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INCIDENCE OF MEDULLATION IN CARPET WOOLS

Part II. Extent of Medullation in Heterotypical Fibres

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Abstract. Fibre diameter and the diameter, length and frequency of medullated fragments were determined in the case of 20 heterotypical fibres of 10 different carpet wools. The various relationships between these characteristics were examined statistically and, where necessary, fully medullated fibres were also included in the studies. It appears that the role of diameter is two-fold: in addition to its effect on the proportion of medullated fibres in a sample as reported earlier,[3] the diameter affects the extent of medullation in individual fibres. As the diameter of heterotypical fibres increases, the medulla diameter also increases rather rapidly till it reaches its maximum at a fibre diameter of about 100 μ, when the medulla occupies more than 85% of the fibre volume.

The need for studying characteristic physical properties of carpet wools has earlier been expressed by Shah and Whiteley.[1] Recently, the quality and character of Pakistani carpet wools were analysed in terms of other characteristics.[2] This was followed by the present studies on the medullation characteristics of these wools. Part I of these studies contained results on the relationship between the fineness of a carpet wool and the proportions of the various types of fibres (true, heterotypical and medullated) and the relationship between the mean fineness and the fineness of the various types of fibres. The fineness differentials in the various types of fibres were also reported.[3]

The heterotypical fibres constitute an intermediate stage between the two extremes of true and fully medullated fibres. In these fibres, medulla is present from negligible proportions to nearly complete stages. These fibres, therefore, present the opportunity of studying the stages at which medullation initiates and is completed. No similar studies were available on the development of medulla through these stages; hence the need for the present investigation.

Preliminary studies indicated that in these fibres not only the length, but also the diameter as well as the frequency of medullated fragments varied from fibre to fibre. It has been demonstrated that medullation is strongly correlated with sample fineness[3] it is further desirable to know how fibre fineness affects the medullation level of individual fibres. Present study aims at examining relationships, if any, of fibre diameter with the diameter, length and frequency of medullated fragments together with other related relationships in the case of heterotypical fibres, with a view to observe the mode of development of medulla at various stages in these fibres.

Materials and Methods

The wool samples employed and the determination of their various characteristics have been described earlier.[3] In the present study the following procedures were employed:

Heterotypical fibres drawn at random from each of the samples were mounted on slides in liquid paraffin. The diameter of the fibres, as well as of the medullated portions was measured at intervals of about 0.1 mm at a magnification of $\times 500$, with the qualification that the point at which a medullated fragment came under view, and that at which it passed, were necessarily included in the measurements. These measurements were made over a length of 2.5 mm of each fibre and 20 fibres per sample were thus examined. From these sets of data on each fibre, the following characteristics were determined: mean diameter of the fibre, mean diameter of the various fragments of medulla in the fibre, frequency and total length of the fragments.

Where necessary, such measurements were also made on the fully medullated fibres, in which case readings were taken at the regular intervals of 0.1 mm.

The various relationships were statistically examined by evaluating the corresponding coefficients of correlation and studying their significance.

Results and Discussion

Tables 1 and 2 represent typical results for two of the samples, Swati and Bibrik. In addition, these Tables include results for 10 fully medullated fibres from each of the samples. The range of diameter of the medulla is 4–12 μ in the case of Bibrik samples, whereas it is 5–14 μ in the case of the Swati sample. The total medullated length for a fibre of 2.5 mm, ranges between 0.062–23.780 mm for Bibrik wool and 0.158–23.760 for Swati wool. Frequency of occurrence of medullated fragments is about 1.48/cm in the case of the Bibrik sample and about 1.15/cm in the case of the Swati sample.

Table 3 gives the mean results for all the ten samples. The ranges are generally larger when compared with those mentioned above. The coefficients of correlation between the various data of Table 3 have been presented in Table 4, which also includes some other coefficients, discussed elsewhere.

Relationship Between Fibre Diameter and Medulla Diameter. The correlation coefficient for the relationship between fibre diameter and medulla diameter

TABLE 1. DATA FOR BIBRIK WOOL.

