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STABILITY AND MODIFICATIONS OF WOOL CRIMP AND THEIR EFFECTS ON FELTING AND COMPRESSION

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Samples of two wools Merino and Southdown differing widely in crimp form were treated in ether, alcohol, water at 21°C and 40°C, sodium iodide, formic acid and thioglycollic acid and their crimp parameters measured. Felting and compressional tests were also carried out on these treated wools. The relationships among felting, compressional load and crimp form were investigated.

Woods[1] in 1935 emphasised that fibres within the staple are generally in a state of strain, due to the closeness of packing within the fleece. He defined "cohesive set" which can be removed by immersing a wool fibre in cold water and "temporary set" which is removed by application of water at a higher temperature than that at which the effect was produced. When these two sets have been removed, the fibre is in "structural form". Goldsworthy and Lang[2] demonstrated that coiling of wool fibres immersed in different liquids is due to the relaxation of pre-existent strains in the fibre. They argued that the strain could be resolved into reversible and non-reversible effects so that coiling could occur during both wetting and drying. Horio and Kondo[3] have shown that wool fibres are bilateral in their cortical structure and that the coiling properties of the wool fibre originate from the dual structure.

In the past, three different forms of crimp have been suggested, namely twisted sine wave, helix and sine wave.[4–6] Further, it has been shown recently that crimp form plays an important part in felting and compressional properties of wool fibre.[7,8] The present work was undertaken, firstly, to study the effect of hydration and swelling agents on the form of crimp and, secondly, to study the felting and compressional properties of wool treated in various liquids.

Materials and Methods

Two different types of wool Merino 64s (predominantly sine form) and Southdown wool (predominantly helical form) were selected and the following tests were carried out.

Crimp Form in Different Liquids.—Twelve fibres about 3–3.5 cm in length were withdrawn from staples for measurement of crimp form, crimp amplitude and crimp frequency.[9] After each treatment, the fibres were condition for 24 hr at 65% R. H. and the crimp parameters again measured.

The following is the order of treatment in different liquids:

1. Raw wool.
2. Diethyl ether at 21°C for 10 min.
3. Ethyl alcohol at 21°C for 10 min.
4. Water at 21°C for 1 hr.
5. Water at 40°C for 1 hr.
6. Sodium iodide 8.3M was used and the wool fibres treated overnight at 25°C and then thoroughly washed with distilled water.
7. Wool fibres were treated for half an hour with formic acid at 21°C (98%) and then washed with distilled water.
8. Thioglycollic acid (90%) was applied to the wool fibres for about 10 min at 21°C.

Compression Tests on Treated Wools.—The wool was hand-carded and randomized to minimize sampling differences and treated in different liquids as described above. Exactly 1g wool was placed in a cylinder 7.5 cm long and 3.47 cm internal diameter containing a freely moving piston and attached to an Instron Textile Tester fitted with automatic integrator. The speed of the piston was kept at 2 cm per min in the forward as well as in the reverse cycle. In use, the piston was lowered to a depth of 6.5 cm corresponding to a compression of 86% of the original volume. From the area of the graph, resilience was calculated.[10] The second cycle was commenced 1 min later and the wool was compressed through four cycles.

Felting Tests on Treated Wools.—The samples used for compression were also used for felting, after carding and conditioning.

Exactly 0.5 g wool was taken and put in a bottle together with 35 ml 0.1N HCl containing one drop of concentrated nonionic detergent. The felting machine designed by Blankenburg and Zahn[11] was used, the same position and jar being used in all the tests. Two balls were made from each sample. After felting for 1 hr, each felted ball was washed, dried and conditioned. The mean diameter of the felted ball was determined in three perpendicular directions on an enlarged image (×10).

Statistical Analysis.—A two-way analysis of variance was applied, using fibres as blocks and different liquids as treatments. The data was further split into 6 high and 6 low values. Duncan's multiple range test[12] was applied to show the significance of differences between treatments.

