Pakistan J. Sci. Ind. Res., Vol. 14, No. 3, June 1971

INTERRELATEDNESS AMONG NATURAL VARIATIONS OF THE LOW-CRIMP MIXED WOOLS

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(Received January 6, 1970; revised September 22, 1970)

Industrially significant attributes of the low-crimp 'mixed' wools are highly correlated with each other. In the ascending order of their importance the clean fibre yield shows significant correlatoin with specific compressional load, 'index of sulphur content' and the bundle tenacity. The tenacity is highly correlated with the index of sulphur content and compressional load. The load is similarly correlated with fibre diameter and sulphur index. The observed contrast between their simple and partial coefficients of correlations, however, reveals a tendency of confounding certain fibre characteristics.

Previous studies[1-3] of a Bibrik wool of West Pakistan suggested that both the scouring yield and single fibre tensile strength could be adversely affected by the prevailing malnutrition of the sheep. A further knowledge of whether the other breeds of Pakistan are also subjected to the unfavourable conditions seems to have considerable economic implications. For example, the assessment of price and end-use of raw wools are generally based on their clean fibre yield and 'soundness' or strength considerations. The strength characteristics are usually evaluated by fibre bundle breaking in commercial situations. Thus wool buyers generally appraise 'tenderness' of the staple by a subjective type of bundle testing[4] and impose a price penalty upto 5% of the normal price when the fault is detected[5] although careless handling could easily miss many tender wools[6] to the disreputation of their subsequent trading. A wool is judged tender if its strength falls between 20 and 50% of its expected tenacity,[7] even though there is likelihood of price penalty when the staple weakens by only 10%.

The Pakistani wools mostly suit pile floor covering for which the resistance to bulk compression is a desirable quality. Heavily compressed wools, on unpacking their shipped bales, tend to be undergraded in yield,[8] perhaps, due to high correlation[9,10] between clean fibre yield and specific volume of greasy wools under high pressures of the order from 11 to 46 lb/in^2. At low pressures, however, fibre crimp and diameter mainly determine the bulk compressibility.[11,12] Since the crimp effect normally disappears at very great pressures, the resulting compressive behaviour of raw wools largely depends on fibre diameter. Obviously, the resistance to compression arises from the reaction of fibre bending. Finer fibres being easier to bend, they would manifest lower specific compressional load. They also possess larger surface per unit mass. The greater fibre surface accumulate more impurities and thereby reduce the clean fibre yield.

The resistance to bulk compression displayed by a variety of Merino wools was positively correlated with bundle strength[11] and sulphur content,[13] although the correlations were nonsignificant statistically. On the other hand, the load shows a significant negative correlation with bundle strength,[14] probably, due to larger weak-link-effect[15] and higher weight in a given bundle length of the crimpier wools which generally exhibit greater compressional load. In view of these findings, 12 low-crimp wools manifesting considerable fibre medullation have been examined here. The correlations thus ascertained are likely to be useful guide to the wool commerce dealing in medullated fibres.

Experimental

Eight greasy wools were drawn from the various districts of West Pakistan as stated below:

Breed	*District*	*Appearance*
Buchi	Bahawalpur	Fairly coarse and medullated
Kaghani	Hazara	True wool-like and quite coarse
Damani	D.I. Khan	Very coarse and medullated
Baluchi	Kalat	True wool-like and somewhat fine
Hashtnagri	Peshawar	Medium coarse and medullated
Kashmiri	Azad Kashmir	Medium coarse and slightly medullated
Kail	Azad Kashmir	True wool-like and nearly fine
Rakhshani	Kalat	True wool-like and quite fine

In addition, 4 low-crimp wools as shown in Table 1 were drawn from Australia and studied along with the native wools. The foreign wools displayed considerable fibre medullation as well. Although medullation of a merino wool is generally called 'dogginess', all the medullated wools produce very uneven yarns and variable dye-shades. Such wools become unsuitable for any apparel cloth of commercial value and are mainly used in carpet manufacture if they conform to the commercial specifications,[16] that ideal carpet wools should possess less than 15% medul-

TABLE 1.—DISTRIBUTION OF FIBRE CHARACTERISTICS AMONG THE EIGHT PAKISTANI and FOUR AUSTRALIAN CARPET WOOLS.

