Effect of Wool Handle Grade of Barki Sheep Wool on Its Manufacturing Characteristics

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ABSTRACT

Egyptian Barki sheep's wool was subjectively graded and sorted according to handle grade of harshness trait into three categories: soft wool (SW), medium wool (MW) and harsh wool (HW) in addition to the fourth category as a wool left without grading or sorting for comparison; non-sorted wool (NW). Each category was separately mechanically manufactured into woolen yarns of nominal count 6/2 metric. Representative samples of raw wool and yarns after spinning were taken from each category for characteristics measurements. Sorting system significantly affected (P<0.05) staple length and highly significant (P<0.01) affected staple crimps frequency, staple strength, loose wool bulk and resilience, fiber diameter, fine fibers percentage, coarse fibers percentage, hetero-type fibers percentage, kemp fibers percentage, medullated fibers percentage, medullation index and prickle factors. Sorting system had a highly significant (P<0.01) effects on yarn count, yarn twisting, yarn strength, yarn elongation, yarn tenacity, coefficient of variation of yarn mass (CVm%) and thin places. The differences in irregularity of the yarn mass (Um%) were significant (P<0.05). Correlations among wool traits and among yarn characteristics were estimated. The results indicated the importance of separating the soft handle wool part of Barki fleeces which may be used in apparel textiles blends. Such procedure will partially save foreign currency utilized to import fine wool, as well as increased the uniformity of the rest of fleeces and their suitability to carpet manufacture that required harsher wool fibers. Therefore, breeders' incomes will increase due to the increase in price of wool. This would result in increased the interest of sheep breeding and wool improvement.

Key words: Barki sheep, Fleece Grading, Handle grade, Harshness, Subjective assessment, Wool Sorting, Yarn manufacture.

INTRODUCTION

The total number of sheep population in Egypt was about 5.1 million heads in 2021, and they produce about 11 217 metric tons of greasy fleece wool annually (FAOSTAT, 2021). Barki sheep breed is one of the three major Egyptian sheep breeds which represent about 8.5% of the total number of sheep population in the country and they predominant distributed at the northwestern coastal zone (NWCZ) of Egypt (Sallam, 2019). The NWCZ of Egypt produces about 15% of the total amount of wool production of the country (Galal *et al.*, 2005).

In Egypt, Wool manufacturer accepted to pay more price about two folds for Barki wool compared with other Egyptian breeds. Wool is considered the second main product of Barki sheep, the dominant breed at NWCZ of Egypt, which contributes to the economic value of that breed of sheep. Barki sheep which classed as a carpet wool type had high variability in their fleece wool characteristics (Guirgis, 1973a and Hamada, 1981). Harsh wool is the common wool type in the desert sheep breeds. There are a high variability among animals in positions on animal body, staples within position and fibers within staple (Helal, 2010). Almost all wool locally produced is usually sold without grading through local merchants. The present system of marketing is disadvantageous to both producer and manufacturer. In the absence of knowledge of the quality of the clip, the wool producer cannot use the sorting information as a guide to his breed improvement (Guirgis, 1995). Clip preparation, as the first step prior to processing, and would promote marketing of wool, hence better prices and income for wool producers. Handle is the most important wool character at the point of sale (EL-Gabbas, 1993). Subjective handle grade of Barki wool was 2.89 which considered as medium handle grade with significant effects of season, body position and animal (El-Gabbas, 1993 and El-Gabbas, 1999). Therefore, El-Gabbas and El-Wakil (2016) stated that Barki wool had slightly soft handle (3.20). Raw wool specification serves as a link between the wool production and wool processing sectors (Hansford, 1997). Abdelaziz and El-Gabbas (1999) indicated that carpet manufacturers could attain processing and economic advantages by using high bulk and harsher wools which would help to increase the utility of the local wool once graded in the carpet industry and in turn attain higher return for carpet manufacturers and sheep breeders. Therefore, the object of the current study was to find suitable and simple procedure to sort out Barki wool according to handle grade or softness into different classes and to process them into yarns for the different uses in the local industry. In addition to investigate the potentiality of separate a fine wool part of Barki sheep fleeces to provide wool brokers and textile

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manufactories by good wool materials and good information about wool of the local Barki sheep breed.

MATERIALS AND METHODS

Wool grading and sorting procedure:

Barki fleece wool (skirted wool) was subjectively graded and sorted according to handle grade (El-Gabbas, 1993) into three grades; soft wool (**SW**), (wool of high handle grades: grade5; extremely soft wool and grade 4; clearly softer wool than average), medium wool (**MW**), (wool of moderate handle grades: grade 3; wool of average handle) and harsh wool (**HW**), (wool of low handle grades: grade 2; slight harsher wool than average and grade 1; extremely hairy wool). The fourth grade was the control, wool without any grading or sorting for comparison; (non-sorted wool, (**NW**)).

