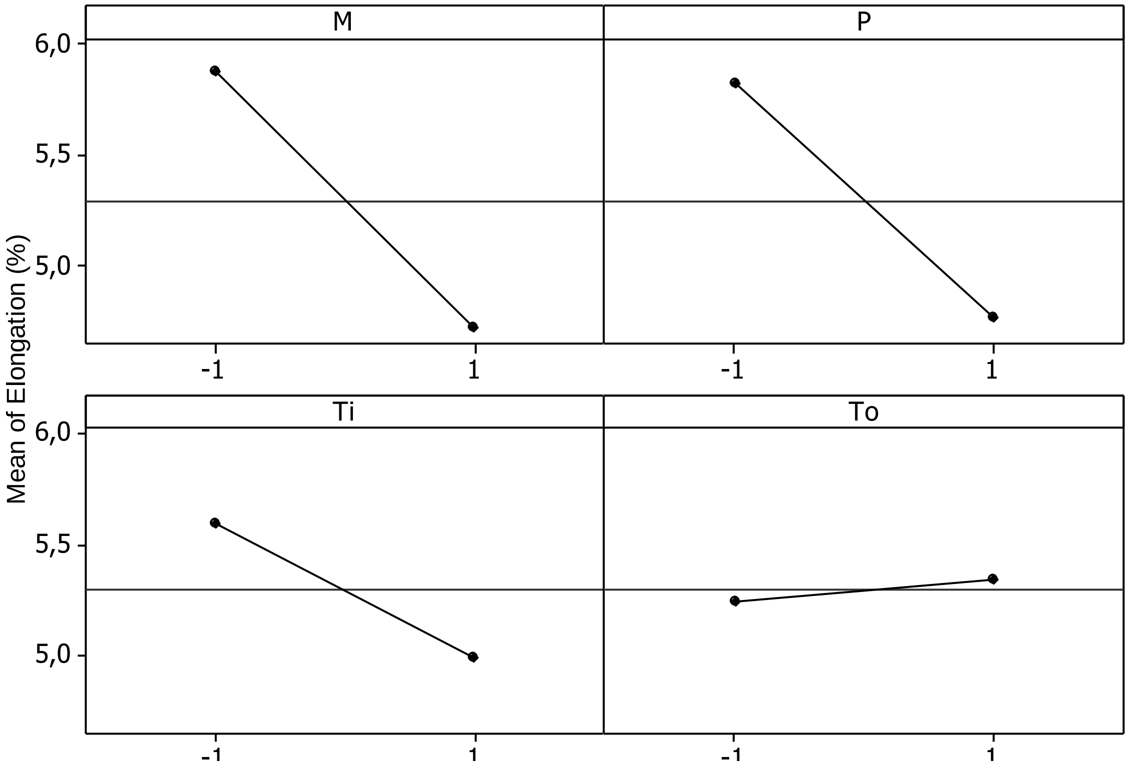

Figure 6: Main Effect Plot (data means) for Elongation of cotton/flax yarns

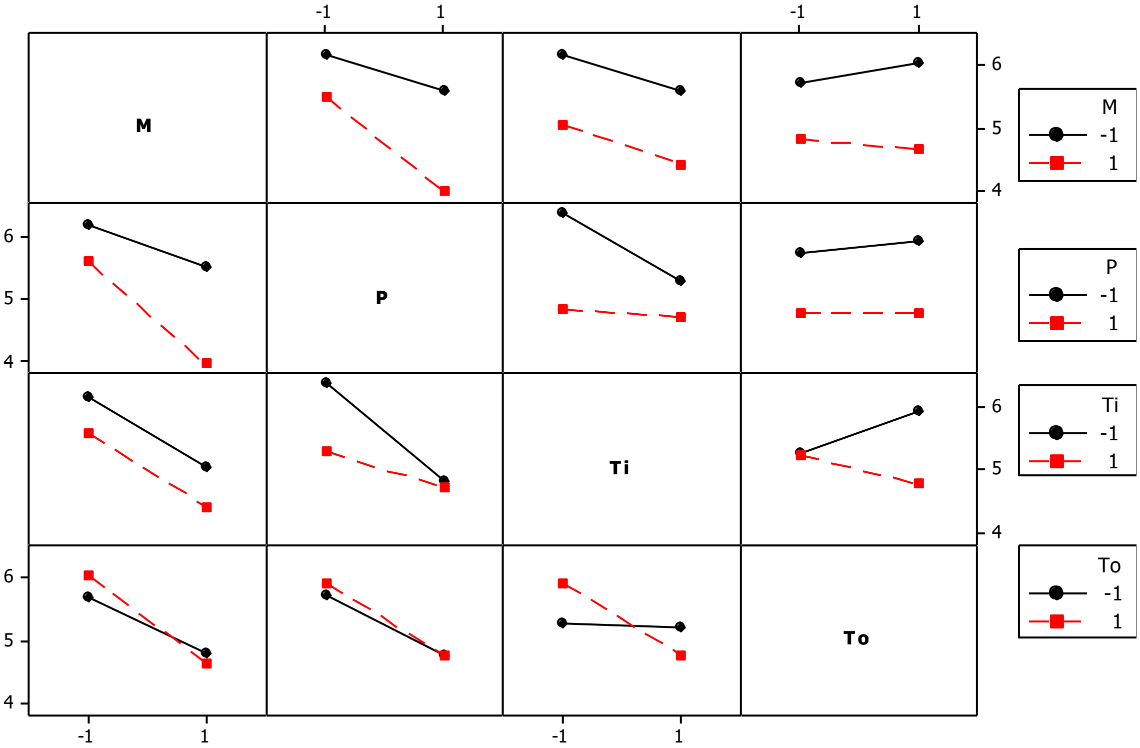

Figure 7: Interaction plot for elongation of cotton/flax yarns

Figure 7 shows the interaction plot of the input factors on blended yarn elongation. Results indicate an important interaction between M and P. Elongation (%) of rotor-yarn blended is more influenced by increasing the blend ratio of flax fiber in the mix than the ring-yarn blended. We can see a negligible interactions reported between M and Ti and also between M and To and between P and To. On the other hand, there is an important interaction between P and Ti; the effect of the yarn count on the elongation % is more important at the ring system than the open-end system. It is clearly seen that there is a significant interaction between Ti and To; the effect of the Twist factor is reversed by increasing the yarn count and vice versa.

5.4. Quality Index analysis

In spinning domain, yarn quality index that encloses major physical properties which are tenacity, elongation and uniformity [Klein, 2011, Cheng ,Adams,1995,Spouid at al.,2012], considering as the quality criterion of spun yarn, implies the production of yarns according to consumer needs. The yarn quality index was calculated using Barella's [barella et al., 1976] formula as shown below:

YQI= Tenacity (cN/Tex) x Elongation (%) / CVm%

The effects of the input factors on Quality Index of cotton/flax yarns are shown in figure 8.Quality index of blended yarns is predominantly influenced by the composition and the linear density of these yarns. It is observed that the blend ratio of flax fiber in the mix has the most significant effect on the YQI. More the proportion of flax in the blend is higher, more the quality index of yarn is low. We can state that a relatively high proportion of flax in the blend is not recommended. While the spinning process as well as the twist of the yarn does not have a large significant effect on the yarn quality index. The yarn count has a negative effect on the yarn quality index. However, it is clear that the cotton /flax blend at this ratio (33.3/66.7 of flax/cotton fibers) is recommendable for coarser yarns.

