Effects of waste cotton usage on properties of OE-rotor yarns and knitted fabrics

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REZUMAT – ABSTRACT

Efectele utilizării deșeurilor de bumbac asupra proprietăților firelor filate cu rotor OE și ale materialelor tricotate

Utilizarea materialelor reciclate a câștigat o importanță masivă atât în sectorul textil, precum și în alte sectoare, deoarece efectele reducerii surselor naturale sunt resimțite peste tot în lume. În acest studiu, s-a urmărit analizarea efectelor utilizării bumbacului reciclat asupra proprietăților firelor filate cu rotor OE și a tricoturilor realizate din aceste fire. În acest scop, firele filate cu rotor OE au fost produse în diferite amestecuri de bumbac virgin și deșeuri de bumbac care provin din bataj, în proporție de 25%, 50%, 75%, și respectiv 100%. Pentru o evaluare mai bună, proprietățile firelor filate cu rotor OE care conțin deșeuri de bumbac au fost comparate cu firele filate cu rotor OE din bumbac virgin. Proprietățile fizice, structurale și mecanice, cum ar fi neuniformitatea, imperfecțiunile, pilozitatea, forța de rupere, alungirea, frecarea fir-fir, frecarea fir-metal și frecarea fir-ceramică, au fost măsurate cu Uster Tester 4 SX, Uster Zweigle Hairiness Tester 5, Uster Tensorapid 3 și CTT Lawson Hemphill. În cea de-a doua parte a studiului, au fost realizate tricoturi glat din firele filate cu rotor OE. Au fost evaluate, de asemenea, efectele ponderii deșeurilor reciclate asupra proprietăților țesăturii tricotate, cum ar fi pilingul, rezistența la abraziune, rezistența la plesnire și permeabilitatea la aer. Rezultatele au arătat că utilizarea a până la 75% în amestec a bumbacului reciclat nu prezintă diferențe semnificative din punct de vedere statistic în ceea ce privește proprietățile firelor și țesăturilor.

Cuvinte-cheie: bumbac reciclat, deșeuri de bumbac, filare cu rotor OE, fire în amestec, proces sustenabil de producție

Effects of waste cotton usage on properties of OE-rotor yarns and knitted fabric

The use of recycled materials has gained massive importance in textile sector as well as in other sectors as the effects of reduction of natural sources are felt all over the world. In this study, it was aimed to analyse the effects of recycled cotton usage on properties of OE-rotor spun yarns and knitted fabrics produced from these yarns. For this purpose, OE-rotor yarns were produced at different proportion levels of virgin cotton and waste cotton that derived from blowroom 25%, 50%, 75%, 100%, respectively. For better assessment, properties of OE-rotor yarns that contain waste cotton were compared with 100% virgin cotton OE rotor yarn. Physical, structural and mechanical properties such as unevenness, imperfections, hairiness, breaking force, elongation, yarn-to-yarn friction, yarn-to-metal friction and yarn-to-ceramic friction were measured by Uster Tester 4 SX, Uster Zweigle Hairiness Tester 5, Uster Tensorapid 3 and CTT by Lawson Hemphill. At the second part of the study, single-jersey knitted fabrics were produced from OE-rotor spun yarns. Effects of waste cotton proportion on knitted fabric properties such as pilling, abrasion resistance, bursting strength and air permeability were also evaluated. Results showed that, the use of up to 75% per cent of waste cotton blended yarns show no statistically significant differences on yarn and fabric properties.

Keywords: recycled cotton, waste cotton, OE-rotor spinning, blended yarns, sustainable production process

INTRODUCTION

Textile industry is one of the major sectors that scope all over the world and consumption level of textile products have been rising year by year as a consequence of growth of the world population and improvements of living standards [1]. Cotton keeps its position as a main raw material for textile industry despite of recent improvements of synthetic and regenerated fibres [2]. The other point of view, production level of cotton has been fluctuated for recent years, and because of strict relation with geographical condition, it is hard to estimate production level of cotton for upcoming years [3].