Fibre No.	Fibre dia (μ)	Medulla dia (μ)	Total length of medullated fragments (mm)	Frequency of medullateda fragments (pre cm)
(a) *Heterotypical fibres*				
1	31·6	7·2	2·078	2·0
2	32·4	8·8	0·852	2·0
3	30·4	4·2	0·062	0·8
4	34·4	5·5	6·180	0·8
5	33·8	6·4	2·376	2·0
6	33·8	7·4	8·844	1·6
7	32·6	6·8	0·312	2·0
8	34·4	9·2	11·180	1·2
9	34·2	9·0	10·898	1·6
10	33·8	7·2	2·076	2·0
11	35·8	5·4	0·520	2·0
12	35·6	6·3	4·100	1·6
13	35·4	8·0	0·730	2·0
14	35·6	8·4	12·570	1·2
15	36·4	8·7	0·290	0·8
16	35·4	7·4	13·960	2·0
17	36·6	11·6	8·940	1·2
18	40·0	8·6	7·490	1·2
19	41·0	10·2	23·780	0·8
20	40·8	9·0	21·920	0·8
Mean	35·2	7·8	6·96	1·48
(b) *Medullated fibres*				
1	55·0	25·4	—	—
2	55·6	29·8	—	—
3	57·6	30·8	—	—
4	52·2	28·3	—	—
5	86·2	61·6	—	—
6	78·0	55·7	—	—
7	90·2	74·6	—	—
8	60·5	34·3	—	—
9	64·7	40·1	—	—
10	71·3	48·9	—	—

TABLE 2. DATA FOR SWATI WOOL.

Fibre No.	Fibre dia (μ)	Medulla dia (μ)	Total lengtth of medullaed fragments (mm)	Frequency of medullated fragment (per cm)
(a) *Heterotypical fibres*				
1	31·4	9·0	21·64	1·2
2	32·0	10·0	1·384	2·0
3	32·4	7·2	0·230	0·8
4	33·6	11·2	1·688	2·0
5	33·2	11·0	3·942	1·2
6	34·4	10·0	2·652	1·2
7	33·6	8·8	0·720	2·0
8	34·0	9·6	0·760	0·8
9	33·4	8·0	0·122	0·4
10	32·8	6·6	0·988	2·4
11	33·4	12·0	0·376	0·8
12	34·4	9·0	0·158	0·4
13	33·4	8·4	0·446	0·8
14	32·8	7·4	0·534	0·8
15	32·6	6·6	0·254	1·6
16	33·8	8·2	1·188	0·8
17	35·8	6·0	8·146	1·2
18	35·2	5·2	4·080	0·8
19	34·8	9·0	0·378	0·8
20	40·8	14·4	23·760	0·8
Mean	33·9	8·9	3·60	1·15
(b) *Medullated fibres*				
1	45·4	20·8	—	—
2	49·0	19·8	—	—
3	51·6	25·2	—	—
4	45·5	19·4	—	—
5	55·0	28·4	—	—
6	66·2	30·2	—	—
7	53·6	23·7	—	—
8	57·3	25·1	—	—
9	58·7	24·5	—	—
10	60.9	27·3	—	—

TABLE 3. MEAN DATA FOR THE TEN SAMPLES.

S. No.	Wool	Fibre dia. (μ)	Medulla dia. (μ)	Total length of medullated fragments per fibre (mm)	Frequency of medullated fragments (per cm)
1	Swati	33·9	8·9	3·60	1·15
2	Kaghani	43·5	20·4	23·56	0·80
3	Terahi	38·3	11·2	6·60	0·72
4	Harnai	47·2	18·1	16·06	2·10
5	Lohi	35·9	9·2	13·26	0·58
6	Damani	29·9	12·3	12·30	1·50
7	Bibrik	35·2	7·8	6·96	1·48
8	Kooka	34·6	13·3	18·90	1·14
9	Hashtnagri	42·0	17·4	21·84	0·90
10	Michni	32·8	6·1	1·52	1·81

TABLE 4. COEFFICIENTS OF CORRELATION.

