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# Effect of a Subjective Grading System and Blending with Polyester on Selected Wool and Yarn Characteristics of Subtropical Egyptian Barki Sheep

**DOI:** 10.5604/01.3001.0013.2897

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**Abstract**

*Seven-hundred kilograms of subtropical Barki wool was collected to study the effect of a subjective grading system and blending with polyester on selected wool and yarn characteristics. Wool was graded subjectively into coarse, fine and raw; then each grade was blended with 0%, 15%, 25%, 35% and 45% of polyester. Staple and yarn strengths were higher in both coarse and fine grades compared with raw wool. Staple elongation of the fine grade reached 3 times that of coarse grade and twice as much as raw grade. Also, in the 100% wool blend, yarn elongation of the fine grade was twice as much as both coarse and raw grades. The fine grade had the highest yarn friction, followed by other grades. Generally, adding polyester to coarse and fine grades led to an improved yarn strength compared with the raw grade. Adding 15% polyester caused the highest improvement among other percentages. Correlations among traits were also discussed.*

**Key words:** *wool, yarn, strength, elongation, friction, polyester blends.*

RESEARCH & DEVELOPMENT

## Introduction

Wool is one of the two naturally occurring raw materials used world-wide on a huge scale in the textile industry. Wool production in Egypt (about 7 thousand tons/year) represents a small contribution to the income of a sheep farmer, since wool is usually sold to manufacturers without grading. The international grading system used with carpet wool is based on medullation, crimp percentage and fibre length. In Egyptian wool, a mixed structure of both fine and coarse fibres can be found in the same fleece, which is the main reason for using subjective assessment instead of objective measurements for the classification of Egyptian wool. Moreover, using wool without grading with variation in medullation, kemp, crimp, diameters and length among fibres leads to producing poor quality yarns. While excellent uniformity is expressed when the coefficient of variation (CV) value becomes less than 20%, poor uniformity occurs with a CV over 27%. Al-Betar E [1] reported that CV % reached 43.8% in the fibre diameter along staples.

Recently, the expansion of the Egyptian wool industry has led to an increase in the demand for more good quality wool, which will improve the economic value of local wool. However, Guirgis RA [2] illustrated that sorting is guided by the requirements of each manufacturer and varies according to the type of yarn and product desired to be produced. Helal et al. [3] found that grading wool subjectively according to coarse (harshness) and fine wool leads to improved quality during industrial processes. Low durability during the yarn process of Egyptian wool is the main reason for rejecting Egyptian wool by manufacturers.

Polyester is one of the most important manmade fibres used in textile industries to improve durability and uniformity. The present article involves studying the effect of grading wool subjectively into coarse, fine and without classification as well as blending these grades with various percentages of polyester (0%, 15%, 25%, 35% and 45%) on the characteristics of wool and yarn obtained from wool/polyester blends.

## Materials and methods

### Experimental design

In the present study, 700 kg of Barki wool was collected from the Mariout Research Station, belonging to the Desert Research Center, Egypt, during the shearing season (2015). The wool was graded subjectively (with visual assessment on a sorting table) into three grades: G1 (coarse wool), G2 (fine wool) and G3 (not sorted) or a control group, then each grade after scouring and carding processes was blended with the following percentages of polyester; Blend 1: 0%, Blend 2: 15%, Blend 3: 25%, Blend 4: 35%, and Blend 5: 45%. The polyester used in the present