Breed	Washing yield %	C.V. %	Bundle tenacity g/tex	C.V. %	Speci. com. load g/cm2	C.V. %	Sulphur index %	C.V. %	Dia.	C.V. μ	Crimp No/mm
Buchi	58.8	11.8	10.0	9.6	136	4.0	1.10	7.6	40.0	26.9	0.23
Kaghani	69.5	11.5	12.4	3.5	91	3.6	2.23	4.5	33.8	36.8	0.29
Damani	56.7	15.4	9.8	8.9	152	5.8	1.39	4.2	42.3	45.5	0.23
Baluchi	64.6	12.0	10.1	5.5	112	6.1	2.44	6.4	31.6	30.2	0.23
Hashtnagari	72.8	17.3	11.4	7.3	125	6.7	2.00	6.8	35.2	49.5	0.24
Kashmiri	87.8	14.1	13.0	8.3	84	6.6	2.67	6.3	33.8	36.2	0.24
Kail	81.7	9.8	13.3	5.8	89	6.5	3.07	1.8	30.3	25.0	0.21
Rakhshani	68.7	11.2	12.3	8.2	90	4.3	2.47	2.1	25.8	30.3	0.27
Coarse merino			12.6	10.4	116	6.3	2.68	6.1	25.4	20.8	0.32
Very coarse merino			13.0	7.9	127	5.4	2.73	4.6	34.8	23.4	0.32
Border Leicester			13.5	9.2	113	3.8	2.75	3.7	36.3	24.9	0.16
Remney Marsh			13.0	4.6	103	4.5	2.45	1.6	37.4	24.5	0.12

lated fibres and average fibre dia 25.4μ or more. Diameter may account for more than 90% of the wool quality[17] which implies the degree of suitability for specific end-uses. Thus the variations in fibre characteristics of the carpet wools are so great as some of them can be similar to the merino wools.[18] All the 12 wools of the present study chiefly conform to the commercial standards for carpet wools and are, according to Burns' chart,[18] termed 'mixed' wools although they may be classed differentaly by the brokers of different countries. However, the wools were practically free from vegetable fault. They were conditioned in the standard atmosphere of 65% r.h. and 21°C, and tested therein.

Washing Yield.—This yield of a raw wool was estimated from 50 g specimens in triplicate. The specimen was weighed and thoroughly scoured in a 0.02% solution of nonionic detergent (Nonidet P40, Shell Chemicals) at 40°C, rinsed with distilled water and air-dried. The dry wool weight was expressed as the percentage of its initial weight.

Bundle Tenacity.—At least 5 random samples of each wool were tested according to the A.S.T.M. standard D. 1294-63T for bundle strength. The testing employed an Instron Tensile Tester (Model TT-BM) which was adjusted to break 1.5 cm long fibre bundle at a constant rate of 2 cm/min.

Specific Compressional Load.—The Instron Tester was also used to compress a sample of 1 g wool inside a copper cylinder of internal dia 3.48 cm and depth 7.55 cm by means of a close-fitted piston traversing at a rate of 2 cm/min. The cyclic compression up to a constant volume of 10 cm was completed 4 times within 12 min. The maximum load developed in each cycle of compression was recorded save in the first cycle owing to its obvious packing defects. The mean load was obtained from observations on 3 random samples of every wool.

Fibre Diameter and Crimp.—The diameter was measured by a projection microscope at a magnification of 500× following the technique recommended by the Technical Committee of International Wool Textile Organisation. However, the mean crimp frequency of 10 fibres drawn at random from each wool was obtained from observations over a given fibre length that had been flattened under a transparent surface.[19] Due to the negligible variation of crimp frequency between the various breeds it was excluded from the final analysis.

Sulphur Estimation.—The polarographic technique for cystine and cysteine measurements[20,21] involved continuous shaking of a given weight of intact wool fibres in a stock solution of MeHgI and recording the resulting decrease of its concentration. Although the physical force of shaking was used to complete the chemical reaction for sulphur estimation in the intact wool fibres, this technique always produced low values of sulphur concentration in the ratio of 3.1:3.5 due, most probably, to the incomplete reaction.[20] Besides, the effective force of shaking definitely varied with the fibre surface area per unit mass, which is inversely proportional to the fibre diameter. The consequent diameter-biased measurements, though overlooked by the original workers, could account for the nonsignificant variation of sulphur content noted between the merino strains[22] because they differ widely in sulphur concentration.[13] In view of the wide variation of fibre diameter in this study (25.4–42.3μ), however, the procedure was slightly modified to minimise the indicaeted diamter-bias.