S. No.	Characteristics	Coefficients
1.	Fibre diameter and medulla diameter-Swati wool, 20 heterotypical fibres only	0·321
2.	Same as No. 1, but now also including data for 10 medullated fibres	0·983*
3.	Fibre diameter and medulla diameter-Bibrik wool, 20 heterotypical fibres only	0·548†
4.	Same as No. 3, but now also including data for 10 medullated fibres	0·880*
5.	Fibre diameter and medulla diameter—mean values of the 10 samples	0·831*
6.	Fibre diameter and total length of medullated fragments—mean value of the 10 samples	0·288
7.	Fibre diameter and frequency of medullated fragments—mean values of the 10 samples	0·185
8.	Total length of medullated fragments and their frequency—mean values of the 10 samples	0·187

*Significant at 1% level; significant at 5% level.

in the case of the heterotypical fibres is 0.321 for the Swati and 0.548 for the Bibrik samples (Table 4). The first of these fails to reach significance whilst the second is significant at 5% level. The rest of the samples follow a similar pattern, as the coefficient is either nonsignificant or just significant. However, the coefficient for the mean values of the ten samples is 0.831, which is highly significant. This difference between the high significance at the overall level and the rather weak significance within individual samples may well be due to the relatively narrow range of fibre diameter within the samples. Within each sample, the range of the fibre diameter was usually 5–6 μ from the minimum to the maximum, but it was about 14 μ in the case of the means of all the 10 samples (Table 3). The latter range allowed more chance for the relationship to get expressed.

The question of behaviour within the same wool was, however, investigated further. Out of the two typical samples, Swati and Bibrik, the former had exhibited a nonsignificant and the latter a significant

(5% level) coefficient; investigations were, therefore, conducted on both of these samples. In order to increase the range of one of the variables viz. fibre diameter, 10 fully medullated fibres were selected at random from each of the two samples. Each fibre was tested for fibre diameter as well as the medulla diameter as described earlier. The correlation coefficients were calculated for the composite samples of heterotypical and medullated fibres (total number of fibres=30) for both the wools. The results have been included in Tables 1, 2 and 4. The coefficients were highly significant in both the cases. This once more strongly confirms the above view that the reason for the rather weak relationship within each wool (heterotypical fibres) is the narrow range of fibre diameter in such cases, otherwise, the relationship is highly significant at an overall level.

As to the form of the relationship, the data for the various wools were plotted on a graph. It was observed that the relationship was generally of a logarithmic rather than linear form. The logarithmic coefficient of correlation was, therefore, calculated for the mean results of Table 4. The coefficient was 0.931 in comparison to the linear coefficient which equals 0.831. The increase in the significance was tested by the z-transformation method,[4] which led to a value t, significant at 1% level. Hence the relationship seems to be of the form: $Y = \text{a } X^{n}$; where Y, fibre diameter; X, medulla diameter and a and n are constants.

Other Relationships. The coefficient of correlation for the relationship between fibre diameter and total length of medullated fractions is nonsignificant (Table 4). Likewise, the coefficients for fibre diameter and frequency and for total medullated length and frequency are also nonsignificant. It may, therefore, be surmised that these characteristics are not related with one another in any particular order.

Development of Medulla in Relation to Fibre Diameter. The mode of development of medulla from the true, through heterotypical to the fully medullated stage may now be discussed. It is obvious from the data given in an earlier communication that below a dia 32±4 μ, all the fibres are expected to be true viz. free from medullation. In most fibres the process of medullation, initiates at this diameter and approaches completion at a minimum diameter of about 51±15 μ. It may be noted that the range at the coarse end has become rather wide, so that some fibres, as fine as 36. may be fully medullated, whereas others, as coarse as about 65 μ may still be heterotypical. It may be recalled that, in general, the proportions of these fibres are strongly correlated with the mean diameter of the sample. The diameter of the coarsest medullated fibre detected in a sample seems, however, to follow an erratic pattern, e.g. the coarsest fibre in Harnai (mean dia 34.4 μ), is 188 μ thick, whereas that in Bibrik (mean dia 39.5 μ) is 106 μ thick.