*Table 1. Least square means ± standard errors of characteristics of different wool grades studied.* ***Note:*** *Values followed by different superscript letters within the same row are significantly different (p < 0.05). FD: fibre diameter, PF: Prickle factor, MF: Medullated fibres, Cr: staple crimps, POBL: point of break as length, SS: staple strength; EL: staple elongation.*

| Grades traits | Coarse wool (G1) | Fine wool (G2) | Raw wool (G3) |
|---|---|---|---|
| FD, μm | $36.2 \pm 0.83^a$ | $26.2 \pm 0.83^c$ | $31.2 \pm 0.83^b$ |
| PF, % | $52.4 \pm 2.53^a$ | $22.7 \pm 2.53^b$ | $47.5 \pm 2.53^a$ |
| MF, % | $27.5 \pm 1.29^a$ | $2.9 \pm 1.29^c$ | $21.0 \pm 1.29^b$ |
| CR, per cm | $0.42 \pm 0.04^b$ | $0.67 \pm 0.04^a$ | $0.51 \pm 0.04^b$ |
| POBL, % | $40.3 \pm 2.10^b$ | $36.1 \pm 2.10^b$ | $60.8 \pm 2.10^a$ |
| SS, N/Ktex | $37.1 \pm 1.55^a$ | $33.0 \pm 1.55^{ab}$ | $30.7 \pm 1.55^b$ |
| STL, cm | $10.7 \pm 0.42^a$ | $7.7 \pm 0.42^b$ | $9.9 \pm 0.42^a$ |
| EL, % | $8.7 \pm 2.01^b$ | $25.8 \pm 2.01^a$ | $13.2 \pm 2.01^b$ |

study had a length of 80 mm, 3.3 decitex [dtex] for fineness.

### Measured traits

Wool samples which represent each grade with 0% polyester were used to measure the following characteristics:

- Staple length (STL): The average lengths of twenty staples were taken randomly from each wool grade. STL was measured against a millimeter ruler fixed on a black velvet board without any stretching.
- Number of staple crimps/cm (CR): The number of crimps along each staple was counted without stretching, and the average staple length was calculated and used to obtain the number of crimps per one centimeter.
- Fibre diameter (FD): FD was measured in microns using an image analyser (LEICA Q 500 MC, Germany) with a 4/0 lens. Five hundred fibres were mounted in liquid paraffin oil and spread on a microscopic slide. Care was taken not to measure a single fibre twice.
- Medullated fibre percentage (MF%): MF% was measured under a microscope as the percentage of medullated fibres from the corresponding total fibres measured in each sample.
- Prickle factor (PF): PF was estimated from the fibre diameter distribution of each sample as the percentage of fibres with diameters exceeding 30μm from the total number of fibres.
- Staple strength (SS), point of break (POB) and elongation (EL): SS indicates the force required to break the staple in Newtons, and this value is divided by the thickness of the staple (Newton in kilotex, N/Ktex). Twenty staples were taken at random from each grade and prepared for measuring their strength using an Agritest Staple Breaker (New Zealand) [4]. The length of the top and base of each broken staple in the strength test were measured and then collected. The increase in the last length as a proportion of the original staple length before testing was used to calculate the EL percentage. The length of the top as a percentage from the length of both the top and base of the same staple was recorded as the POBL.

All yarns from the blends within the grades had an average yarn count (length in meters per 1 gram mass) of 124.69 tex and yarn twisting (yarns were played at a nominal level of 243 turns per meter ((TPM)) in the S direction). Yarns were prepared for the following measurements:

- Yarn strength (YS): RKM is the abbreviation of "Breaking-kilometer", which can be expressed by the breaking force of yarn per kilometer at which yarn will break of its own weight. This is equivalent to the breaking load in cN/tex. Twenty five measurements for each Blend within each grade (15 samples) were performed for a 50cm length of yarn extended until the thread breaks. An Uster 3 tester (Zellweger Uster, Switzerland) was used to measure YS.
- Yarn elongation (YE): Twenty five observations for each grading blend processed were recorded for yarn elongation when the force at the breaking point was reached. The Uster 3 tester (Zellweger Uster) was used to measure YE.
- Yarn friction (YF): yarn samples were used in this test to examine the friction for a standard length of yarns (Revs) using Friction SDL Atlas apparatus.

### Data analysis

Data were statistically analysed using analysis of variance (ANOVA) with a General Linear Model (GLM) of SAS [5] and differences between means were tested using Duncan's multiple range test [6]. The significance level was set at $P < 0.05$. Correlations were also calculated using data from the wool grades and the first blend, which contains 100% pure wool.

