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FELTING OF PAKISTANI WOOLS AND ITS RELATIONSHIP WITH MEDULLATION

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Studies have been made on felting behaviour of a number of Pakistani wools. The possible factors which affect felting such as diameter, friction, fibre length, crimps/inch and crimp form have also been studied. It was found that Kaghani wool exhibited the lowest felting ability whereas Lohi wool the highest. It was also found that, in order to make a good felt, the percentage of true fibres should not be less than 60%, and conversely that of medullated fibres not more than 40%, provided the configuration of true fibres is sine and that of medullated fibres straight.

Most of the factories located in north western areas of West Pakistan are making felts for local consumption. The quality of these felts differs widely, because of unscientific methods used for the production of these felts. One of the drawbacks in such felts is that medullated fibres are loosely held and can easily be taken out. Lack of scientific data on the felting of medullated fibres could well be the reason for this situation.

Considerable work has been done abroad on felting, most of this being on yarn and fabric.[1] In recent years, however, some work has also been done on loose wool.[2,3,4] These studies have been made on wool fibres which are completely free from medullation. As such, these studies are not directly applicable to Pakistani wool as it contains considerable amount of medullation.[5]

The mechanism and causes of felting have been the subject of a great deal of previous investigation and controversy. It has now been proved experimentally that migration of the fibres occurs during felting.[6,7,8] As for the effect of friction on felting, it is still not clear what part is actually effected in felting. All that seems to have been established is that, a fibre must have a directional frictional effect (D.F.E.) in order that felting can take place. As regards the effect of other characteristics, it has been shown recently that crimp form is an important factor in felting i.e. a fibre with helical configuration does not felt easily in comparison to that with sine form.[9,10,11,12] The other physical characteristics such as diameter, crimps/inch and fibre-length have been shown to be of little importance.

The present study aims at finding out the felting behaviour of different Pakistani wools. Emphasis has been laid on the effect of medullation on felting i.e. how far the increase or decrease of medullation affects the felting behaviour. The effects of a number of other factors viz. fibre-length, diameter, friction, crimps/inch and crimp form have also been studied.

Materials and Methods

Wool Samples.—Out of some 20 breeds found in the country,[13] 12 were included in the present investigations. These breeds included some progenies obtained by crossing the local breed with imported Rambouillet. Thus the samples ranged from fine to coarse wool types. Table 1 shows the various breeds and the areas where they are raised, It may be mentioned that these areas are not specific for the reason that some of the breeds are migratory and are reared in different localities in different weathers.

Table 1.—Distribution of Pakistani Breeds.

No.	Breed	Area
1	Hashtnagri	Charsadda, Mardan
2	Michni	Peshawar, Tribal areas of Kohat
3	Kaghani (cross)	Kaghan Valley of Hazara District
4	Kail (cross)	Azad Kashmir
5	Lohi	Lyallpur, Multan, Lahore, Sahiwal
6	Buchi	Bahawalpur, Cholistan
7	Harnai	Quetta
8	Bibrik	Makran, Sibi
9	Damani	Dera Ismail Khan
10	Dumbi	Sind
11	Kooka	Jacob Abad, Hyderabad
12	Country (cross)	Azad Kashmir

The samples from the above breeds were taken from body wool (mid-side) and were treated first with petroleum ether followed by alcohol and distilled water. The following tests were made on these wools.

Medullation.—About 0.3 g of wool from each sample was taken and the three types of fibres i.e. true, heterotypical and medullated were separated with the help of benzene test.[14] Each type was weighed and the percentage calculated. Due to their low occurrence, kempy fibres were not included in the present investigation.

Diameter.—A representative sample from each breed was taken, cut into small pieces and mounted on a glass slide covered with a coverslip which was secured by glycerine. Diameter of some 300 fibres was recorded at a magnification of $\times 500$, employing a Lanameter.