Raw Wool Measurements:

About 30 staples were taken at random from each grade to objective wool measurements. For measuring staple length (STL), each staple was measured against a millimeter ruler on a black velvet covered board. Just enough tension was applied to straighten the staple without stretching it as described by Booth (1964). Wool staple lengths were measured from the base of the staple up to the base of the triangle forming by the ends of the fibers at the tip of the staple. Staple crimp frequency (CR) was measured according to Chapman (1960). All crimps along the staple were count using a crimp gauge with teeth that were fitted to the peaks of the crimps. Number of crimps per cm or crimp frequency was calculated by dividing the total length of staple by the number of crimps along the staple. For medullated fibers percentage (Med%), a suitable sub-sample was separated from each sample, placed on a black velvet board and split into the different fiber types (Guirgis, 1967) i.e. fine (non-medullated), coarse (medullated), heterotype (part kemp and part wool) and kemp (more than 85% of cross sectional area as medulla). The fiber from each type was counted and then the percentages were calculated. The total number of fibers taken in each grade was about 6000 fibers. Benzene test was used (Ryder and Stephenson, 1968). Medullated fibers could be seen when immersed in benzene whereas fine fibers are invisible. Staple strength (SS) was measured by Agritest staple breaker (Agritest Pty. Ltd.) after trimmed the bundles by cutting its tip. The SS was calculated and recorded in terms of Newton / Kilotex (Heuer, 1979 and Caffin, 1980). Point of break by length (POBl) was calculated by measuring the length of top portion after staple cutting and divided it by the Sumiton length of both top and bottom portions. Point of break by weight (POBw) was also calculated by estimating the weight of tip portion and divided it by the Sumiton weight of both top and bottom portions. Elongation (EL), the increase in staple length in proportion to the original length was measured. Point of break by weight and by length (the weight and length of top in proportion to the weight and length of both top and base) were calculated at the time of measuring staple strength. Loose wool bulk (BUL) and resilience (RES) was measured using WRONZ loose wool Bulkometer (Dunlop *et al.*, 1974). Fiber diameter (FD) was measured using Image analyzer (LEICA Q 500 MC) with lens 4/0.12. A section of 0.2 mm in length was cut by a hand-microtome at a level of 2 cm from the base of the staples of each sample. These cuttings were put on a microscope slide with 2-3 drops of paraffin oil and covered with a slide cover. About five hundred fibers chosen at random were measured from each sample. The mean of fiber diameters (FD) together with the standard deviation of fiber diameter (SDFD) were calculated for each sample. While measuring fiber diameter, medullated fibers percentage (fiber contains medulla) as well as prickle factor (the percentage of fibers had greater than 30 μm in diameter) were calculated and recorded for each sample. Prickle factor (PF) was estimated from the fiber diameter distribution in each sample as the percentage of fibers had diameters more than 30μm from the total fibers number (El-Gabbas, 1998).

To obtain the medullation index (MI) adapted by Guirgis (1973b) for whole fiber types of adult fleeces, the percentage of each type of fiber was multiplied by the class number and the sum was divided by 10 as follows:

$$\text{Medullation index} = \frac{1}{10}\sum_{i=1}^{4} iPi,$$

Where i = 1, 2, 3 and 4 as scores (class number) for fine, coarse, heterotype and kemp, respectively, P_i is the percentage of i^{th} class.

Processing of wool into yarns:

Wool of each grade was separately blended with nylon 6; 85% wool: 15% nylon and processed by woolen spinning system to produce woolen yarns of 6/1 metric counts at the Arab Carpet and Upholstery Company.

Measurement of some yarn characteristics:

Random samples of yarns of each category were tested as follows:

Yarn count (YC) (metric) = yarn length (m) / yarns weight (g).

Yarn twisting: The single yarns of each class were spun at nominal twist level of 280 turn per meter (TPM) on “S” direction. The single yarns were plied at nominal level of 170 (TPM) on “Z” direction.

Yarn strength (YS), tenacity (Rkm) and elongation (YEL): The maximum breaking force was expressed in kilogram force (Kg). USTER TENSORAPID 3 (Zellweger Uster) was used to measure yarn strength, tenacity and elongation.

Yarn evenness: USTER TESTERS 3 (Zellweger Uster) was used to measure yarn evenness. The print out report was contained the following abbreviation:

Um: Irregularity U of the mass with a cut length of approximately 1cm.

CVm: Coefficient of variation of mass with a cut length of approximately 1cm.

Thin places (-50%): Number of mass reduction of 50% or more in a yarn with respect to the mean value.

Thick places (+50%): Number of mass increase of 50% or more in a yarn with respect to the mean value.

Statistical analysis:

Data were statistically analyzed using one way analysis of variance using General Linear model (GLM) procedure (SAS, 2000) to test the sources of variation for the dependent variable (grades). Differences between means were tested using Duncan's multiple range test (Duncan, 1955). Simple correlation coefficients among various traits were also calculated and tested. The following model was used to assess the significance of associations:

$Y_{ij} = \mu + G_i + e_{ij}$

Where, Yij is the trait of interest; μ is the overall mean; G_i is the fixed effect of the i^{th} grade (4 grades, SW, MW, HW and NW) and e_{ij} is the random error. The random error was assumed to be normally distributed with a mean equals zero, and variance equals δ^2e.