## Results and discussions

***Table 1*** illustrates that the fine wool grade had significant differences in all traits studied, except for the point of break (POBL) and staple strength (SS), as compared with the other two grades. No significant differences were found between both the coarse and control wool grades for Prickle factor (PF), Crimp % (CR), staple length (STL) and elongation (EL), while the coarse grade had significantly higher values in FD, MF, POBL and SS compared with the control grade. The fibre diameter is responsible for approximately 75% of the total price of raw wool [7-9]. In the present study, fibre diameter was found to be 10 μm higher in the coarse grade compared with the fine wool grade. Fine wool can be processed into yarns which are aptly suited to high value apparel textile end uses [10, 11]. Also, the coarse grade had a 30% higher PF % compared with the fine grade. The same results were found by Helal A [12] i.e. coarse wool was higher in the fibre diameter, medullation fibre percentage and prickle factor than fine wool fibres. Also, the prickle factor is a sensation where coarseness causes sufficient distortion of the skin to excite some skin receptors, as opposed to that caused by fine fibres [13]. In the same context, with a force greater than 75 mg/cm$^2$ upon the wearer's skin [14], nerve and pain receptors are stimulated and the formation of an irritation or prickling sensation is commonplace [15, 16]. Moreover, a percentage of fibres greater than 30 micrometers is a useful predictor of the prickle response [17]. The same results were found by El-Gabbas HM [18], who reported that a harsher wool grade was found to be associated with a high prickle factor. In the same context, Dolling et al. [19] and Hansford KA [20] reported that the prickle factor had a high correlation with the mean fibre diameter.

In the present study, MF% increased 9.5 times for the coarse grade compared with the fine one, which was also associated with the increase in FD and PF. Helal A [21] showed the same trend i.e. the medullated fibre percentage was found to be associated with both the fibre diameter and prickle factor. The number of crimps in staple was found to be higher in the fine grade and lower in the coarse grade compared with the control wool grade.

Highly significant and positive correlations were found (***Table 2***) between FD and both PF (r = 0.90) and MF% (r = 0.54). The same result was found by Hansford KA [20] and Whiteley and Thompson [22], who illustrated that PF had a high correlation with the mean fibre diameter. Also, a higher level of coarse fibre content was found to be associated with more prickly fabric [19]. Moreover, significant and positive correlation coefficients of FD with the medullated fibre percentage were reported in [23]. In the present study, a highly significant and negative correlation was found between STL and CR (r = -0.55). The same result was obtained by Gadallah AAI [24]. Also, CR had a significant and positive correlation with SS. Coarse fibres contain a high percentage of medulla, decreasing the ability of the fibre to be stretched, which might explain the negative and significant correlation between MF and EL percentages. A high correlation was found between the staple strength and yarn strength [21, 25]. On the other hand, Gadallah AAI [24] found no significant correlation between staple and yarn strengths, consistent with the result of the present study, which could refer to the presence of polyester in yarns when the staple is 100% wool. Moreover, many factors affect yarn strength during yarn processing like the twisting speed, number of twists, the presence of weak points etc., while no such factors exist for the staple strength.

According to ***Table 3***, yarn elongation (YEL) of the fine wool grade was twice as much as both the coarse and control wool grades in the blend with 100% wool. In accordance with the results obtained, Helal et al. [26] illustrated that Yarn elongation tended to increase with a decrease in fibre diameter, which might be related to the increase in fibre crimps. In the second, third and fourth blends (15%, 25% and 35% of polyester, respectively), fine wool yarns were significantly higher in YEL than the other grades. While yarns of coarse grade had the same elongation as the control wool grade (in the first blend), coarse wool yarn elongation increased 3 times with the second blend compared with that of yarns from the control wool grade. In the 25% and 35% polyester blends, the increases were insignificant for yarns from coarse and the control wool grades. The worst performance of yarn elongation among the wool grades was found for the control wool grade, which reflects the importance of grading to improve elongation at yarn stage of industrial processes. The overall mean of yarn elongation among the blends, regardless of the wool grade, indicated that no differences were found when increasing polyester from 25% (blend 3) to 35% (blend 4). Also, the highest increase in yarn elongation happened when adding 15% polyester (blend 2), where the YEL increased from 7.7%, 14.7% and 7.6% in blend (1) to 23.6%, 25.4% and 18.0% in blend (2) for the coarse, fine and control grades, respectively (***Table 3***). Thus, it could be concluded that improving wool yarn elongation could be done just by adding 15% of polyester, as compared with the improvement in the other blends. Yarn from fine wool grade had the highest values of YEL followed by the coarse grade, and finally the control wool grade.