Fibre Length.—About 50 fibres were withdrawn at random from each type of fibre i.e. true, heterotypical and medullated, and were tested for length measurement. Each fibre was straightened (crimp removed, but not stretched) on a black velet board against a scale (in inches) placed along the side and the length recorded.

Crimps per inch.—Only 11 of the true and 2 of the heterotypical samples were crimped and the rest had little or no crimp. Fifty fibres were withdrawn at random from each type. The crimps or waves were counted for the whole fibre. The fibre was then straightened and the length measured.

Crimp Form.—A crimp rotator is needed to determine the form of crimp.[15] Due to the non-availability of the apparatus, the assessment was done visually. The author gained experience in Australia about the crimp form of various wools and so was able to judge the form qualitatively without assigning any numerical score.

The crimp configuration of Pakistani true wool is mostly either of sine form or a combination of sine and helical forms. Medullated and most of the heterotypical fibres have some crimp, but the amplitude is very small. Thus these fibres are virtually straight fibres. In order to distinguish these fibres from the usual sine form fibres, they have been denoted by straight type in the subsequent discussion.

Felting.—The wool samples were hand-carded and vegetable matter removed thoroughly. Two types of felting experiment were performed. In the first experiment, the various wools were tested for felting as such. In the second experiment, felting behaviour of different proportions of true and medullated fibres was examined. In the latter case, the fibres employed were withdrawn from Hashtnagri wool, which is a typical carpet wool and the composite samples had proportions of medullated fibres varying in steps of 10% from 0% up to 100%.

One g of wool, conditioned at 65% R.H. and 21°C was put in a bottle which contain 70 ml of 0.1N HCl together with a drop of non-ionic detergent. The bottle was put in a laboratory shaking machine. After shaking for one hour, the felted ball was throrughly rinsed several times with distilled water. The shape of the ball was not circular, but somewhat elleptical. Faure's method was used for finding the volume of felted ball as it does not depend on the shape of the ball.[16] The felted ball was saturated with water whereby air is completely removed and weighed in this condition. From the weight of the felted ball a correction factor (0.23) is substracted to get the volume of the felted ball in cubic centimeters. At least two balls were made from each sample and the volume determined twice for each felted ball.

Friction.—Lipson's method[17] was used for finding frictional parameters. The following techniques were employed.

About 10 fibres were withdrawn at random each from the various types of wool fibre. Two wools, Kooka and Bibrik were not included as the fibres were too short. Hooks, weighing 0.2 g each, were attached to both ends of the fibre. The fibre was suspended on a cylindrical rod of polished horn on which wool yarn had been wrapped. The medium used was 0.1N HCl together with a drop of non-ionic detergent. The flow of the liquid was maintained constant throughout the experiment. Small weights were added to one of the ends, until slippage of the fibre occured, when the difference in tension T_1-T_2 reached a critical value. The frictional coefficient is then given by

$$\mu = \frac{1}{\theta} \log \frac{T_1}{T_2}$$

where θ is the angle of contact between fibre and cylinder and in this case $\theta = \pi$ radian. Difference in frictional coefficients against and with the scale ($\mu_1 - \mu_2$) gives "directional frictional effect" (D.F.E.). Further, the coefficient "scaliness" has been defined by Speakman[18] to be

$$\text{Scaliness } (\%) = \frac{(\mu_1 - \mu_2) \times 100}{\mu_2}$$

Results and Discussion

Table 2 shows the percentage of the three types of fibres i.e. true, heterotypical and medullated in the various wools.

The wools can be classified in terms of medullation in three categories. In the first category comes the finer types i.e. Kaghani, Kail and Country (Azad Kashmir) wools, which contain mostly true fibres, with little or no medullation. In the second category falls Kooka and Michni, where the amount of true fibres is less than 50%. The third category comprises Hashtnagri, Bibrik, Damani, Harnai and Dumbi wools, in which the amount of true fibres ranges between 60% to

TABLE 2.—PERCENTAGE OF DIFFERENT TYPES OF FIBRES IN VARIOUS WOOLS.