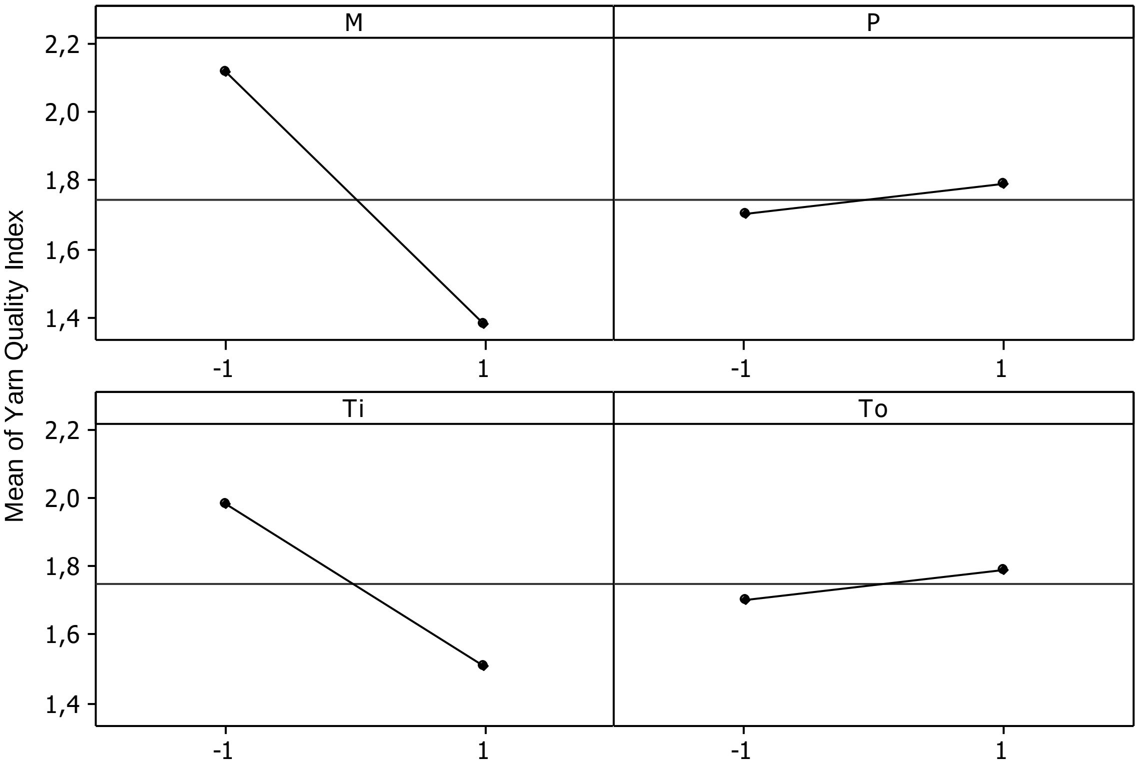

Figure 8: Main Effect Plot (data means) for Quality Index of cotton/flax yarns

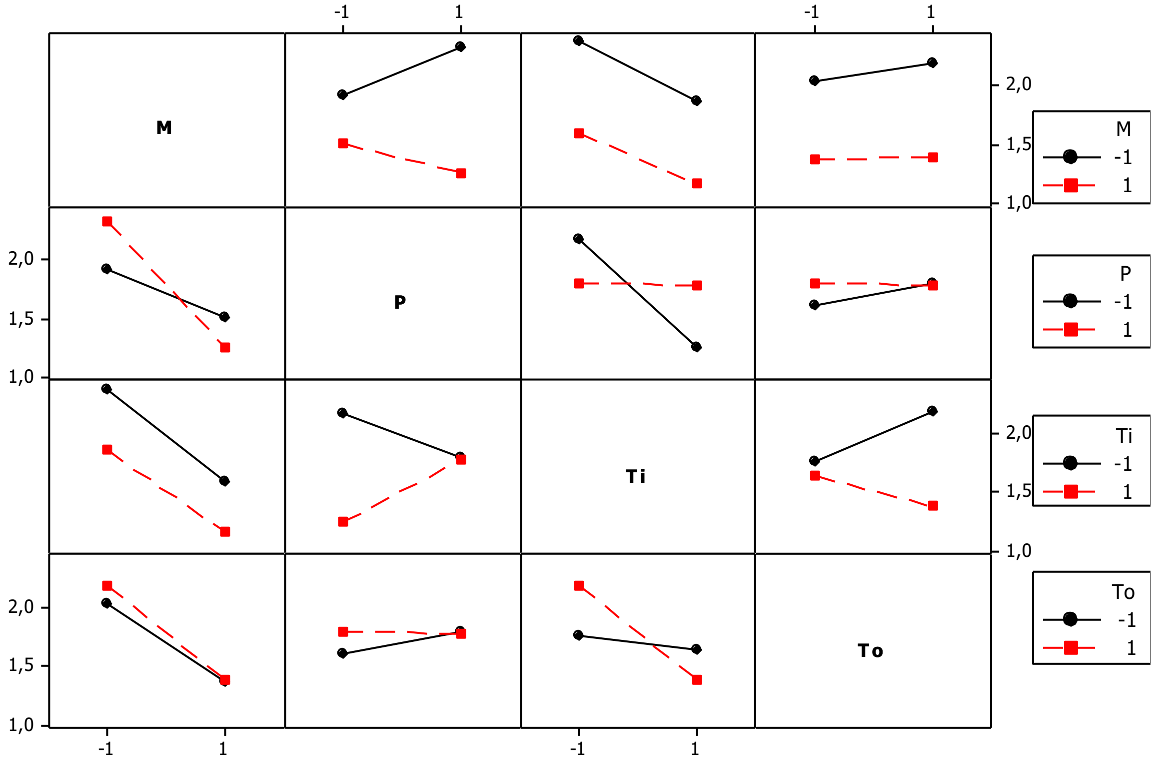

Figure 9: Interaction plot for yarn quality index of cotton/flax yarns

From the interaction matrix (Figure 9), the interaction of different factors can be stated as follows: significant interaction between M and P, the effect of M is more important at the ring system than the open-end system. The interaction plot shows a non-significant interaction between M and the other factors. However, higher linear density of blended yarn decreases the quality index at the ring spinning than at the open-end process. It is clear that yarn count decrease strongly the quality index at the higher twist factor. Quality index of finer blended yarns with higher levels of twist factor decrease slightly than coarser yarn.