Yarn strength (YS) represented by the RKM, which means the breaking force of yarn per kilometer (at which the yarn will break of its own weight). In blend (1), with 0% polyester, the fine grade had the highest value, followed by the coarse grade and then by the control wool grade (7.0, 5.4 and 4.9 RKM, respectively). Similarly, Helal et al. [26] found that Yarn tenacity decreased with an increase in the fibre diameter and staple length. Moreover, Mahar TJ [27] concludes that a finer fibre diameter is associated with better processing performance and yarn quality. In the present study, with 15% polyester (Blend 2), the difference between the coarse and control wool grades was not significant, while the fine grade still had the highest value, with significant differences compared with the other grades (***Table 4***). The differences among grade values reached the minimum in blend 3, with 25% polyester. Blends 4 and 5 reflect significant differences among grades, with the superiority of the fine grade, followed by the coarse and control wool grades. Regardless of the effect of grades, YS varies significantly among the blends. Also, regardless of the effect of the blends, YS varies significantly among the grades studied. Generally, adding polyester to both coarse and fine grades tended to improve YS as compared with

***Table 2.*** *Correlation coefficients among the traits of wool grades and yarn blends studied.* ***Note:*** ** = significant at $P < 0.05$; ** = significant at $P < 0.01$. FD: fibre diameter, PF: Prickle factor, MF%: Medullated fibres percentage, Cr: staple crimp, POBL: point of break as length, STL: Staple length, SS: staple strength, EL: staple elongation %, YEL: yarn elongation, YS: yarn strength and FR: yarn friction.*

| Traits | PF | MF | CR | POBL | El | STL | SS | YEL | YS | YFR |
|---|---|---|---|---|---|---|---|---|---|---|
| FD, µm | 0.90** | 0.54** | 0.01 | -0.01 | -0.02 | 0.06 | -0.06 | -0.49** | -0.39* | -0.57** |
| PF, % | | 0.51** | -0.06 | 0.08 | 0.05 | 0.15 | -0.05 | -0.40* | -0.35* | -0.49** |
| MF, % | | | 0.15 | 0.30 | -0.38* | -0.06 | 0.21 | -0.61** | -0.74** | -0.68** |
| CR, per cm | | | | -0.11 | -0.09 | -0.55** | 0.41* | -0.26 | -0.17 | -0.14 |
| POBL, % | | | | | -0.03 | 0.03 | 0.28 | -0.48** | -0.63** | -0.35* |
| EL, % | | | | | | -0.19 | -0.21 | 0.33 | 0.36* | 0.39* |
| STL, cm | | | | | | | -0.11 | 0.05 | -0.01 | -0.04 |
| SS, N/Ktex | | | | | | | | -0.21 | -0.25 | -0.09 |
| YEL, % | | | | | | | | | 0.91** | 0.89** |
| YS RKM | | | | | | | | | | 0.82** |