RESULTS AND DISCUSSION

A. Raw wool Characteristics:

Table (1) shows that subjective grading and sorting system according to harshness or handle grade had a significant effect on staple length and harsh wool group had the longest stable length followed by control, medium and soft wool groups, respectively. The effects of sorting system on all wool traits were significant (P<0.01) except that of elongation and point of break as length or weight which were not significant. It could be observed that harsh wool group had the highest values of fiber diameter (35.4μ), staple strength (31.1 N/Ktex), heterotype fibers percentage (2.9%), kemp fibers percentage (12.0%), medullated fibers percentage (31.8%), medullation index (15.9), yield percentage (61%) and prickle factor (38.3%) compared with that of soft wool, medium wool and non-sorted wool groups. Fiber diameter found to be lower about 8 microns in soft wool grade (27.6 ± 0.65 μ) compared with harsh wool grade and about 4 micron lower than medium wool grade (31.1 μ). Shah and Whiteley (1971) reported that softness of loose wool is heavily dependent on fiber diameter both within and between breeds whereas crimp parameters were of significant but minor role. These results indicated that grading and sorting wool according to handle grade was effective to separate Barki wool into three categories differ in many wool characteristics. Moreover, soft wool grade could be blended with fine wool to produce apparel textiles. Warn *et al.* (2006) and Rowe, (2010) reported that fine wool can produce yarns which are aptly suited to high value apparel textile end use. On the other hand, soft wool grade had about 9% lower in PF% compared with harsh wool grade and 6.5% lower than medium wool grade. The same results were found by El-Gabbas *et al.* (2009) who reported that harsh wool grade found to be associated with maximum prickle factor. In the same context, Dolling *et al.* (1992) and Hansford (1992) reported that prickle factor had higher correlation with mean fiber diameter. El-Gabbas (1998) stated that as the average fiber diameter increase the PF% tended to increase. It could be observed that the coarse wool has the longest staple. Gad-Allah (2001) reported that grade A3 which included long Barki wool with abundant kemp fibers percentage had grater fiber diameter than that of grade A1 which included short wool and low kemp fibers percentage. The values of fiber diameter, medulleted fibers percentage, medullation index, staple strength, yield percentage and prickle factor of harsh wool group were the highest compared with all groups.

Staple crimp frequency, bulk and resilience were significantly affected by subjective grading and sorting system according to harshness or handle grade (Table 1). The increase of bulk and resilience in soft wool group may be due to the increase of crimp frequency and fineness in this group. Bulk found to be associated with high crimp (Chaudri and Whitley, 1968) as well as with high fiber diameter (Carnaby and Elliot, 1980). Resilience tends to increase as the number of crimps increased (Roberts and Dunlop, 1957). Previous results were in agreement with the results obtained by Helal(2000) and Azzam (1982).

The overall average of prickle factor of Barki wool was 34.9% (Table 2). This result was less than that estimated by El-Gabbas (1998) who found that prickle factor was 45.1% in Barki sheep wool. Clean wool percentage of harsh wool had the highest value (61%) followed by medium, control and the soft wool grades, respectively which means that wool yield increases as the harshness increased. That may be due to high amount of grease and impurities in fine wool. Gad-Allah (2001) found that the wool of lateral line positions (the finer wool part of Barki sheep fleeces) had lower

Table 1. Least squares means ± standard errors for raw wool characteristics (staple length (STL), staple crimp frequency (CR), staple strength (SS), point of break as weight (POBw), point of break as length (POB), staple elongation (EL), loose wool bulk (BUL) and resilience (RES) obtained from the studied wool sorting lines

Trait / factor	No.	STL (cm)	CR (No./cm)	SS (N/Ktex)	EL (%)	PoBw (%)	PoBl (%)	BUL (cm^3/g)	Res. (cm^3/g)
Overall mean	120	11.2 ± 0.42	0.7 ± 0.05	27.2 ± 0.84	24.98 ± 1.10	0.53 ± 0.01	0.57 ± 0.01	31.4 ± 0.15	10.7 ± 0.43
Grade line		*	**	**	NS	NS	NS	**	**
Soft wool	30	10.3^{a} ± 0.42	1.1^{a} ± 0.04	27.5^{ab} ± 1.38	26.67 ±2.21	0.55 ± 0.02	0.58 ± 0.02	31.7^{a} ± 0.31	11.1^{a} ± 0.17
Medium wool	30	11.4^{ab} ± 0.42	0.6^{c} ± 0.04	24.5^{b} ± 1.38	26.28 ±2.21	0.53 ± 0.02	0.57 ± 0.02	31.9^{a} ± 0.31	10.8^{a} ± 0.17
Harsh wool	30	12.1^{b} ± 0.42	0.5^{b} ± 0.04	31.1^{a} ± 1.38	20.76 ±2.21	0.53 ± 0.02	0.56 ± 0.02	30.6^{b} ± 0.31	10.1^{b} ± 0.17
Control	30	11.2^{ab} ± 0.42	0.8^{c} ± 0.04	25.8^{b} ± 1.38	26.23 ±2.21	0.52 ± 0.02	0.57 ± 0.02	31.3^{ab} ± 0.31	10.9^{a} ± 0.17
R^2		0.08	0.52	0.10	0.04	0.01	0.002	0.01	0.13
CV%		20.58	30.38	27.83	48.38	23.88	18.82	5.33	8.61

Means within columns followed by the same superscript letter are not significantly different.
*: Significant at P<0.05. **: Significant at P<0.01.

Table 2. Least-squares means ± Standard error for raw wool characteristics (fiber diameter (FD), fiber type ratios (F, C, H and K), medullated fibers percentage (Med%), medullation index (MI), yield percentage (YLD%) and prickle factor (PF%) obtained from the studied wool sorting lines