By the relation with cotton position in textile industry, efficient waste management plays major role for cost of textile product. In order to reduce production costs and obtain sustainable and ecological production processes as well as to prevent harmful effects of cotton farming such as release of carbon dioxide, water and energy consumption, many multinational textile suppliers begin to use recycled or waste cotton [4–6]. With the rising concern of global warming and reduces of natural sources, some protocols i.e. Kyoto and Montreal are put into effect in order to protect environment and prevent release of greenhouse gases. Moreover, international organisations such as Global Organic Textile Standard (GOTS), Better

Cotton Iniative (BCI), e^3 Sustainably Grown Cotton, Cotton Leads focus on sustainable production process of textile products as well as provide cotton farming in better ecologic environment. On the other hand, products that produced from recycled materials find position between many consumers' first consumption choices and create their own market share known as "green market" or "environmental marketing" [7].

In the literature, it is seen that many researchers produced open-end rotor spun yarns by using recycled cotton. It can be related with the reason of capability of rotor spun technology to produce yarn from cotton waste at high twist level unlike other spinning technologies. Hassani *et al*. investigated the optimum spinning conditions for rotor spun yarns that different proportional cotton wastes derived from ginning machines blended with secondary raw material [8]. Khan *et al*. studied on the prediction of the properties of cotton/waste blended OE rotor spun yarns using Taguchi OA design [9]. They concluded that the proportion amount of waste cotton is the most influential parameter on the properties of cotton/waste blended yarns. Taher *et al.* analysed the influence of spinning parameters and recover fibres from cotton waste on the uniformity and hairiness of rotor spun yarns [10]. They indicated that yarn count, rotor parameters such as diameter, form and rotor speed have considerable effects as much as waste proportion. Furthermore, they also denoted that using 25% of recycle fibre does not change the uniformity and appearance of rotor spun yarn in their study. Halimi *et al*. also examined the effect of cotton waste and spinning parameters on the rotor yarn quality [11]. Results of their study also verified that up to between 15% and 25% cotton waste ratio does not cause any change on rotor yarn quality with the optimum spinning parameters. Hassani and Tabatabei focused on optimising of spinning variables in order to reduce hairiness of rotor yarn produced from waste fibres that collected from ginning process [12]. According to conclusions of study, rotor diameter and navel type have significantly higher effect than other production parameters on the hairiness of rotor spun yarn with all proportion levels (65%, 50%, 35%) of waste cotton. Halimi *et al.* investigated proportion of good fibres inside cotton wastes that derived from blow room and card machines using both of the qualitative and quantitative methods [13]. In order to determine cotton wastes as a good fibre, OE rotor yarns produced and analysed. Results showed that between 15% and 25% cotton wastes can be blended with virgin cottons without noticeable drawbacks on rotor yarn quality. Celep *et al.* presented an experimental study on the thermal comfort properties of single jersey knitted fabrics that produced from 100% virgin cotton, %100 recycled cotton, 50%-50% recycled-virgin cotton OE yarns [14]. Regarding the comparative analysis between samples, it is seen that thermal conductivity, thermal absorptivity, air permeability decreased and thermal resistance increased with the increased proportion of recycled cotton fibres. Vadicherla and Saravanan were also studied thermal comfort properties of single jersey knitted fabrics that contain different ratios of recycled polyester and cotton blended yarns [15]. It was seen from their study that fabrics become thinner, lighter, more porous with higher thermal conductivity, air permeability and less thermal resistance with increasing ratio of recycled polyester.

Aim of this study is to investigate how cotton waste proportion effects yarn and fabric quality and propose an optimum blend ratio for effective waste management. For this purpose, OE-rotor spun yarns were produced at different proportions of virgin and waste cotton that was obtained from blow-room and single jersey knitted fabrics were also produced from all yarn types.