No.	Breed	True	Heterotypical	Medullated
1	Kaghani (cross)	100.00	—	—
2	Kail (cross)	100.00	—	—
3	Country (cross)	100.00	—	—
4	Kooka	23.5	3.4	73.1
5	Michni	44.3	2.1	53.6
6	Hashtnagri	59.0	13.3	72.7
7	Bibrik	60.0	9.1	30.9
8	Damani	68.1	2.7	29.2
9	Harnai	70.5	10.2	19.3
10	Dumbi	70.1	2.9	27.0
11	Lohi	70.0	30.0	—
12	Buchi	81.9	—	18.1

TABLE 3.—VOLUME OF THE FELTED BALL AND FINENESS OF THE VARIOUS WOOL.

No.	Breed	Volume (Cm^3)	Diameter (μ)
1	Kaghani	17.47	28.4
2	Kooka	11.97	50.6
3	Michni	11.87	44.6
4	Country	10.32	28.2
5	Kail	10.22	27.0
6	Buchi	10.12	41.4
7	Hashtnagri	9.87	39.8
8	Bibrik	9.57	39.4
9	Damani	9.37	31.5
10	Harnai	8.22	36.6
11	Dumbi	8.22	30.0
12	Lohi	7.87	29.5

TABLE 4.—FRICTIONAL PARAMETERS OF VARIOUS WOOLS.

Breed	Type of fibre	μ_1	μ_2	D.F.E.	Scaliness
Kaghani	True	0.5274	0.3217	0.2058	64.0
Michni	True	0.5319	0.3391	0.1928	56.8
	Het	0.5453	0.3237	0.2216	68.5
	Med	0.6631	0.3772	0.2859	75.8
Country	True	0.5422	0.3400	0.2022	59.4
Kail	True	0.5367	0.3379	0.1987	58.9
Buchi	True	0.5853	0.3910	0.1945	49.7
	Med	0.6600	0.4280	0.2318	54.1
Hashtnagri	True	0.5401	0.3195	0.2205	69.2
	Het	0.5487	0.3500	0.1982	54.2
	Med	0.5718	0.3776	0.1942	52.2
Damani	True	0.5459	0.3492	0.1967	56.4
	Het	0.5601	0.3334	0.2262	67.9
	Med	0.5747	0.3234	0.2514	78.0
Harnai	True	0.5598	0.3436	0.2162	62.1
	Het	0.5488	0.3703	0.1911	52.2
	Med	0.6615	0.4185	0.2429	58.1
Dumbi	True	0.5788	0.3796	0.1990	52.5
	Het	0.5617	0.3508	0.2108	59.9
	Med	0.6680	0.3913	0.2767	70.7
Lohi	True	0.5566	0.3423	0.2143	62.6
	Het	0.5642	0.3656	0.1985	54.3

70%. Buchi wool contains about 80% of true fibres, while Lohi contains only true and heterotypical fibres. It may be mentioned that these percentages do not fully represent the whole breed, as large variations do occur within, as well as, between flocks and also between various parts of the same breed.[19,20]

From Table 3 it is evident that Kaghani (cross) exhibits the highest volume of the felted ball, thus showing least felting. Kooka and Michni wools with highest medullation shows poor felting. In the same manner, Hashtnagri, Bibrik, Harnai, Damani and Dumbi with moderate medullation exhibit good felting. The two crossbred wools Country and Kail exhibit an intermediate felting behaviour. The best felting behaviour was exhibited by Lohi wool, which contains only true and heterotypical fibres. These results do not indicate any relationship between feltability and diameter of the single fibres.