Trait / factor	No.	FD (µm)	F (%)	C (%)	H (%)	K (%)	Med (%)	MI	YLD (%)	PF (%)
Overall mean	120	31.2 ± 0.33	71.4 ± 0.67	21.4 ± 0.67	1.4 ± 0.18	5.8 ± 0.32	28.6 ± 0.71	14.2 ± 0.12	56.5 ± 0.77	34.9 ± 0.87
Grade line		**	**	**	**	**	**	**	**	**
Soft wool	30	27.6^{a} ± 0.65	75.0^{a} ± 1.35	22.4^{a} ± 1.34	0.9^{a} ± 0.35	1.7^{a} ± 0.65	25.0^{a} ± 1.41	12.9^{a} ± 0.22	52.7^{a} ±1.56	29.6^{a} ± 1.69
Medium wool	30	31.1^{b} ± 0.65	70.0^{bc} ± 1.35	22.0^{a} ± 1.34	1.2^{a} ± 0.35	6.8^{b} ± 0.65	29.9^{b} ± 1.41	14.5^{b} ±0.22	58.3^{b} ±1.56	36.2^{b} ± 1.69
Harsh wool	30	35.4^{c} ± 0.65	68.2^{c} ± 1.35	16.9^{b} ± 1.34	2.9^{b} ± 0.35	12.0^{c} ± 0.65	31.8^{b} ± 1.41	15.9^{c} ±0.22	61.0^{b} ± 1.56	38.3^{b} ± 1.69
Control	30	30.9^{b} ± 0.65	72.3^{ab} ± 1.35	24.5^{a} ± 1.34	0.7^{a} ± 0.35	2.5^{a} ± 0.65	27.7^{b} ±1.41	13.3^{a} ±0.22	53.9^{a} ±1.56	35.6^{b} ± 1.69
R^2		0.38	0.11	0.13	0.17	0.58	0.09	0.49	0.14	0.11
CV%		11.40	10.35	34.36	13500	61.61	26.46	8.40	15.15	26.52

Means within columns followed by the same superscript letter are not significantly different.
* : Significant at P<0.05; ** : Significant at P<0.01.
F: fine fibers percentage, C: coarse fibers percentage, H: hetero-type fibers percentage and K: kemp fibers percentage.

Table 3. Correlation coefficients among objective wool characteristics:

	STL	CR	SS	POBw	POBl	EL%	BuL	Res	FD	F%	C%	H%	K%	Med%	MI	YLD
PF%	0.12	- 0.33**	-0.19 *	- 0.06	- 0.01	0.11	- 0.18*	-0.2 *	0.81 **	-0.32**	-0.09	0.06	0.26**	0.11	0.23 **	- 0.07
STL		- 0.37**	- 0.03	0.16	0.13	- 0.06	- 0.01	0.08	0.26 **	- 0.09	0.08	0.03	0.002	0.14	0.13	0.29 **
CR			- 0.18*	- 0.1	0.02	- 0.08	0.08	0.30 **	- 0.52 **	0.24 **	0.12	- 0.08	- 0.48**	- 0.25**	-0.48**	-0.30**
SS				- 0.11	-0.14	-0.28 **	-0.07	-0.29**	0.26**	-0.19 *	- 0.01	0.25 **	0.18 *	0.25 **	0.33**	0.27*
POBw					0.88**	0.03	0.04	0.03	-0.09	0.03	0.03	- 0.16	- 0.03	- 0.03	- 0.06	- 0.08
POBl						-0.03	0.08	0.07	-0.04	0.04	0.02	- 0.08	- 0.06	- 0.04	-0.07	- 0.10
EL%							- 0.13	0.02	-0.11	0.09	- 0.04	- 0.09	- 0.03	- 0.09	-0.18*	-0.23**
BUL								0.59**	-0.29**	0.2*	0.06	0.05	- 0.15*	0.01	-0.20*	0.22*
Res									-0.36**	0.22**	0.06	0.1	-0.27**	- 0.05	-0.22*	-0.24**
FD										-0.36 **	-0.14	0.21*	0.36**	0.2 *	0.5**	0.23**
F%											-0.66**	-0.21 *	-0.40**	- 1.0 **	-0.76**	-0.18*
C%												-0.29**	-0.39**	0.66 **	0.02	-0.11
H%													0.33**	0.21 *	0.44**	0.23**
K%														0.4 **	0.89**	0.32**
Med%															0.076 **	0.18
MI																0.32**

*: Significant at P<0.05. **: Significant at P<0.01.

PF%: prickle factor, (STL: staple length, CR: staple crimp frequency, SS: staple strength, POBw: point of break as weight, POBl: point of break as length, EL: staple elongation, BUL: loose wool bulk, RES: resilience, F: fine fibers percentage, C: coarse fibers percentage, H: hetero-type fibers percentage and K: kemp fibers percentage, Med%: medullated fibers percentage, MI: medullation index and YLD: Yield percentage.

percentage of clean wool content compared to that of dorsal line positions (the coarser wool part of Barki sheep fleeces).

The present results also showed that grading and sorting system or harshness had no significant effect on point of break as length and point of break as weight of Barki wool staples (Table 1). Those results were in agreement with those reported by El-Gabbas *et al.* (2009).

Data presented indicated that Barki wool staples broken much closer to the tip of the staple (57%) which represented growth of 7 months after shearing time; (57% (the length from the tip of the staple) multiples by 12 (number of year months) divided by 100. The reminder length is 43% from the base of staples which represented growth of 5 months before shearing time. So, Barki wool staples tended to break at the point that represented the growth of late autumn which may be due to poor pasture in autumn season where rain fall in winter season and shearing occurred once yearly in spring season. The second reason was that of physiological status where the ewes were in late pregnant period and the fetus consume the majority of blood nutritional elements. So, good management should be provided the nutrition supplements as well as the good concentrate ration at this time of year to avoid the malnutrition effects on wool quality and production.