EXPERIMENTAL

In this study, Ne 22/1 OE-rotor yarns with α_e = 4.2 twist level were produced from 100% virgin cotton, 100% waste cotton and virgin-waste cotton blends (75%-25%,50%-50% and 25%-75%). Turkish cotton was used as virgin cotton and waste cotton was obtained from blowroom. HVI values of Turkish cotton are shown in table 1.

Table 1

HVI VALUES OF VIRGIN COTTON

Property	Value
Micronaire (mg/inch)	4.29
Maturity	0.88
Length (mm)	28.56
Uniformity (%)	82
Short Fibre Index (SFI)	8.0
Strength (cN/tex)	32.1
Elongation (%)	7.5

Ne 0.12 slivers were produced after two drawframe passages. In OE-rotor yarn production, rotor and opening roller revolutions were 95000 and 8600 rpm, respectively. Physical, structural and mechanical properties of these yarns were measured by Uster Tester 4 SX, Uster Zweigle Hairiness Tester 5, Uster Tensorapid 3 and Lawson Hemphill CTT.

At the second part of the study, single-jersey knitted fabrics were produced from OE-rotor yarns. Effects of waste cotton proportion on knitted fabric properties such as pilling, abrasion resistance, bursting strength and air permeability were also evaluated. Abrasion resistance and pilling tendency tests were performed using James H. Heal Nu-Martindale Abrasion and Pilling Tester. The weight losses (% and mg) and changes of thickness (% and mm) of the samples were calculated at the end of 15000 cycles to measure the abrasion resistance of the fabrics. Pilling tendencies of fabrics were determined in accordance with ISO 12945:2. In this method, ratings for tested samples were determined by comparing with standard photographs. "5" rating shows that there is no visible change on the surface of the fabric. Bursting strength tests were performed by James H. Heal TruBurst Bursting Strength Tester by using 7.3 cm^2 test area according to ASTM D3786/D3786M-13. Air permeability values of fabrics were measured in accordance with ISO 9237 using 20 cm^2 test area and 100 Pa test pressure.

RESULTS AND DISCUSSION

Evaluation of yarn properties

For a better understanding of how usage of waste cotton affects quality of OE-rotor spun yarns, properties such as unevenness, imperfections, hairiness, breaking force, breaking elongation and friction (yarn-to-yarn, yarn-to-metal and yarn-to-ceramic) were analysed statistically using ANOVA and confidence interval graphs at 95% confidence level.

Unevenness

Figure 1 shows the effect of waste cotton proportion on yarn unevenness. Unevenness and proportion of waste cotton show parallel increase due to the increasing amount of short fibre in the yarn. Moreover, there is no statistically significant difference amongst the blended yarns up to 75% waste content.

Table 2 shows the ANOVA results and table 3 shows the pairwise comparisons of the yarn types. As it is indicated in table 2, waste cotton usage is statistically significant on yarn unevenness (p=0.007). Moreover, results in table 3 shows that there is no

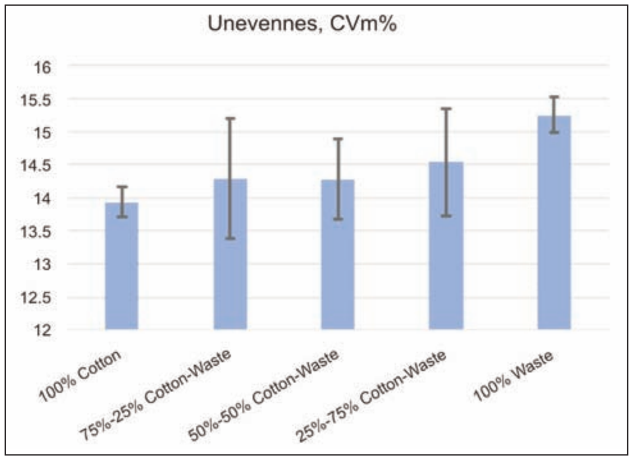

Fig. 1. Unevenness (*CVm%*) values and 95% confidence intervals

statistically significant difference between 100% cotton, 75%–25%, 50%–50% and 25%–75% cotton-waste yarns. Only 100% cotton waste yarns show statistically significant difference with other yarn types (p<0.05).