Results

The crimp form changes in different liquids for Merino wool are given in Table 1. There are small differences in mean amplitude for the different treatments, except in thioglycollic acid, where the amplitude is least, but crimps/in greatest. In Southdown wool also, the crimp score is almost the same in different liquids, with the exception of thioglycollic acid treatment during which there is a big decrease. There seems to be little change in crimps/in and amplitude in the various treatments for these wools, except in thioglycollic acid, where the amplitude is much smaller.

The mean results of compressional load for Merino wool are given in Table 2. The mean values refer to second, third and fourth cycle. As packing of the wool occurs in the first cycle it was excluded from the mean. There is no change in compressional load after ether and alcohol but there is a slight decrease after water at 21°C and 40°C, a noticeable increase after sodium iodide and a decrease after formic acid treatment. In Southdown wool, the compressional load is almost equal for ether, alcohol and water treatments at 21°C and 40°C, but decreases sharply after sodium iodide and again rises after formic acid. The felting of Merino wool shows small changes in the various liquids. In Southdown, however, the ball diameter is approximately the same after ether, alcohol, water 21°C and 40°C but decreases sharply after sodium iodide and formic acid.

TABLE 1.—MEAN CRIMP PARAMETERS OF MERINO AND SOUTHDOWN WOOL.

Treatment	Merino			Southdown		
	Crimp form (score)	Crimps/in	Amplitude (mm)	Crimps form (score)	Crimps/in	Amplitude (mm)
Raw wool	8.1	5·7	0·453	79·5	10·5	0·474
Ether	4·0	5·4	0·473	78.8	10.6	0·429
Alcohol	1.8	5·2	0·467	85.2	10.4	0·411
Water 21°C	4·0	5·0	0·467	64.2	10.4	0·428
Water 40°C	−7.6	5·4	0·448	65.6	10.3	0·439
Sodium iodide	−5·9	5·5	0·449	76.2	9.8	0·423
Formic acid	−3·7	5·0	0·445	83·3	9·7	0·393
Thioglycollic acid	−0·5	6.2	0·371	42.6	10.0	0·377

TABLE 2.—FELTING AND COMPRESSIONAL PROPERTIES OF MERINO AND SOUTHDOWN WOOL.

Treatment	Merino			Southdown		
	Ball dia (mm)	Comp. load (g)	Comp. res. (%)	Ball dia (mm)	Comp load (g)	Comp. res. (%)
Raw wool	19.10	786	27.1	30.81	1825	30·9
Ether	18.35	968	28.2	30.42	2333	32·3
Alcohol	18.45	968	30·3	30.61	2375	33·5
Water 21°C	19.07	926	31·4	30.40	2341	35·6
Water 40°C	18.94	890	32·3	30.14	2341	36·1
Sodium iodide	19.09	1030	31·7	28.02	2133	35·7
Formic acid	19.09	966	32.8	27.58	2241	35·2

It is clear from Table 3 that there are significant differences due to treatment in all the 12 fibres studied. It is also clear that fibres with high scores vary with the treatments to a much greater extent than fibres with low scores. Analysis of variance of Southdown amplitude (Table 4) shows the same behaviour as above except that the interaction is also significant.

Discussion and Conclusions

Effect of Different Liquids on Crimp Parameters.—Statistical analyses show that the crimp form of Southdown wool treated with thioglycollic acid differed significantly from that of raw wool and samples treated with ether, alcohol, sodium iodide and formic acid, but there was no significant difference in the case of Merino wool. Our results are thus in accordance with Wood's[1] work for Southdown wool, but in Merino although visually the fibres appeared to coil, crimp form measurement did not support this observation.

It is of interest to note that chemical treatments behave differently with high and low crimp score values. In Southdown wool, the six high score values are significantly affected, while the low values are not (Table 3). This was also found in Southdown crimp amplitude (Table 4), but not in crimp/in.