B. Correlation coefficients among some objective wool characteristics:

Phenotypic correlation coefficients among objective wool characteristics of Barki wool are presentedin (Table 3). Prickle factor (PF%) showed high positive and significant (P< 0.01) correlation with fiber diameter (0.81). Many authors found that prickle factor had very significant correlation (P< 0.01) and high positive values with mean fiber diameter (Helal *et al.*, 2013; Abdelaziz & El-Gabbas, 1999; Dolling *et al.*, 1992; Hansford, 1992; Whitely and Thompson, 1985). Prickle factor (PF%) showed low positive and significant (P< 0.01) values of correlation with K% (0.26) and MI (0.23). Low negative and significant (P< 0.05) values of correlation coefficient were found between PF% with CR (-0.33), SS (-0.19), BUL (- 0.18), RES (-0.2) and F% (- 0.32). Fiber diameter (FD) showed moderate positive and significant (P< 0.05) values of correlation with K% (0.36), medullation index (MI) (0.5), low positive and significant (P< 0.01) values of correlation with staple strength (0.26), H% (0.21) and YLD% (0.23). Tekin *et al.* (1998) reported that FD was positively and significantly correlated with kemp ratio. Fiber diameter (FD) showed moderate negative value of correlation with CR (- 0.52), Res (-0.36) and F% (-0.36), low negative value of correlation with BUL (- 0.29). The correlation coefficients were highly significant (P< 0.01). These results were agreed with those reported by Gad-Allah (2007), in Barki wool. Ramadan (2005) found a negative and significant correlation coefficient (-0.76) between fiber diameter and fine fibers percentage of Barki ewes wool. He found that correlation coefficient between fiber diameter and coarse fibers percentage was significant (P< 0.01) and positive (0.75). Moreover, Significant and positive correlation coefficients of FD with medullated fibers percentage were reported by Ghoneim *et al.* (1974) and Ahtash (1998), on Barbary sheep, Abd El-Maguid (2000), on Barki and Ossimi sheep, Abdel-Moneim *et al.* (2000) and Helal (2000), on Siwa and El-Wady sheep. Pokharna and Patni (1980) reported that the value of crimp frequency per cm increases with increase in fineness. Significant and negative correlation coefficients of FD with both BUL and RES were reported by Helal (2000).

Staple length (STL) had low positive value of correlation with yield percentage (0.29) and moderate negative value of correlation with staple crimp frequency (CR) (-0.37). The correlation coefficient between staple length and both of staple crimp frequency and yield percentage were highly significant (P< 0.01). These results agreed with those reported by Gad-Allah (2007). It could be observed that fiber diameter had positive low value and significant (P< 0.01) correlation coefficient (0.26) with STL.

Staple crimp frequency (CR) had significant (P< 0.01) and low positive value (0.30) of correlation with wool resilience (RES) and significant (P< 0.05) low negative value with staple strength (SS) (-0.18). It could be observed that CR had medium negative value of correlation with MI; =-0.48 and low negative value with Med%; - 0.25, YLD; - 0.3. The correlation coefficients between staple crimp frequency and each of the above mentioned characteristics were significant (P< 0.01) except that of SS which was significant (P< 0.05). Gad-Allah (2001) reported that staple crimp frequency had significant (P< 0.01) and low negative values with K% (-0.2) and MI (-0.3).

Staple strength (SS) had low positive values of correlations with H% (0.25), K% (0.18), MI (0.33), and YLD% (0.27). The correlation coefficients between staple strength and each of H% and MI were highly significant (P< 0.01) and with K% and YLD% were significant (P< 0.05). Staple strength (SS) showed low negative values of correlations with EL% (-0.28), RES (-0.29), and F% (-0.19).

Bulkiness (BUL) showed significant (P<0.01) positive correlation value with resilience (RES) (0.59), and significant (P<0.05) low positive value of correlation coefficient with F% (0.20), and YLD% (0.22) and significant (P<0.05) low negative value of correlation with, K% (r=-0.15) and MI (r=-0.20). Significant and positive correlation coefficients of BUL with RES of Barki wool were reported by Gad-Allah (2007) and Abd El-Maguid (2000), of both Barki and Ossimi sheep, and of Siwa and El-Wady sheep (Helal, 2000). Significant and positive correlation coefficient of BUL with RES and F% and negative correlation coefficients of BUL with C%, K% and MI of Barki wool were reported by Gad-Allah (2001).

Resilience (RES) had significant (P<0.01) and low negative values of correlation coefficient with FD, PF%, SS, K%., MI and yield percentage. Resilience (RES) had significant (P<0.01) and low positive correlation coefficient with F% and significant (P<0.01) and medium negative correlations with K% (-0.27), MI (-0.22) and YLD (-0.24). Gad-Allah (2007) reported that resilience (RES) had significant (P<0.01) low positive correlation values with F%, significant (P<0.01) and medium negative correlation values with K% and MI and significant (P<0.05) low negative correlation value with fiber diameter (FD).

Fine fibers percentage (F%) had significant (P<0.01) and high negative values of correlation coefficients with coarse fibers percentage (C%) and medullation index (MI), medium negative value with kemp fibers percentage (K%) and low negative (P<0.05) values with H% and YLD%. These results are similar to those reported on Barki wool by Gad-Allah (2007). Coarse fibers percentage (C %) had significant (P< 0.01) and medium negative value of correlation coefficient with K% (- 0.39) and significant (P< 0.01) low negative correlation value (- 0.29) with H%. Abd El-Maguid (2000), working on Barki and Ossimi sheep, found that C% was negatively and significantly correlated with both F% and K%. Similar findings were reported by Ahtash (1998), on Libyan Barbary sheep and Gad-Allah (2001), on Barki sheep. Heterotype fibers percentage (H %) had significant (P< 0.01) and medium positive values of correlation coefficient (0.44) with medullation index (MI) and significant (P< 0.01) low positive correlation values with both K% (0.33) and YLD% (0.23). Kemp fibers percentage (K %) had significant (P< 0.01) and high positive values of correlation coefficient (0.89) with medullation index (MI) and significant (P< 0.01) low positive value of correlation coefficient (0.32) with YLD%.