6. STATISTICAL ANALYSIS

The statistical analyses were performed using Minitab 14 software package. ANOVA tables for selected responses evenness CVm%, Tenacity, yarn elongation (%) and YQI are given in Tables 5, 6, 7 and 8 respectively. The impact of all the variables on the responses is discussed separately in the following sections:

The experimental results have been statistically evaluated by using Design Expert analysis of variance (ANOVA).F test used to treat the interaction between design variables. For analyses of multi-variance p value < 0.05 was applied. If it is less than 0.05 than we can state the effect is statistically significant.

6.1. Blended yarn evenness CVm%

From ANOVA table of blended yarn evenness CVm%, we get spinning system as a significant term for yarn evenness. It can be said that other selected parameters, blending ratio and yarn count are statistically significant terms in the uniformity of cotton/flax yarn blend. Whereas To have less effect on the yarn evenness ($p > 0.05$). According to p-value, the factors can be classified according to the level of importance as:

$$P>M>Ti>To$$

Table 5: The analysis of variance for the blended yarn CVm%

Source of Variation	DF	AdjMS	F	P
M	1	28.064	7.63	0.040
P	1	318.712	86.64	0.000
Ti	1	24.182	6.57	0.050
To	1	9.97	2.71	0.161
M*P	1	4.94	1.34	0.299
M*Ti	1	0.328	0.09	0.777
M*To	1	0.544	0.15	0.716
P*Ti	1	21.506	5.85	0.060
P*To	1	2.882	0.78	0.417
Ti*To	1	2.633	0.72	0.436
Error	5	3.679		
Total	15			

6.2. Tenacity of blended yarn

Yarn strength, is one of the most important parameter influencing the yarn's use in terms of quality. ANOVA table for yarn strength has been given in table 6. According to table 6 results the independent variables blend ratio, spinning system and yarn count have a significant effect ($p<0.05$) on the strength of blended yarn. Whereas, twist factor has not the same effect ($p> 0.05$).The trend is in agreement with Sevkan [Sevkan, Kadoglu, 2012].The interaction effect of spinning system and yarn count statistically significant. The difference between the yarn tenacity values of conventional and open-end yarns increases as the yarn becomes coarser.

Table 6: The analysis of variance for the tenacity of blended yarn

Source of Variation	DF	AdjMS	F	P
M	1	1.9321	8.96	0.030
P	1	1.6384	7.6	0.040
Ti	1	4.1006	19.02	0.007
To	1	1.1449	5.31	0.069
M*P	1	0.1296	0.6	0.473
M*Ti	1	0.2450	1.14	0.335
M*To	1	0.0289	0.13	0.729
P*Ti	1	2.8392	13.17	0.015
P*To	1	0.8836	4.1	0.099
Ti*To	1	1.2432	5.77	0.062
Error	5	0.2156		
Total	15			

According to p-value, the factors can be classified according to the level of importance as:

$$Ti>M>P>To$$

6.3. Elongation of blended yarn

According to p-value the independent parameters can be classified according to the level of important as:M (blend ratio) and P (spinning system) > Ti (yarn count).It may be due to the presence of more short fibers in blend composition, create disturbance during drafting system. Ultimately yarn elongation will loss at high blend ratio and at fine yarn on ring or rotor yarn. The interaction effect of spinning system and yarn count is statistically significant. The difference between the elongation values of conventional and open-end yarns increases as the yarn becomes coarser.

Table 7: The analysis of variance for the elongation of blended yarn

Source of Variation	**DF**	**Adj MS**	**F**	**P**
M	1	5.313	50.32	0.001
P	1	4.4944	42.57	0.001
Ti	1	1.452	13.75	0.014
To	1	0.04	0.38	0.565
M*P	1	0.9216	8.73	0.032
M*Ti	1	0.0072	0.07	0.804
M*To	1	0.25	2.37	0.184
P*Ti	1	0.9801	9.28	0.029
P*To	1	0.024	0.23	0.653
Ti*To	1	1.2321	11.67	0.019
Error	5	0.1056		
Total	15			

According to p-value, the factors can be classified according to the level of importance as:

M≥P>Ti>To

6.4. Quality index of blended yarn

ANOVA table for yarn quality index has given in table 8.The independent variables blend ratio and linear density of yarn have a significant effect ($p< 0.05$)on the quality index of yarn. Whereas, spinning system has not the same effect ($p > 0.05$). The interaction effect of spinning system and linear density of yarn is statistically significant. The difference between the quality index values of conventional and open-end yarns increases as the yarn becomes coarser.