Imperfections

The effects of waste cotton proportion on imperfections are illustrated in figure 2. As it is seen from the figure, the number of thin places and thick places which are more likely related with drafting system do not show statistically significant difference regarding the proportion of waste cotton. Comparing neps values shows that 100% waste cotton have the greatest value and it might be related with amount of immature cotton fibres in yarn structure.

Table 2

ANOVA RESULTS FOR UNEVENNESS (CVM%) VALUES

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.847[a]	4	1.212	4.754	.007
Intercept	5225.460	1	5225.460	20499.087	.000
Yarn Type	***4.847***	***4***	***1.212***	***4.754***	***.007***
Error	5.098	20	.255		
Total	5235.405	25			
Corrected Total	9.945	24			

[a] R Squared = .487 (Adjusted R Squared = .385)

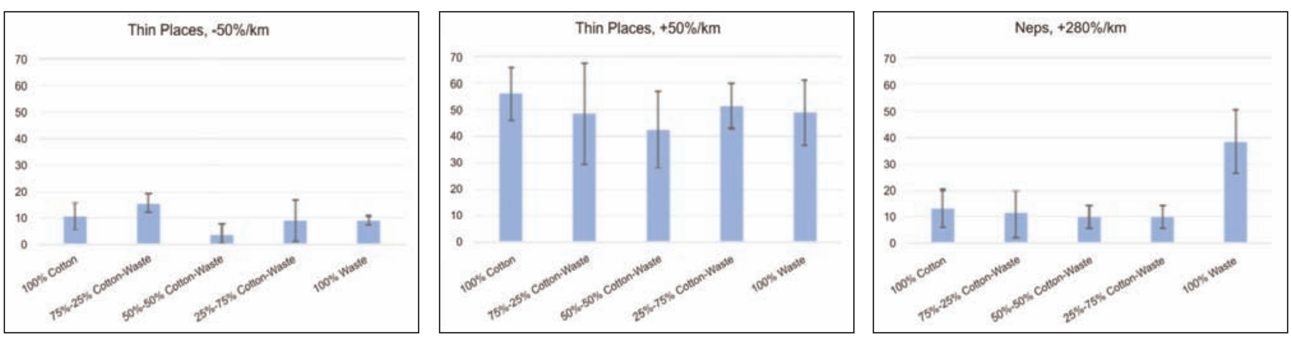

Fig. 2. Imperfections (thin places, thick places and neps) and 95% confidence intervals

Table 3

PAIRWISE COMPARISONS FOR UNEVENNESS (CVM%) VALUES						
(I) Raw	**(J) Raw Material**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**^{b}	**95% Confidence Interval for Difference**^{b}	
					Lower bound	Upper bound
%100 Cotton	%25 Waste	–0.370	0.319	0.260	–1.036	0.296
	%50 Waste	–0.350	0.319	0.286	–1.016	0.316
	%75 Waste	–0.596	0.319	0.077	–1.262	0.070
	%100 Waste	**–1.321***	0.319	**0.001**	–1.987	-0.655
%25 Waste	%100 Cotton	0.370	0.319	0.260	–0.296	1.036
	%50 Waste	0.020	0.319	0.951	–0.646	0.686
	%75 Waste	–0.226	0.319	0.487	–0.892	0.440
	%100 Waste	**–0.951***	0.319	**0.007**	–1.617	–0.285
%50 Waste	%100 Cotton	0.350	0.319	0.286	–0.316	1.016
	%25 Waste	–0.020	0.319	0.951	–0.686	0.646
	%75 Waste	–0.246	0.319	0.450	–0.912	0.420
	%100 Waste	**–0.971***	0.319	**0.006**	–1.637	–0.305
%75 Waste	%100 Cotton	0.596	0.319	0.077	–0.070	1.262
	%25 Waste	0.226	0.319	0.487	–0.440	0.892
	%50 Waste	0.246	0.319	0.450	–0.420	0.912
	%100 Waste	**–0.725***	0.319	**0.034**	–1.391	–0.059
%100 Waste	%100 Cotton	**1.321***	0.319	**0.001**	0.655	1.987
	%25 Waste	**0.951***	0.319	**0.007**	0.285	1.617
	%50 Waste	**0.971***	0.319	**0.006**	0.305	1.637
	%75 Waste	**0.725***	0.319	**0.034**	0.059	1.391
Based on estimated marginal means						
* The mean difference is significant at the .05 level						
^{b} Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments)						