The samples (20–50 mg for disulphide plus thiol and 50–100 mg for thiol groups) in triplicate were drawn at random from each wool, and soaked in two changes of diethyl ether and absolute alcohol followed by their rinsing with distilled water. They were submerged with minimum amount of shaking in the stock solution and the recommended reaction times were almost doubled for the completion of MeHgI uptake. This analysis produced slightly low values of sulphur content, as indicated by the proportion of 2.8: 3.1 noted for a series of 16 Australian wools, perhaps, due to the absence of continuous shaking here. This deviation which is smaller than that indicated before, practically followed a linear change because a small fraction of even a curve can be regarded as straight line. In order to account for this small difference of measurement, however, the observed percentage of sulphur has been termed an 'index of sulphur content' which is mostly free from error of diameterbias.

Since the thiol (SH) groups in wool fibre are produced from hydrolytic fission of the disulphide (SS) groups, the ratio SS/SH (an index of stability of the S—S cross link) showed a positive correlation with the observed index of sulphur content as expected. In addition, an analysis of variance of the sulphur indices demonstrated significant variations from breed to breed. These expected relationships justify further analysis of the sulphur indices, particularly, because the statistical generalisations are generally independent of any fixed variation of measuring procedure as adopted here.

Results and Discussions

The fibre properties are set out in Table 1. An initial analysis of the Pakistani wools alone (Table 2A) shows that washing yield can be best predicted from the bundle tenacity. For this reason, the yield has been deleted from the analysis of all the 12 wools (Table 2B). The results indicate that the statistical significances of the correlations derived from the small population of 8 wools are similar to those noted in the large population. In addition, the correlations obtained for the 8 Pakistani wools tend to retain their senses and statistical significances on adding 1, 2, 3 or 4 comparable wools to the initial population; hence by mathematical induction, the indicated correlations are most likely to be significant in their respective senses for the low-crimp medullated wools of any number greater than 12 if their ranges of fibre characteristics do not exceed the present limits. The succeeding discussion, however, refers chiefly to the observations on the Pakistani wools.

Compared to the previously indicated mean sulphur content (2.8%) for a series of high-crimp Australian wools the indices of sulphur content (Table 1) exhibited by the low-crimp wools are as low as expected from a positive correlation between crimp frequency and sulphur concentration.[13,23,24] This agreement certainly confirms the present point of view vis-a-vis the modified measurement of sulphur in intact wool fibres. Although the carpet wools vary so widely in their fibre properties, the present range of washing yield from 56.7% to 87.8% is considerably greater than a corresponding range from 65% to 85% exhibited by the Asiatic carpet wools.[18] The comparison shows that the factors affecting scouring yield might have been left largely uncontrolled in West Pakistan. This proposition is in harmony with the large variation of the index of sulphur content of the Pakistani wools from 1.10% to 3.07%. Besides, its mean value (2.17%) for the native wools is certainly lower than that (2.65%) of the comparable foreign wools due, probably, to higher fibre medullation of the former. Medulla not only contains little sulphur[25] but the inherited propensity of fibre medullation[26,27] also increases with nutritional stress[1,28] that reduces both the yield and sulphur content. The reduction of yield is partly associated with the loss of fibre dust arising from natural brittleness of the extremely medullated fibres such as the kemps.

The index of sulphur content is significantly correlated with the specific compressional load and bundle tenacity which is basically similar to yarn tenacity,[29] particularly, at very low yarn twists. In view of the significant correlations (Tables 2A, 2B and 3), the yarn tenacity could largely depend on the bulk compressibility of a variety of raw wools as noted later.

Diameter and Yield.—As reasoned before, the yield may show a positive correlation with fibre diameter but this analysis (Table 2A) shows a negative sign of their correlation. The reversal of sign could arise from an indirect effect due to high positive correlation between fibre diameter and medullation[2,3] since the latter varies inversely with both the yield and sulphur content as evident from the stress of malnutrition on the animal. This inference tends to conform to the positive sign of the coefficients of partial correlation between the yield and diameter (Table 3) on adjustment for sulphur index, tenacity or load.

Table 2A.—Correlation Matrix of the Indicated Varieties for a Population of the Eight Pakistani Carpet Wools.