These results disagreed with those reported by Guirgis (1973b), on Barki wool; Guerreiro *et al.* (1984), on Corriedale and Romney March sheep, Garcia and Alvarez (1992), on German Mutton Merino wool; Ahtash (1998), on Libyan Barbary ewes; Abd El-Maguid (2000), on Barki and Ossimi sheep and Gad-Allah (2001), on Barki wool. They reported positive and significant correlation coefficients between wool length and fiber diameter. On the other hand, Azzam (1982) and Helal (2000) reported a negative and insignificant correlation coefficient between staple length and fiber diameter. Ramadan (2005), in Barki ewes, found a negative correlation coefficient (r=-0.18) between staple length and fine fibers percentage.

It could be concluded that selection for low values of fiber diameter could result in an increase in fine fiber % (true wool), CR, BUL and RES and a decrease in PF%, STL, SS, M%, MI and YLD, which might cause a decrease in wool production. Some authors reported significant positive correlation between clean fleece weights and SL (Soltan, 1991 and Ahtash, 1998). Gad-Allah (2001) found that fiber diameter had significant (P< 0.01) and medium positive correlation coefficient with staple length. Soltan (1991) and Ahtash (1998) reported positive and significant correlations between greasy fleece weight and FD.

C. Yarn characteristics:

Table (4) shows that sorting system had significant (P< 0.01) effects on single yarn count, yarn strength, yarn elongation, yarn abrasion and tenacity of the single yarn. Soft wool grade had the highest value of yarn strength (965.16 ± 29.5 gf) followed by medium and harsh wool grades (949.11 ± 29.5 and 925.84 ±29.5 gf.), respectively and the lowest was that of control wool grade (893.90 ±29.5 gf.). Helal *et al.* (2008) reported that yarn tenacity tended to decrease with the increase in fiber diameter and staple length. The increase in yarn strength may be due to the increase of numbers of fibers in the yarn cross section. Yarn elongation of control wool grade had the highest value followed by soft and medium wool grades, respectively and the lowest value of yarn elongation was that of harsh wool grade. Helal *et al.* (2008) reported that yarn elongation tended to increase with the increase of fineness, which might be related to the increase in fiber crimps. For plied yarn, sorting system significantly (P< 0.05) affected yarn count and significantly (P< 0.01) affected yarn strength, tenacity and twisting (Table 5).

For yarn evenness, results showed that sorted lines differed significantly in the irregularity of yarn mass (Um%) and highly significantly in Coefficient of variation of yarn mass (CVm%) and the numbers of thin places (Table 6). It could be observed that the irregularity of the yarn mass (Um%) tended to increase as the wool harshness increased where the high value of yarn mass irregularity was that of yarn processed from harsh wool line followed by medium and soft wool lines, respectively. Similar trend was observed for coefficient of variation of yarn mass (CVm%) and the numbers of thin places. On the same context, El-Gabbas *et al.* (2009) found that the irregularity of yarn mass (CVm%) tended to be higher in yarns processed from lines originated from harsher wool compared with those yarns processed from lines of finer wool but the differences were not significant. However, the lowest value of all yarn evenness parameter was that of control wool line.

D. Phenotypic correlation coefficients among the studied yarn characteristics:

Phenotypic correlation coefficients among the studied yarn characteristics of Barki wool are presented (Table 7). Yarn strength had significant (P<0.01) high positive values of correlation with yarn elongation and yarn tenacity, significant (P<0.05) and low positive value with thick places. Yarn elongation showed positive and significant (P<0.01) correlation of moderate value with yarn tenacity and significant (P<0.05) low negative values with Um%, CVm%, and thin places. El-Gabbas *et al.* (2009) reported that yarns processed from lines of harsher wool had higher content of medullated fibers in the raw state and after carding which expected to be more susceptible to break with less extensibility and hence, resulted in low YS compared with those yarns made from lines of finer wool. Yarn tenacity had low positive value of correlation coefficients with CVm and thick places. Numbers of yarn twisting negatively correlated with Um, CVm and numbers of thin places and the values were moderate and significant (P<0.01). The correlation coefficient between Um and each of CVm and thin places were significant (P<0.01) and very high values and significant (P<0.01) moderate value with thich places. CVm had significant (P<0.01) and moderate positive correlation values with number of thin and thick places. Number of thin places was significantly (P<0.01) correlated of moderate positive value with number of thick places. Helal *et al.* (2014) found that thin places had significant (P<0.01) correlation (0.63) with thick places.

Table 4. Least squares means± standard errors for single yarns count (YC), strength (YS), elongation (YE), tenacity (Rkm) and twisting obtained from the studied wool grading lines after spinning stage

Trait / Factor	No.	YC (Nm)	YS (gf)	YEL (%)	Rkm (Kgf * Nm)	Twisting (TPM)
Overall mean	120	6.31 ± 0.04	933.2 ± 14.76	21.14 ± 0.46	6.67 ± 0.2	282.76 ± 1.49
Grade line		**	**	**	**	NC
Soft wool	30	6.24 [b] ±0.07	965.2 [a] ± 21.16	22.11 [a] ± 0.71	6.54 [a] ± 0.16	282.13 ± 2.99
Medium wool	30	6.19 [b] ±0.07	949.1 [ab] ± 21.16	21.60 [a] ± 0.71	7.52 [b] ± 0.16	279.00 ± 2.99
Harsh wool	30	6.46 [a] ±0.07	925.8 [b] ±21.16	17.79 [b] ±0.71	6.48 [a] ± 0.16	282.43 ± 2.99
Control	30	6.42 [a] ±0.07	893.9 [c] ±21.16	22.62 [a] ± 0.71	6.13 [a] ± 0.16	287.50 ± 2.99
R^2		0.16	0.07	0.13	0.38	0.03
CV%		7.31	16.55	23.99	11.40	6.68

Means within columns followed by the same superscript letter are not significantly different.
*: Significant at P<0.05. **: Significant at P<0.01.