The presence of scales on the surface of wool gives rise to the ability of wool fibres to felt and move in the root to tip direction. Table 4 does not show any significant differences in μ_1 between the various wools. However, medullated fibres have consistantly greater μ_1 in comparison to true fibres. In the same manner μ_2 is greater in the case of medullated than in that of true fibres. Generally D.F.E. or scaliness is greater in medullated than true fibres, with some exceptions. No relationships between feltability and D.F.E. or scaliness were observed in the present work. It may be mentioned that previous studies have failed to correlate quantitatively D.F.E. and felting ability.[21,22,23,24] It may well be due to the fact that coefficients of friction measured on single fibres do not correspond to those actually operating during felting. However, it seems to have been established that migration of the fibres taking place during felting is basically due to scale structure of the fibres.[6,7,8]

Table 5 gives data on the physical characteristics viz: fibre length, crimps/inch and crimp form of the various wools. It is evident that fibre length does not effect feltability which is also in accordance with the previous studies.[25] All the true fibres (with the exception of those of Lohi) and heterotypical fibres from two of the samples have crimp. The rest have virtually no crimp. There seems to be no relationship between crimps/inch and feltability. Recently, it has been shown that it is not the crimp, but the form of the crimp that plays an important part in felting and compression.[9,10,11,12] Thus it has been shown that wool fibres with helical configuration do not felt, while that of sine configuration felt easily. Fibres are associated with a variety of forms of crimp, but on the basis of preliminary experiments, indigenous wools could be classified in the following categories:

(i) Sine form
(ii) Helical form
(iii) Combination of sine and helical (combination)
(iv) Straight

True fibres have sine as well as combination of sine and helical configurations. Medullated and most of the heterotypical fibres are of straight type. Kaghani wool with helical configuration exhibits least felting, but Lohi wool which is the best felting wool has straight fibres. These findings are in accordance with the previous studies, which show that with the straightening of the fibres from a helical to sine form, feltability increases.[10,26] It is worth mentioning here that five of the carpet wools, Hashtnagri, Damani, Bibrik, Harnai and Dumbi, which are associated with almost the same level of medullation and a similar fibre configuration, have approximately the same feltability.

It was possible to study the felting ability of combination of true and medullated fibres over a wide range by varying the amount of medullation from 10% to 100%. It is evident from Table 6 that only true wool fibres exhibit maximum felting. With the increase of medullated fibres in the combination, felting decreases, so that 100% medullated fibres give least felting. This decrease in felting is not steady, e.g. an increase in medullated fibres from 50% to 70% does not effect the felting appreciably. One important point, which emerges from this experiment, is that, a good felt should have at least 60% of true fibres and conversely not more than 40% of medullated fibres. However, due consideration must be given to the form of crimp in drawing any conclusions from such work, because as discussed above, Kaghani wool which contains only true wool fibres does not felt due to its helical configuration.

TABLE 5.—FIBRE LENGTH, CRIMPS/INCH AND CRIMP FORM OF VARIOUS WOOLS.

Breed	Type of fibre	Fibre length (inches)	Crimps/ inch	Crimp form
Kaghani	True	3.93	2.50	Helix
Kooka	True	2.59	2.80	Combination
	Het	2.03	3.06	Combination
	Med	1.56	—	Straight
Michni	True	3.28	3.20	Combination
	Het	1.97	2.95	Sine
	Med	2.88	—	Straight
Country	True	3.97	1.20	Combination
Kail	True	4.07	2.80	Combination
Buchi	True	4.00	1.30	Combination
	Med	2.59	—	Straight
Hashtnagri	True	3.58	1.31	Sine
	Het	3.59	—	Straight
	Med	3.80	—	Straight
Bibrik	True	1.54	0.94	Sine
	Het	1.65	—	Straight
	Med	3.33	—	Straight
Damani	True	3.10	2.61	Sine
	Het	3.25	—	Straight
	Med	3.57	—	Straight
Harnai	True	3.51	0.88	Sine
	Het	4.15	—	Straight
	Med	1.99	—	Straight
Dumbi	True	3.66	1.27	Sine
	Het	3.60	—	Straight
	Med	4.88	—	Straight
Lohi	True	4.45	—	Straight
	Het	4.30	—	Straight

TABLE 6.—VOLUME OF FELTED BALL IN VARIOUS PROPORTION OF TRUE-MEDULLATED FIBRES.