Washing yield (y)	Specific compr. load (l)	Bundle tenacity (t)	Index of sulphur content(s)	Fibre dia (d)	
1.000	0.785*	0.879**	0.808*	0.510	y
	1.000	0.887**	0.871**	0.822*	l
		1.000	0.804*	0.646	t
			1.000	0.821*	s
				1.000	d

*Statistical significance at 5% levels; **Statistical significance at 10% level.

Table 2B.—Correlation Matrix for a Population of All the Twelve Carpet Wools Shown in Table 1.

Load, l	Tenacity, t	Sulphur index, s	Diameter, d	
1.000	0.669*	0.691*	0.600*	l
	1.000	0.825**	0.422	t
		1.000	0.658*	s
			1.000	d

*Statistical significance at 5% level; statistical significance at 10% level.

The nonsignificant values of these partial coefficients could arise from the relatively high suint content of the coarse wools. The normal washing easily removes the soluble suint and largely retains the insoluble wool wax that occurs conspicuously in the finer wools. But the fine wools tend to reduce the yield by depositing high amount of impurities on their large surface per unit mass.

Yield, Sulphur Index, Load and Tenacity.—The yield (y) shows significant correlations with bundle tenacity (t), index of sulphur content (s) and spe-specific compressional load (l) in the descending order of their commercial importances, i.e. square of the coefficients of correlation. The senses of these simple correlations are in conformity with those of their corresponding partial correlations (Table 2A and 3) whilst the coefficients of partial correlation obtained by adjusting for any one of the parameters t, s or l are always reduced to their nonsignificant levels. Hence, these fibre properties are largely confounded in their influences on the washing yield. For example, their respective partial correlations, on adjustment for fibre diameter alone, with the yield are generally significant.

Contrary to the trade opinion,[8–10] however, the significant correlation between the yield and compressional load shows a negative sign, probably, due to the indirect influences of sulphur concentration and tenacity as evident from the positive sign of their partial correlation on adjustment for both s and t, i.e., $r_{yl.st}=0.242$. This analysis clearly implies that the previous reports are generally applicable to those wools which possess high degree of uniformity in their tenacity and sulphur concentration as shown by the foreign wools (Table 1). In addition, the small value of $r_{yl.st}$ may be attributable partly to the high positive correlation of the adjusted variates (s and t) with the uncontrolled ones (y and l) and partly to the large difference between the degrees of bulk compression employed here and those in the previous works.[8–10] This is because, the chemical bonds of wool fibres which are deformed under low pressures tend to differ both in kind and quantity from those participating in high compression testing.

Tenacity and Load.—Whilst the specific compressional load is significantly correlated with fibre diameter, the latter does not show a significant correlation with bundle tenacity (Table 2A and 2B) as expected in a wide range of fibre characteristics commonly encountered in practical situations. The highly significant simple correlation between tenacity and load shows a negative sign in conformity with the senses of their partial correlations (Table 3). The casual basis of the negative correlation is that the resistance to bulk compression of a wool assembly tends to oppose the interfibre cohesion during bundle breaking. Consequently, the previous report of a positive correlation between load and bundle tenacity,[11] though contrary to another observation,[14] could be fortuitous. In this analysis, however, the positive correlation between t and s is significant. But the negative sign of the significant correlation between s and l contrasts with an early report,[13] probably, due to the indirect influence of fibre medullation, *i.e.* the finer wools of lower resistance to bulk compression tend to possess less medulla and consequently more sulphur.

Conclusion

The presence of fibre medullation together with its effects on diameter and sulphur concentration tends to overwhelm certain significant correlations usually observed in the nonmedullated wools. Thus in the Pakistani medullated wools, bundle tenacity accounts for the maximum amount of variation (77.3%) of the washing yield. The greatest variation of bundle tenacity (78.7%) is accounted for by the difference of specific compressional load. The load records the highest positive correlation with fibre diameter. But the negative correlation between load and the index of sulphur content is attributable to the higher concentration of sulphur in the finer wools of this study. In addition to breeding away from the existing state of fibre medullation, the analysis clearly suggests a need for incorporating sulphur-rich fodder into the sheep's diet in order to improve the fibre yield and strength for better price of the 'mixed' wools of West Pakistan.