Hairiness

Figure 3 demonstrates the hairiness values (H and S3) of OE-rotor yarns. As it is seen from the figure, H values increase but S3 values decrease while the waste cotton proportion increases. The main reason behind this situation should be the difference between measuring principles of H and S3 values. H value is total length of all protruding fibres along the yarn, while S3 value is the count of the fibres longer than 3 mm. The increasing ratio of waste cotton means more amount of shorter fibres take place around the yarn surface, so that H and S1+2 values increase. On the other hand, decreasing total staple length cause decreasing S3 value.

Breaking force and elongation

Figure 4 shows breaking force and breaking elongation values. 100% waste cotton yarns have the lowest breaking force and elongation values and it is

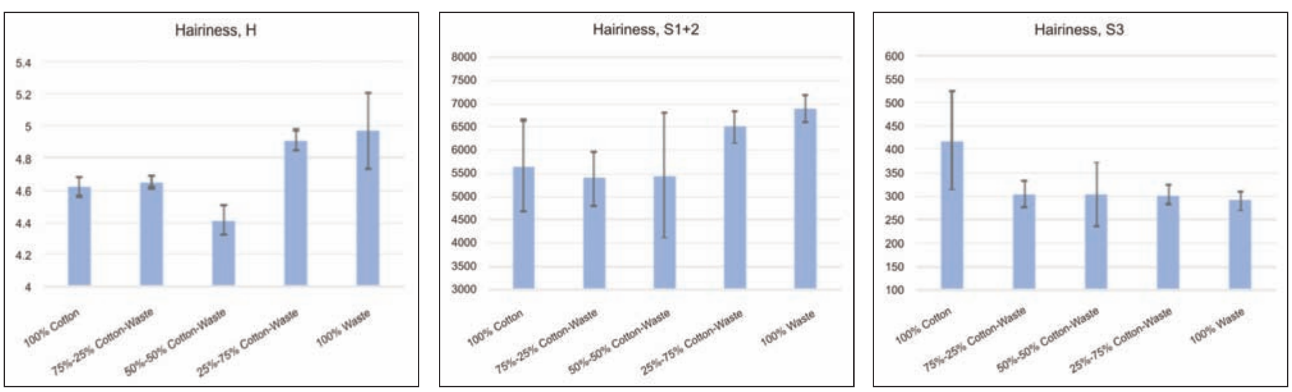