Table 5. Least squares means± standard errors for plied yarns count (YC), strength (YS), elongation (YEL), tenacity (Rkm) and twisting obtained from the studied wool grading lines after spinning stage

Trait / Factor	No.	YC (Nm)	YS (gf)	YEL (%)	Rkm (Kgf * Nm)	Twisting (TPM)
Overall mean	120	6.26 ± 0.04	1916.3 ± 12.08	21.89 ± 0.24	12.00 ± 0.08	146.01 ± 0.94
Grade line		*	**	NC	**	**
Soft wool	30	6.28 [ab] ±0.07	1915.5 [a] ± 24.16	21.71± 0.48	12.90 [a] ± 0.16	143.3 [a] ± 1.87
Medium wool	30	6.43 [a] ±0.07	1863.5 [a] ± 24.16	21.79 ± 0.48	11.98 [b] ± 0.16	151.5 [b] ± 1.87
Harsh wool	30	6.1 [b] ±0.07	1853.7 [a] ±24.16	20.88 ±0.48	11.30 [c] ± 0.16	146.0 [ab] ± 1.87
Control	30	6.22 [b] ±0.07	2032.5 [b] ±24.16	23.18 ± 0.48	12.64 [a] ± 0.16	142.8 [a] ±1.87
R^2		0.09	0.18	0.07	0.34	0.1
CV%		5.93	7.97	13.84	8.50	7.02

Means within columns followed by the same superscript letter are not significantly different.
*: Significant at P<0.05. **: Significant at P<0.01.

Table 6. Least squares means± standard errors for plied yarns irregularity of yarn mass (Um), coefficient of variation of irregularity of yarn mass (CVm%), thin places and thick places

Trait / Factor	No.	Um (%)	CVm (%)	Thin places (No.)	Thick places (No.)
Overall mean	72	16.09 ± 0.18	20.8 ± 0.19	37.00 ± 1.77	11.18 ± 0.67
Grade line		**	**	**	**
Soft wool	18	15.66^{a} ± 0.37	19.88^{a} ± 0.39	28.22^{a} ± 3.53	14.28^{a} ± 1.34
Medium wool	18	16.76^{b} ± 0.37	21.3^{b} ± 0.39	39.33^{b} ± 3.53	10.78^{a} ± 1.34
Harsh wool	18	18.11^{c} ± 0.37	23.41^{c} ± 0.39	62.67^{c} ± 3.53	14.22^{a} ± 1.34
Control	18	13.83^{d} ± 0.37	18.77^{d} ± 0.39	17.78^{a} ± 3.53	5.44^{b} ± 1.34
R^2		0.52	0.55	0.57	0.30
CV%		9.63	7.79	40.53	50.90

Means within columns followed by the same superscript letter are not significantly different.
*: Significant at P<0.05. **: Significant at P<0.01.

Table 7. Correlation coefficients among the studied plied yarn characteristics

	YEL	Rkm	TW	Um	CVm	Thin	Thick	YC
YS	0.74^{**}	0.6^{**}	- 0.08	0.15	0.17	0.11	0.25^{*}	0.03
YEL		0.34^{**}	0.16	-0.27^{*}	-0.25^{*}	-0.23^{*}	-0.03	-0.01
Rkm			-.02	0.19	0.24^{*}	0.19	0.24^{*}	0.07
TW				-0.34^{**}	-0.41^{**}	-0.35^{**}	-0.16	-0.11
Um					0.98^{**}	0.91^{**}	-0.51^{**}	0.04
CVm						0.9^{**}	0.52^{**}	0.03
Thin							0.48^{**}	-0.01
Thick								-0.03

*: Significant at P<0.05. **: Significant at P<0.01.
YC: yarns count, YS: yarn strength, YEL: yarn elongation and Rkm: yarn tenacity, TW: yarn twisting, Um: irregularity of yarn mass, CVm %: coefficient of variation of irregularity of yarn mass, Thin: thin places and Thick: thick places.

The present results indicated the importance of subjective assessment as well as objective measurements in clip preparation in terms of grading and sorting to produce wool lines distinguish in raw wool and carpet yarn characteristics. Helal *et al.* (2019) recommended assessing the wool subjectively and objectively.

El-Gabbas (1998) indicated that the prickle factor percentage of Barki wool had high value so it would never be suitable for fabrics worn against the skin. On the other hand, he reported that while Barki wool is not proper carpet wool, it is much closer to the carpet wool specifications than to those for apparel. Also, he reported that animal had highly significant effect on average fiber diameter and its variability as well as prickle factor and medullated fiber percentages. Those findings indicated the importance of genetics factors to improve the above mentioned traits. Ali *et al.* (2022) illustrated the possibility to utilize Egyptian Barki wool fibers in the production of fabrics suitable for garment production which can be performed by grading and sorting the wool fleece according to handle and fineness to separate class of fine fleeces and patches with no kemp fibers, and by blending Barki wool fibers with polyester fibers using different blending ratios, taking into consideration the fibers' properties.