***Table 3.*** *Least square means ± standard errors of yarn elongation of different blends and grades studied.* ***Note:*** *Values followed by different small superscrips letters within the same row are significantly different ($p < 0.05$). Values followed by different capital subscript letters within the same columns are significantly different ($p < 0.05$).*

| Grades blends | Coarse | Fine | Control | Overall mean |
|---|---|---|---|---|
| 1(0% polyester) | 7.7 ± 0.43$^{bD}$ | 14.7 ± 0.43$^{aC}$ | 7.6 ± 0.43$^{bD}$ | 10.0 ± 0.23$^{E}$ |
| 2(15% polyester) | 23.6 ± 0.51$^{bC}$ | 25.4 ± 0.51$^{aB}$ | 18.0 ± 0.51$^{cC}$ | 22.3 ± 0.23$^{D}$ |
| 3(25% polyester) | 27.5 ± 0.45$^{bB}$ | 28.9 ± 0.45$^{aA}$ | 26.0 ± 0.45$^{cB}$ | 27.5 ± 0.23$^{B}$ |
| 4(35% polyester) | 28.6 ± 0.26$^{bAB}$ | 29.8 ± 0.26$^{aA}$ | 25.2 ± 0.26$^{cB}$ | 27.9 ± 0.23$^{B}$ |
| 5(45% polyester) | 29.8 ± 0.33$^{aA}$ | 29.9 ± 0.33$^{aA}$ | 28.1 ± 0.33$^{bA}$ | 29.3 ± 0.23$^{A}$ |
| Overall mean | 23.434 ± 0.18$^{b}$ | 25.762 ± 0.18$^{a}$ | 21.006 ± 0.18$^{c}$ | |

*Table 4*. *Least square means ± standard errors of yarn strength of different blends and grades studied.* ***Note:*** *Values followed by different small superscript letters within the same row are significantly different ($p < 0.05$). Values followed by different capital subscript letters within the same columns are significantly different ($p < 0.05$).*

| Grades blends | Coarse | Fine | Control | Overall mean |
|---|---|---|---|---|
| 1(0% polyester) | $5.3 \pm 0.11^{bE}$ | $6.9 \pm 0.11^{aE}$ | $4.8 \pm 0.11^{cE}$ | $5.7 \pm 0.12^{E}$ |
| 2(15% polyester) | $8.3 \pm 0.20^{bD}$ | $9.3 \pm 0.20^{aD}$ | $8.5 \pm 0.20^{bD}$ | $8.7 \pm 0.12^{D}$ |
| 3(25% polyester) | $13.6 \pm 0.32^{abC}$ | $14.03 \pm 0.32^{aC}$ | $12.8 \pm 0.32^{bB}$ | $13.5 \pm 0.12^{C}$ |
| 4(35% polyester) | $15.5 \pm 0.17^{bB}$ | $16.9 \pm 0.17^{aB}$ | $10.6 \pm 0.17^{cC}$ | $14.3 \pm 0.12^{B}$ |
| 5(45% polyester) | $17.1 \pm 0.21^{bA}$ | $18.6 \pm 0.21^{aA}$ | $15.3 \pm 0.21^{cA}$ | $17.0 \pm 0.12^{A}$ |
| Overall mean | $12.0 \pm 0.09^{b}$ | $13.2 \pm 0.09^{a}$ | $10.4 \pm 0.09^{c}$ | |

*Table 5*. *Least square means ± standard errors of yarn friction of different blends and grades studied.* ***Note:*** *Values followed by different small superscript letters within the same row are significantly different ($p < 0.05$). Values followed by different capital subscript letters within the same columns are significantly different ($p < 0.05$).*