Fig. 3. Hairiness (*H*, *S1+2* and *S3*) values and 95% confidence intervals

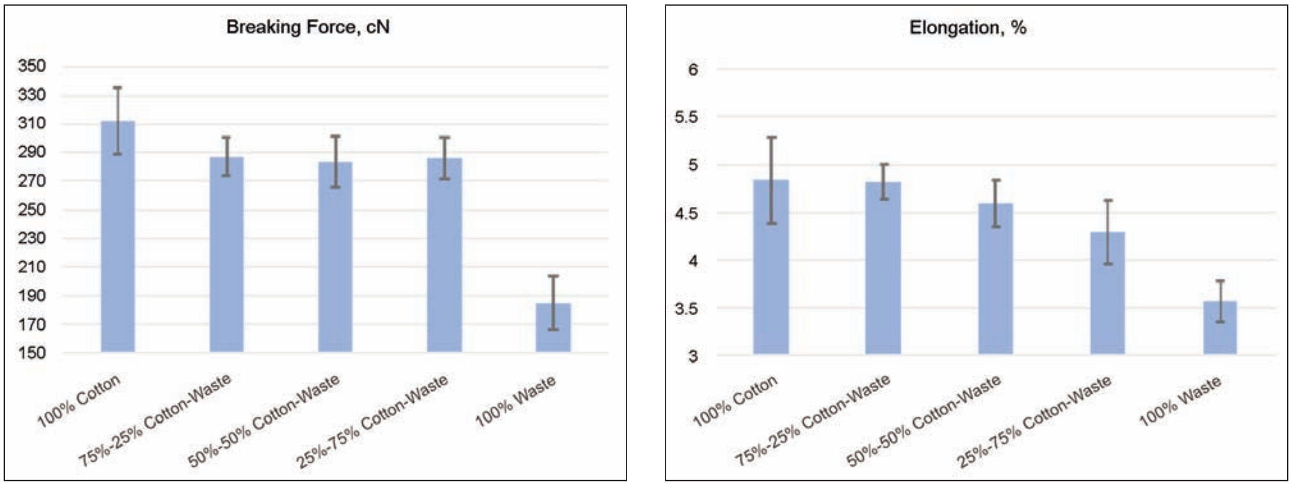

Fig. 4. Breaking force (cN) and breaking elongation (%) values and 95% confidence intervals

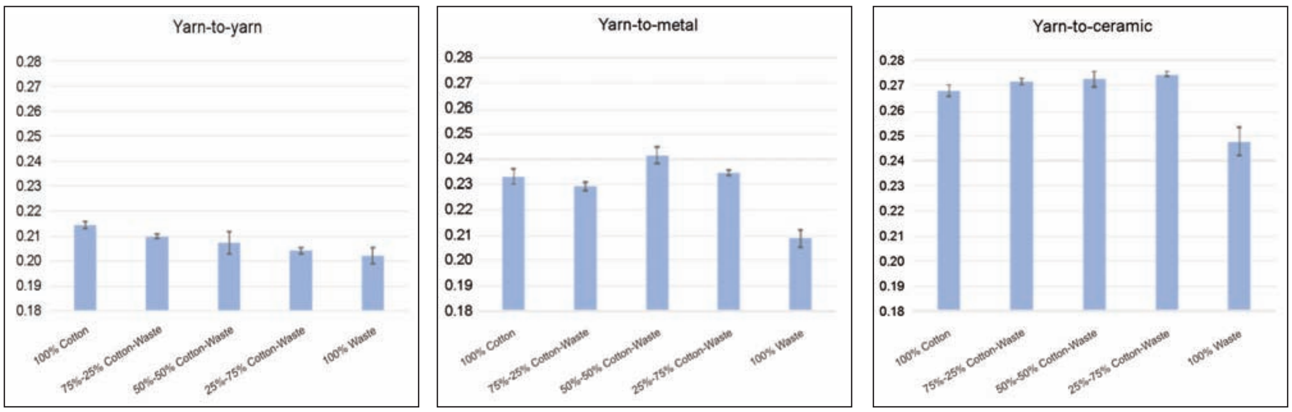

Fig. 5. Friction coefficients and 95% confidence intervals

related with increasing amount of short fibres create smaller contact surface.

Friction

Figure 5 shows yarn-to-yarn, yarn-to-metal, yarn-to-ceramic friction values. The most significant point illustrated by graphs that 100% waste cotton yarns have the lowest friction values for all surfaces (yarn, metal, ceramic). Friction coefficient is related with yarn hairiness. Because short fibres create a smooth surface, S1+2 values do not cause significant change on friction properties. On the other hand, due to longer fibres might cause stick-slip motion, increasing S3 values give rise to either friction coefficient or output tension.