Sample No.	% of true	% of medullated	Volume (cm^3)
1	100	—	7.22
2	90	10	7.57
3	80	20	7.77
4	70	30	8.72
5	60	40	8.72
6	50	50	9.67
7	40	60	9.77
8	30	70	9.87
9	20	80	10.82
10	10	90	11.87
11	—	100	12.65

Conclusions

The following conclusions may be drawn from the present study:

1. Out of 12 wools studied, Lohi wool was found to exhibit the maximum felting ability and Kaghani wool the minimum. The other carpet wools with good felting capacity were Harnai, Dumbi, Hashtnagri, Bibrik and Damani. The rest of the wools tested showed moderate feltability.
2. Diameter, friction, fibre length and crimps/inch appear to be of little or no significance in felting. Only crimp configuration seems to affect feltability: sine form positively and helical negatively.
3. Our experiments show that for making a good felt, a wool should contain at least 60% of true fibres. This applies strictly to combinations of fibres associated with sine or straight forms, but not helical form.

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References

1. R.W. Moncrieff *Wool Shrinkage and its Prevention* (National Trade Press, London, 1953).
2. G. Blankenburg and H. Zahn, Textile, Praxis, **16,** 228 (1961).
3. H. Zahn and G. Blankenburg, Text. Res. J. **32,** 986 (1962).
4. K. J. Whiteley and E. Balasubramanium, 3rd Int. Wool Text. Res. Conf. Paris (Cirtel), Section 1, 593 (1965).
5. T.A. Wazir, F. Khan and A.A. Wakil, Pakistan J. Sci. Ind. Res., **10,** 91 (1967).
6. K.R. Makinson, Text. Res., J. **29,** 439 (1959).
7. K.R. Makinson, Text. Res. J., **30,** 598 (1960).
8. K.R. Makinson, Text. Res. J., **32,** 364 (1962).
9. K. J. Whiteley, Nature, **211,** 757 (1966).
10. M.A. Khan, M.Sc. Thesis, University of New South Wales, Australia (1966).
11. M.A. Chaudri, Ph.D. Thesis, University of New South Wales, Australia (1966).
12. S.M.A. Shah, Ph.D. Thesis, University of New South Wales, Australia (1965).
13. Anonymous, Wool Test House Report (1964).
14. Anonymous, Wool Science Review, **13,** 38 (1954).
15. E. Balasubramanium and K. J. Whiteley, Aust. J. App. Sci., **15,** 41(1964).
16. P.K. Faure, Text. Res. J. **35,** 861 (1965).
17. M. Lipson, Nature, 156, 268 (1945).
18. J.B. Speakman and E. Stott, J. Text. Inst., **22,** T339 (1931).
19. S.M.A. Shah, Pak. J. Sci. Ind. Res., **5,** 104 (1962).
20. A.A. Wakil and A.A. Khan, Pakistan J. Sci. Ind. Res., **7,** 125 (1964).
21. J.H. Bradbury, 2nd Wool Text. Res. Conf. Part II, 51, T1226 (1960).
22. J.H. Bradbury, Text. Res. J., **31,** 735 (1961).
23. J.R. McPhee and H.D. Feldtman, Text. Res. J., **31,** 1037 (1961).
24. J.B. Speakman, E. Stott and H. Chong, J. Text. Inst., **24,** 273 (1933).
25. P.K. Faure, S.A. Wool Text. Res. Inst. Technical Report No. 35 (1965).
26. W.G. Crewther and L.M. Dowling, Text. Res. J., **31,** 14(1961).