Table 8: The analysis of variance quality index for the blended yarn

Source of Variation	**DF**	**AdjMS**	**F**	**P**
M	1	2.17563	29.92	0.003
P	1	0.0289	0.4	0.556
Ti	1	0.9025	12.41	0.017
To	1	0.0289	0.4	0.556
M*P	1	0.4356	5.99	0.058
M*Ti	1	0.0064	0.09	0.779
M*To	1	0.0256	0.35	0.579
P*Ti	1	0.80103	11.02	0.021
P*To	1	0.05062	0.7	0.442
Ti*To	1	0.46923	6.45	0.052
Error	5	0.07272		
Total	15			

According to p-value, the factors can be classified according to the level of importance as:

M>Ti>P≥To

7. CONCLUSION

The target of this work was to optimize and model the yarns manufactured with the use of a ring and rotor spinning machines from cotton/flax blended. For these reasons, physical properties of yarn blends that have relations by blend ratio, nature and parameters characterization of constituent fibers are analyzed through statistical and graphical methods in order to optimize the yarn blends.

To sum up, the tenacity and yarn elongation of final yarn is largely influenced by the characteristics of raw materials and the spinning system. The blend ratio has the most significant effect on the yarn quality, while the spinning processes as well as the twist of the yarn were found statistically significant on yarns properties. Whereas, the linear density is not the most influencing factors on the resistance of the yarn. On the other hand, the higher blend ratio of flax fiber in the blend composition not recommended for fine yarn count.

From the above all discussion and results it can conclude that flax/cotton fiber ratio in the mix and its yarn properties are influenced by fibers proportion, yarn specifications and operational parameters.

The research results concerning the selected properties served for the development of a model of the flax/cotton blend in order to improve the quality and cost of flax/cotton yarn at the optimal blend ratio.

REFERENCES

A.J. Jhala, L.M. Hall (2010). Flax (Linumusitatissimum L.): current uses and future applications. *Aust. J. Basic Appl. Sci.*, 4, pp. 4304–4312.

Anindya G.,Sayed I.,Seenivasan R.,Prithwiraj M. and Asis P (2005). *Autex research journal , Volume 5,N°1 ,March 2005,pp. 20-29.*

Azzouz B.,M.B.Hassen,and Sakli F.(2005).,"Quality prediction and optimizing cotton blend using ANN",*IndianTexile journal* , Volume 1 ,March2005,pp. 27-34.

Barella,A., Vigo,J.P., Tura,JM.Esperon,H.O.(1976).An application of mini-computers to the optimization of the open-end spinning process. Part I. Consideration of the case of case two variables. *In:Journal Textile Institute*. Vol. 253, issue 67, 1976.

Ben Hassen M.,Sakli F (2005).Experimental study of mechanical splicing. *AUTEX Research journal,*vol.5,N°2,June2005.

BennetJ.M.,and Postle,R (1979a). A study of yarn torque and its dependence on the distribution of fiber tensile stress in the yarn .Part I.: Theoretical Analysis*, Journal of the textile Institute* 70(4),1979a,pp.121-130.

Cheng L. and Adams D.L (1995)."yarn strength prediction using neural networks. Part I : Fiber properties and yarn strength relationship",*Textile Research Journal* , Volume 65 (9) ,1995,pp. 495-500.

Cierpucha W, Czaplicki Z, Mańkowski J, Kołodziej J, Zaręba S, Szporek J (2006). Blended Rotor-Spun Yarns with a High Proportion of Flax. *Fibres& Textiles in Eastern Europe*; 14, 5 (59): 80-83 (2006).

Cierpucha W, Mańkowski J, Waśko J, Mańkowski T, Zaręba S, Szporek J (2002). Application of flax and hemp cottonised fibres obtained by mechanical method in cotton rotor spinning. *Fibres & Textiles in Eastern Europe*; 2 (37): 32.