Evaluation of knitted fabric properties

Pilling

Figure 6 illustrates pilling grades of fabrics. Pilling is related with protruding fibre ends, therefore 100% waste cotton fabrics have the worst pilling values between all fabric types. The other point of view, comparing fabrics produced from blended yarns show that up to 75% blended ratio does not cause significant change on pilling grade.

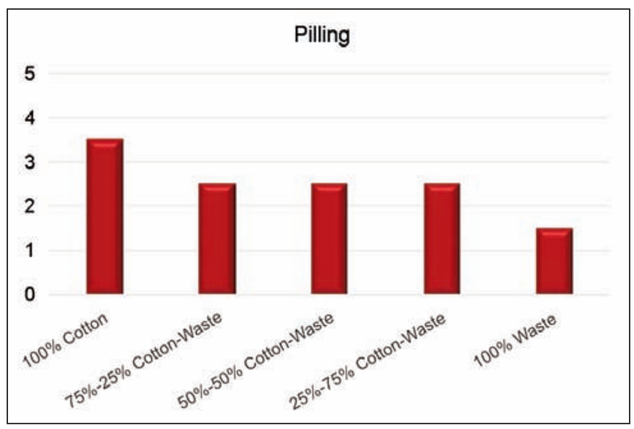

Fig. 6. Pilling ratings

Abrasion resistance

Figure 7 shows the abrasion resistance results in terms of weight loss (%) and change in fabric thickness (%). It can be obtained from the graphs that there is a negative tendency between the waste cotton ratio and abrasion resistance results. However, statistical analysis showed that waste cotton proportion has no significant effect on these values except 100% waste cotton fabrics. The most probable reason for this situation might be decreasing contact

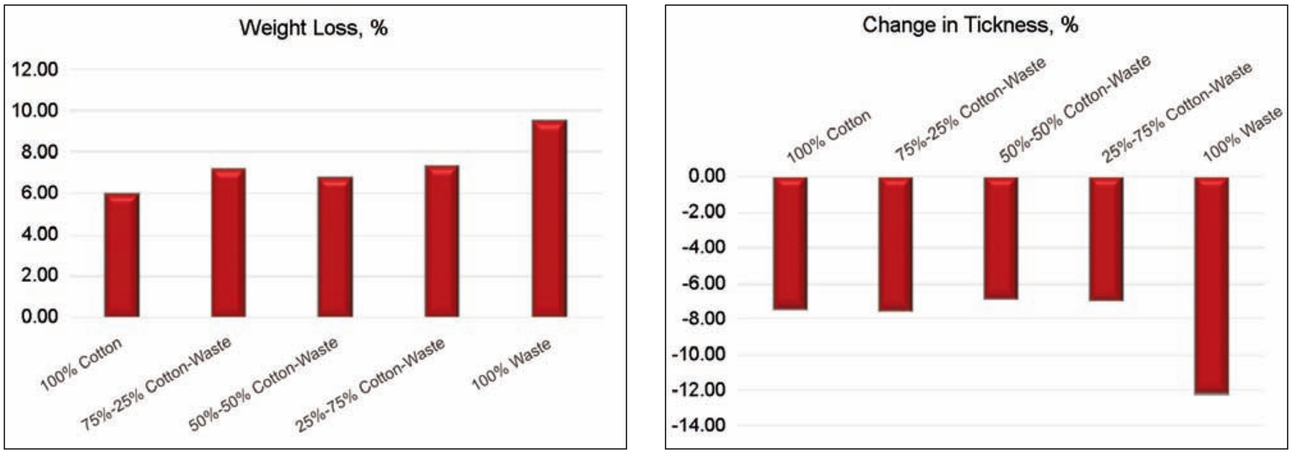

Fig. 7. Weight loss (%) and change in thickness (%) after 15000 cycles abrasion test