TABLE 3.—COEFFICIENTS OF PARTIAL CORRELATION ($r_{12.3}$) BETWEEN THE FIRST AND SECOND VARIATE ON HOLDING THE THIRD OR BOTH THE THIRD AND FOURTH VARIATE ($r_{12.34}$) CONSTANT, USING THE RESULTS AND NOTATIONS OF TABLE 2A.

$r_{yt.s}$	=0.657	$r_{yd.l}$	=0.382	$r_{ts.l}$	=0.141	$r_{yt.ls}$	=0.649
$r_{yt.l}$	=0.640	$r_{yd.s}$	=0.456	$r_{ts.y}$	=0.106	$r_{ys.lt}$	=0.598
$r_{yt.d}$	=0.838*	$r_{yd.t}$	=0.160	$r_{ts.d}$	=0.628	$r_{yl.ts}$	=0.242
$r_{ys.t}$	=0.356	$r_{yl.s}$	=−0.280	$r_{tl.d}$	=−0.819*	$r_{tl.ds}$	=−0.711
$r_{ys.d}$	=0.792*	$r_{yl.t}$	=−0.023	$r_{tl.s}$	=−640	$r_{ty.dl}$	=0.593
$r_{ys.l}$	=0.375	$r_{yl.d}$	=−0.747	$r_{tl.y}$	=−0.670	$r_{ts.dl}$	=0.293

*Statistical significance at 5% level.

Acknowledgements.—The author is highly grateful to Dr. S.A. Warsi, the then Director of the PCSIR Laboratories, Peshawar, for his kind encouragement by supplying me the raw wools studied here.

References

1. M.A. Ali and S.M. Fatima, Pakistan J. Sci. Ind. Res., **10,** 68 (1967).
2. M.A. Ali and S.M. Fatima, Pakistan J. Sci. Ind. Res., **10,** 74 (1967).
3. M.A. Ali and S.M. Fatima, Pakistan J. Sci. Ind. Res., **10,** 216 (1967).
4. H.G. Belschner, *Sheep Management and Diseases* (Augus & Roberts, Sydney, 1953), p. 37.
5. N.F. Roberts, J.F. James and V.D. Burgmann, J. Textile Inst., **51,** T935 (1960).
6. P.R. McMahon, Wool Technol. Sheep Breeding, **2,** 24 (1955).
7. D.A. Ross, New Zealand J. Agri. Res., **2,** 214 (1959).
8. W. J. Onions, *Wool* (Earnest Benn, London, 1962), p. 287.
9. R.H. Burns and A. Johnston, J. Textile Inst., **28,** T13 (1937).
10. A. Johnston and J. Gray, Proc. Am. Soc. Ani. Prod., **32,** 188 (1939).
11. C.M. Van Wyk, Ond J. Vet. Sci. and Ani. Ind., **21,** 99 (1946).
12. G.E. Scheepers and R.I. Slinger, SAWTRI Tech. Rep. No. 103 (1968)
13. R.I. Slinger and S. Smuts, SAWTRI Tech. Rep. No. **89** (1967).
14. A. Demiruren and R.H. Burns, Textile Res. J., **25,** 665(1955).
15. F.T. Peirce, J. Textile Inst., **17,** T355 (1926).
16. R.H. Burns, A. Johnston and W.C. Chen, J. Textile Inst., **31,** T37 (1940).
17. A.D. Bastawisy, W. J. Onions and P.P. Townend, J. Textile Inst., **52,** T1(1961).
18. H.R. Mauersberger, *Mathew's Textile Fibre* (John Wiley, New work, 1947), p. 460.
19. L.W. Rainard and D. Abbott, Textile Res., J., **20,** 301(1950).
20. S. J. Leach, Australian J. Chem., **13,** 520, 547 (1960).
21. J.A. Maclaren, S. J. Leach and J.M. Swan, J. Textile Inst., **51,** T665 (1960).
22. S. J. Leach, Wool Sci. Rev., **21,** 27 (1962).
23. J.G. Snyman, Textile Res. J., **33,** 803(1963).
24. J.M. Gillespie, Textile Res. J., **35,** 128 (1965).
25. S. Blackburn, Biochem. J., **43,** 114 (1948).
26. F.W. Dry, New Zealand J. Agri., **46,** 10 (1933).
27. H. Goot, New Zealand J. Sci. Tech., **A27,** 173 (1945).
28. K.M. Rudall, J. Textile Inst., **36,** 358 (1935).
29. H.W. Holdaway, J. Textile Inst., **56,** T121 (1965).