| Grades blends | Coarse | Fine | Control | Overall mean |
|---|---|---|---|---|
| 1(0% polyester) | $30.1 \pm 1.12^{cD}$ | $58.5 \pm 1.12^{aD}$ | $34.7 \pm 1.12^{bE}$ | $41.1 \pm 2.19^{E}$ |
| 2(15% polyester) | $54.4 \pm 2.99^{bC}$ | $65.7 \pm 2.99^{aD}$ | $60.0 \pm 2.99^{abD}$ | $60.0 \pm 2.19^{D}$ |
| 3(25% polyester) | $74.4 \pm 2.76^{bB}$ | $126.8 \pm 2.76^{aC}$ | $72.6 \pm 2.76^{bC}$ | $91.3 \pm 2.19^{C}$ |
| 4(35% polyester) | $107.8 \pm 5.18^{cA}$ | $152.1 \pm 5.18^{aB}$ | $126.8 \pm 5.18^{bB}$ | $128.9 \pm 2.19^{B}$ |
| 5(45% polyester) | $107.7 \pm 4.82^{bA}$ | $172.5 \pm 4.82^{aA}$ | $164.1 \pm 4.82^{aA}$ | $148.1 \pm 2.19^{A}$ |
| Overall mean | $74.9 \pm 1.70^{c}$ | $115.1 \pm 1.70^{a}$ | $91.6 \pm 1.70^{b}$ | |

the control wool grade. Both the staple strength (***Table 1***) and yarn strength (in 100% wool blend, ***Table 4***) were higher in both coarse and fine grades compared with the control wool grade. Regardless of the variation in SS among all grades, the SS of all grades has good wool strength according to many authors, who reported that wool was tender when the staple strength was less than 25 N/ktex [28-30]. The elongation percentage of the fine grade reached 3 times that of the coarse grade and twice that of the control wool grade.

Abrasion is the physical destruction of fibres, yarns, and fabrics resulting from the rubbing of a textile surface over another surface [31]. Thus, with an increase in the level of abrasion needed to break the yarn, the friction decreased as a yarn characteristic. Also, Yarn friction (YFR) is a very important factor in all phases of knitting. Yarn friction is affected by many factors such as surface smoothness, yarn twist, hardness, moisture content, yarn lubricants, yarn tension and yarn structure. Moreover, Helal et al. [26] reported that friction tended to increase with an increase in fibre diameter. Results in ***Table 5*** showed the same result, where in the 100% wool blend, yarns from fine wool grade had almost the twice value of YFR as the control and coarse grades (58.5, 34.7 and 30.1, respectively). Blending polyester in all the percentages studied and all wool grades improved YFR, which is in agreement with the results reported by Manich et al. [32] and Saville BP [33]. In blends 2 and 3 (15 and 25% of polyester), no significant differences were found between the coarse and control wool grades, while they were significant in the other blends. With an increasing polyester percentage in the blends, YFR increased, varying varied among the wool grades. In the coarse wool grade, YFR was found to be the same when the polyester was increased from 35% to 45%, while for the fine grade it increased from 152.1 to 172.5 and for the control wool grade – from 126.8 to 164.1. Only in blend 2 were the differences in YFR values among the different grades minimum (65.7, 60.0 and 54.4) for the fine, control and coarse wool grades, respectively, compared with the other blends. Usually, the control wool grade was higher than the coarse grade in all blends studied, except for blend 3 (25% polyester), which might be related to the scale structure of coarse wool fibres being harsher than that of the control one. Regardless of the effect of blending, the fine grade had the highest yarn friction (115.1), followed by the control grade (91.6), and finally the coarse grade (74.9). Also, regardless of the effect of grading, yarn friction increased with an increase in the polyester percentage in the blend. However, blending fibres with polyester led to improved yarn properties [32-34].

It is worthwhile mentioning that fibre diameter (FD) had a negative but highly significant correlation with both yarn elongation ($r = -0.49$) and yarn friction ($r = -0.57$) as well as a significant negative correlation with YS ($r = -0.39$). Fibre diameter in wool is generally the limiting factor governing yarn strength [18, 35, 36]. Moreover, many authors found that the coefficient of the variation in fibre diameter had a measurable effect on yarn tenacity [37, 38]. Both PF and MF% followed the same trend of fibre diameter but had a negative and significant correlation with YEL, YS and YFR ($R = -0.4$, $-0.35$ and $-0.49$ for PF and $R = -0.61$, $-0.74$ and $-0.68$, respectively), as shown in ***Table 2***. All yarn traits studied had a highly significant positive correlation with each other.

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❑ ***Received 27.04.2018 Reviewed 11.03.2019***