D. Nurwaha and X. Wang (2008), Comparisons of the new methodologies for predicting the CSP strength of Rotor Yarn. *Fibers and polymers*, Vol.9, No.6, 2008, pp.782-784.

Doraiswawy, I., Chellamani, P., and Gnanasekar, K.(1993). Effect of Fibre Properties on Cohesive Force of Man-made Fibres, *Synth. Fibres*, 22,pp. 13–17 (1993).

E.J.W. Barber (1991). Prehistoric Textiles. *Princeton University Press*, Princeton, NY, USA (1991) p. 12.

HALIMI M.T.,Ben Hassen M.,Sakli F (2008). Cotton waste recycling: Quantitative and qualitative assessment. *Science Direct.Ressources,Conversation and recycling* 52:785-791 (2008).

H.Souid,M.Sahnoun,A.Babay an M.Cheikhrouhou (2012),"A Generalized Model for Predicting Yarn Global Quality Index". *The Open Textile Journal , Volume 5 2012,pp. 8-13.*

Jonn A. F, Roy B. D, David M, David C, Danny E. A, Herb. M. Flax-cotton fiber blends (2007). Miniature spinning, gin processing, and dust potential. *Industrial Crops and Products*. Volume 25, Issue 1, Pages 8–16.2007.

J. Shore.(1995). *Cellulosics dyeing Society of Dyers &Colourists*, England (1995).

K. Kavkler, A. Demšar (2011). Examination of cellulose textile fibres in historical objects by micro-Raman spectroscopy.SpectrochimicaActa Part A: Molecular And Biomolecular Spectroscopy. *Elsevier* 78 (2), February, 2011, pp. 740–746.

Klein W.(2011). *The textile institute ,Manuel of textile technologie. New spinning systems,short-staple spinning series,* Volume 5.April,2011,pp. 40-41.

Kozłowski R, Czaplicki Z, Zaręba S, Mańkowski J (2012). OE Cotton Yarns with a High Content of Enzyme – Modified Flax Fibers. *Journal of Natural Fibers*; 9(3), 2012, pp. 137-149.

Kozlowski R, Zareba S, Szporek J, Czaplicki Z (2008). Technology of Producing OE cotton yarns with high content of modified Flax Fibres. *In: ITC&DC: 4th.International Textile Clothing & Design Conference*, 2008,p. 216.

Krifa M.,J.P.Gourlot and J.Y.Drean (2001),"Effect of seed coat fragments on cotton yarn strength: dependence on fbrequality*:Textile Research Journal*" , Volume 71(11),2001,pp.981-9865.

M. Lewin, E. Pearce(1998). *Handbook of Fiber Chemistry*.(2nd ed.)Marcel Dekker, New York.1998

Mortan, W. E.(1956). The Arrangement of Fibers in Single Yarns, *Textile Res. J*. 26, pp 325-331 (1956).

NANA A.(2015). International Cotton Advisory Committee, Report ,February 2015 .Available from:www.commodafrica.com.[23.01.2016].

Rungsima. C,Jean.F. O, Artan. S, Jean. Y. D.**(2008)** Effects of Blending Parameters on the Cross-section Fiber Migration of Silk/Cotton Blends. *Tex Res J* Vol 78(4):April 2008, pp.361–369.

Ruppenenicker, G. F., Happer, R. J., Sawhney, A. P., and Robert, K. Q.(1989). Comparison of Cotton/Polyester Core and Staple Blend Yarns and Fabrics, *Textile Res. J*. 59, 12–16 (1989).

Sedelnik N, Zaręba S, Szporek J (2006). Preparation of Enzymatically Modified Flax Fiber for Producing of Rotor-Spun Yarn for Apparel. *Fibres & Textiles in Eastern Europe*; 14, 1 (55): 22-26*5 (2006).*

Sevkan A. and Kadoglu H. (2012) , An investigation on ring and open-end spinning of flax /cotton blends. *Textile and confection*, Mars 2012, pp.218-222.

Townend, P. P., and Dewhirst, J.(1964). Fibre Migration of Viscose Rayon Staple-fibre Yarns Processed on the Bradford Worsted System, *J. Textile Inst*. 55(10), 485–502 (1964).

Uster (2013).*Uster statistics,Application Handbook,edition 2013*. *Textile Technology* /V1.0 January 2013/240 840 14020.

Vasconcelos, A. J. C. (2005). *Obtenção de Tecidos de Poliéster de Baixo Peso porTratamentoEnzimático. Departamento de EngenhariaTêxtil (Vol. Mestrado, p. 68). Braga: Universidade do Minho.*