In view of the current results, it is important to improve Barki sheep wool. This could be achieved through a survey study for measuring fiber diameter of individual Barki sheep animals along the north-western desert of Egypt to grade and separate the fine wool individual animals and the coarse wool ones to form two lines of Barki sheep distinguish in fiber diameter or fineness. Secondary, improvement of each line of Barki sheep separately. The first one includes the animals that had coarse wool and applying the selective breeding programs among those animals for increasing fibers diameters to produce carpet wool, the second one the animals that had fine wool and applying the selective breeding programs among these animals for decreasing fibers diameters to produce apparel wool.

CONCLUSION

Local Barki sheep fleeces subjected to the grading system implemented in the present study had different grades of raw wool to process into yarns that differs from each other in many properties. Hence, the grading system was more effective in producing raw wool lines distinguished in harshness and the majority wool characteristics of Barki sheep.

Correlation coefficient relationships of raw wool characteristics showed high values of correlation between PF% with FD, POBL with POBW, F% with C%, F% with MI and K% with MI. Correlation coefficient were of medium magnitude between STL with CR, RES with BUL, CR with FD; CR with K% and MI, RES with FD, FD with F%; FD with K%, FD with MI; F% with K%; C% with K%; H% with MI. So it could be concluded that selection for low values of fiber diameter could result in an increase in fine fiber% (true wool), CR, BUL and RES and a decrease in PF%, STL, SS, M%, MI and YLD, which might cause a decrease in wool production.

Correlation coefficient relationships of plied yarn characteristics showed high values of correlation between YS with both YEL and Rkm, between Um with both CVm and number of thin places, and between CVm with number of thin places. Correlation coefficients were of medium magnitude between yarn twisting with both CVm and minus number of thin places, between CVm with number of thick places and between numbers of thin places with number of thick places.

The present study indicated the possibility of applying clip preparation and subjective grading to separate the soft handle wool part of Barki sheep fleeces which can be used in apparel textiles after blending with fine wool or / and synthetic fibers. Such procedure will reserve part of foreign currency utilized to import fine wool, as well as increased the uniformity of the rest of fleeces and their suitability to carpet manufactory that required harsher wool fibers. Therefore, the breeder income will increase due to the increase in price of wool. This would result in increased the interest of sheep breeding and improvement of wool production.

The present study recommends that enforcement of clip preparation and subjectively grading and sorting Barki wool according to harshness or handle grade to separate the soft wool grade which consider the finest part of Barki fleece wool and use this part to blend with the expensive Merino or fine wool to produce good and low cost apparel yarns. The medium wool grade may be blend with other types of wool or / and synthetic fibers to produce blankets or common tops yarns which apply in high quality goblin. The reminder harsh wool grade could be used in producing good quality yarns for kleem and carpet makers.

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الملخص العربي

تأثير درجة ملمس صوف أغنام البرقى على صفاته التصنيعية

أيمن علي اسماعيل جاد الله

تم تدريج وفرز صوف أغنام البرقي المصرية وفقا لدرجة الملمس التقديرية لصفة الخشونة إلى ٣ أقسام: صوف ناعم (SW) وصوف متوسط (WM) وصوف خشن (HW) بالإضافة إلى قسم رابع يحتوى على صوف بدون تدريج أو فرز للمقارنة (NW). تم تصنيع كل قسم على حده بنظام الصوف المسرح لإنتاج خيوط ميكانيكية ذات نمرة خيط ٢/٦ مترى. تم أخذ عينات ممثلة من الصوف الخام والخيوط الناتجة من كل درجة علي حده لقياس خصائص كل منها.

أوضحت النتائج أن تأثير نظام الفرز كان معنويا (P< 0.05) علي طول الخصلة ومعنويا جدا (P< 0.01) على قطر الألياف وعدد البرمات في وحدة الطول وقوة شد الخصلة ومقاومة الإنضغاط والمرونة والنسبة المئوية للألياف الناعمة والخشنة والألياف المختلطة والكمب والنسبة المئوية للألياف المحتوية علي النخاع ومعامل النخاع ومعامل الوخز للألياف.

كما أوضحت النتائج أن تأثير نظام الفرز كان معنويا جدا (P< 0.01) على نمرة الخيط وعدد البرمات فى المتر الطولي وقوة شد ومتانة واستطالة الخيط والانحراف المعياري لمعامل اختلاف كتلة الخيط (CVm%) وعدد المناطق الرفيعة في الخيط. ومعنويا (P< 0.05) على عدم إنتظامية كتلة الخيوط (Um%).

تم تقدير معاملات الارتباط بين الصفات الطبيعية والميكانيكية للصوف الخام وكذلك بين خصائص الخيوط الناتجة.

أوضحت النتائج أهمية إعداد الجزة بإجراء فصل للجزء ناعم الملمس من جزات صوف أغنام البرقى والذى يمكن استخدامة فى خلطات الألياف لصناعة الملابس. وبذلك يتم توفير جزء من العملات الأجنبية المستخدمة فى استيراد الصوف الناعم كما أنه يزيد من تناسق المتبقى من الجزات وملائمته لصناعة السجاد الذى يتطلب خشونة عالية للألياف الصوفية. وفي النهاية تزداد دخول المربيين نتيجة بيع الصوف بسعرعالي وذلك يمكن أن يؤدى إلى زيادة الاهتمام بتربية الأغنام وتحسين صفات الصوف.

الكلمات المفتاحية: أغنام البرقى، تدريج الجزة، درجة الملمس، الخشونة، القياسات التقديرية، فرز الصوف ، ضناعة الخيط.