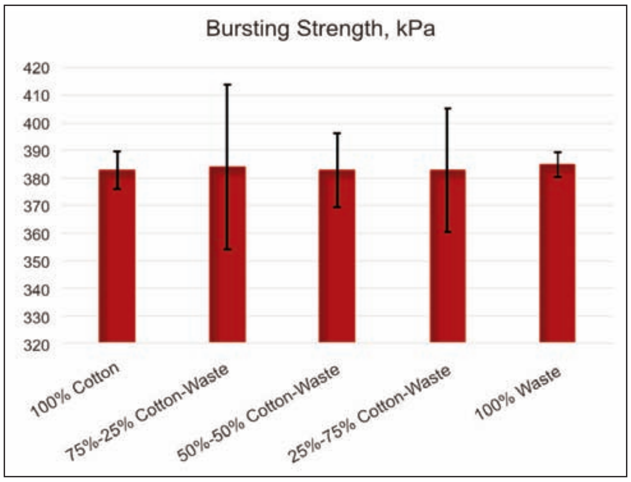

Fig. 8. Bursting strength (kPa) values and 95% confidence intervals

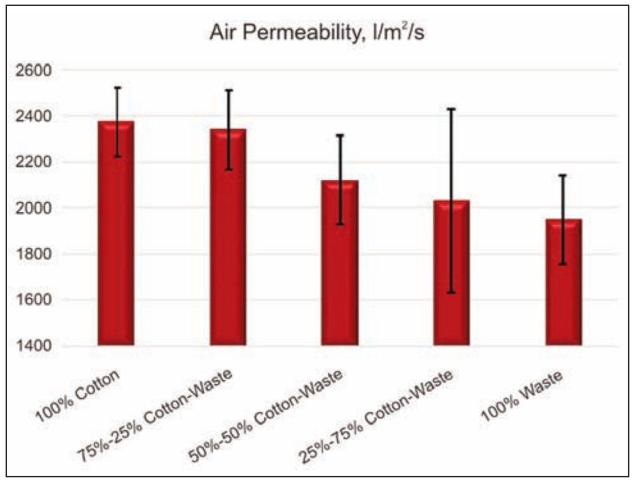

Fig. 9. Air permeability (l/m^2/s) values and 95% confidence intervals

area between the fibres that causes damage in yarn structure easily after the abrasive movements.

Bursting strength

Figure 8 illustrates the bursting strength (kPa) results for the fabrics produced from OE-rotor spun blended yarns. Statistical analysis showed that waste cotton proportion has no significant effect on fabric bursting strength.

Air permeability

Figure 9 shows air permeability values for the produced fabrics. It is clearly seen that air permeability decreases by increasing proportion of waste cotton usage. This situation explained by increasing amount of protruding fibre ends that decrease the fabric porosity.

CONCLUSIONS

In this study, it was aimed to analyse the effects of cotton waste usage on the properties of yarns and fabrics. For this purpose, OE-rotor yarns made of 100% virgin cotton, 100% waste cotton and virgin/waste cotton blends at different proportions (%25, %50, %75) were produced. Moreover, single jersey knitted fabrics were produced from all yarn types. Physical, structural and mechanical properties of all yarn types such as unevenness, imperfections, hairiness, breaking force, elongation, yarn-to-yarn friction, yarn-to-metal friction and yarn-to-ceramic friction were measured. Properties of single jersey knitted fabrics such as pilling, abrasion resistance, bursting strength, air permeability were also evaluated.

Results showed that, as it is expected, yarns and fabrics produced from 100% virgin cotton have superior results while yarns and fabrics produced from 100% waste cotton have inferior results in terms of all properties. With respect to the performance properties of yarns and fabrics produced from virgin/waste cotton blends show that using up to 75% of cotton waste does not cause statistically significant change on the most of yarn and fabric properties. Consequently, it can be concluded that for sustainable, more ecological and economic production process, waste cotton could be used up to 75% with minor performance reduction of yarn and fabric properties.

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