With the above limits for initiation and completion of medullation in view, the results of the present study indicate that as the diameter of the heterotypical fibres increases, it is the medulla diameter which follows a regular pattern, i.e. it increases with fibre diameter, while both the frequency and the total length of the medullated fragments vary irregularly.

TABLE 5. EXPECTED MEDULLA DIAMETER FOR GIVEN FIBRE DIAMETER.

Fibre dia (μ)	Expected medulla dia (μ)	Medulla diameter as percentage of fibre dia (%)
30	8	27
35	11	31
40	16	40
50	25	50
75	50	70
100	85	85

It appears, therefore, that within a wool, once medulla is present at a minimum fibre diamter, it would become coarser in those fibres coarser than this minimum, but would be often discontinuous untill again at a certain other minimum diameter, the medulla would become continuous. Throughout this transition, the relationship persists: the coarser the fibre, the coarser the medulla, whether continuous or discontinuous.

Expected Diameter of Medulla. In the case of the heterotypical fibres (35 μ), the medulla is only about 11μ thick, As fully medullated fibres (100 μ), are approached, the medulla diameter becomes coarse enough to constitute 85% of the fibre diameter (Table 5). It may be mentioned that beyond this diameter, the fibre is almost completely medullated and the medulla occupies about 90–95% of the whole fibre, leaving near the periphery a small area adjoining the cuticle.

Double Medulla. Occurrence of double and triple medulla has already been reported by some workers.[5–7] In a preliminary investigation a large number of samples were scanned, to observe general modes of medullation. During the course of these investigations, one of the samples of Hashtnagri wool was found to exhibit double medulla. The rare existence of such phenomenon in carpet wools is, therefore, confirmed.

Conclusion

In Part I it was concluded that the larger the diameter of the wool sample, the greater the proportion of medullated fibres it contains. It has now become obvious that the role of diameter is two-fold. Apart from the above effect, the larger the diameter of an individual fibre (above a certain minimum), the larger the diameter of its medulla. With the increase in diameter of heterotypical fibres, the diameter of the medullated fragments would also increase almost consistently till the medulla becomes continuous. This relationship also holds beyond this stage, i.e. for fully medullated fibres.

Fibres having a diameter below about 32 μ are almost free from medulla. Beyond this stage, medulla appears in a fragmented form in carpet wools and becomes continuous at about 51±15 μ.

For a 35-μ fibre, the medulla is about 11μ thick, but for coarser fibres, the medulla diameter increases rapidly until the fibre diameter is about 100μ when the medulla diameter is about 85μ. The relationship between the two diameters seems to be of a logarithmic nature. For fibres thicker than 100 μ dia, the medulla seems to occupy 95% of the fibres volume, thereby reaching its maximum. As this relationship is rather consistent, the medulla diameter can be roughly estimated if the fibre diameter is known (Table 5).

There appears to be little or no relationship between: (a) fibre diameter and total length of medullated fragments (b) fibre diameter and the frequency of the fragments and (c) total length of the fragments and their frequency.

As an additional observation, some early reports[5–7] of the unusual occurrence of a multiple medulla are confirmed in the case of carpet wools.

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References

1. S.M.A. Shah and K.J. Whiteley, J. Textile Inst., **37,** T286 (1966).
2. S.M.A. Shah and A.H. Mohsin, Pakistan J. Sci. Ind. Res., **13,** 134 (1970).
3. S.M.A. Shah, Mumtaz Fatima and A.H. Mohsin, Pakistan J. Sci. Ind. Res., **14,** 550 (1971).
4. R.A. Fisher, *Statistical Methods for Research Workers* (Oliver & Boyd, London, 1958), thirteenth edition, pp. 197.
5. T.D. Brown and W.J. Onions, Nature, **186,** 93(1960).
6. G. Jones, Nature, **193,** 1001 (1962).
7. J.M. Doney and W.F. Smith, Nature, **195,** 723 (1962).