In Southdown, crimp amplitude of raw wool is significantly different from that after thioglycollic acid and formic acid treatments at the 1% level. Similarly, the amplitude as affected by water at 40°C is significantly different from that after thioglycollic acid treatment at the 5% level only. In the case of Merino, crimp amplitude obtained after thioglycollic acid treatment was significantly different from those obtained after the other treatments.

The results of crimp form (Table 1) show that wool fibres treated in water at 21°C and 40°C do not show helical forms as expected, but on the contrary, give sine forms. It should be pointed out that when Merino wool fibres were immersed in water, they began to curl and retained the new shape on drying. When small pieces of sticky paper were attached to each end of the fibre for crimp form measurement, however, the fibres were slightly stretched and did not retain the helical shape. In the case of Southdown wool which was already curly, there was no apparent difference. Goldsworthy and Lang[2] have applied a different technique for measuring the coiling of wool fibres in different liquids. They have shown that, in a Merino 80s, part of the coiling obtained after the first immersion in cold water is non-reversible and in addition, in successive drying and immersion, a reversible coiling is also exhibited.

Bulk Compression.—In compressional parameters, compressional load is important in determining the quality of wool.[13] From Table 2 it is clear that raw wool has the lowest compressional load. The thioglycollic acid treatment was not included in the table, as the wool became very weak and brittle on drying.

The compressional load in Southdown wool is fairly constant in ether, alcohol, water at 21°C and 40°C, whereas in Merino wool, it is constant in ether and alcohol, but decreases in water at 21°C and 40°C. It should be noted that when a single Merino wool fibre is immersed in water, it is free to move in any direction, but if a bulk of carded wool is put in water, the individual fibres are not free to move and the material may or may not exhibit the same coiling as individual fibres, depending upon the free space available and the swelling of the ortho-cortex.

The results of compressional load agree with the crimp form (score) values i.e. high crimp score gives higher compressional load and low crimp score gives low compressional load in water up to 40°C. The resilience of both wools increases steadily from ether to water at 40°C.

Supercontraction and Swelling.—The results of compressional tests after sodium iodide treatment indicate an opposite trend in the two wools (Table 2). In Southdown wool, compressional load decrease, whilst it increases in Merino wool. This has been explained as follows:-

In Figure 1, state a shows the bilateral structure of the untreated wool fibre, with the ortho-cortex on the outside. State b shows the preferential supercontraction of ortho-cortex which has straightened the fibre. Further supercontraction of ortho-cortex has caused the fibre to coil up again, but with the ortho-cortex on the inside of the crimp (state c). In Southdown wool, the fibres tended to straighten, showing lower compressional load. Merino wool fibres, apparently supercontracted to a greater extent in the ortho-cortex as they appeared to coil and failed to recover on washing,[14] thus giving a high compressional load.

In formic acid, maximum swelling (70%) occurs without damage. From Table 1, it is evident that there are small differences in crimp score after formic acid treatment in Merino and Southdown wool. The felting results correspond with the

TABLE 3.—ANALYSIS OF VARIANCE SOUTHDOWN WOOL (CRIMP FORM) TREATED WITH DIFFERENT LIQUIDS.

Fibres	Source of variation	Degree of freedom	Sum of squares	Mean square	F
12 fibres	Treatment	7	16668.0	2381.1	3.15**
	Fibres	11	13746.1	1249.6	
	Error	77	58183.3	755.6	
	Total	95	88597.4		
6 high values	Treatment	7	20155.9	2879.4	3.29**
	Fibres	5	4568.7	913.7	
	Error	35	30614.9	874.7	
	Total	47	55339.5		
6 low values	Treatment	7	5926.4	846.6	1.63
	Fibres	5	4141.6	828.3	
	Error	35	18154.0	518.7	
	Total	47	28222.0		
Interaction	Fibre groups	1	5035.7	5035.7	
	Fibre within groups	10	8710.3	871.0	
	Treatments	7	16668.0	2381.1	3.42**
	Interaction (Treatment x group)	7	9414.4	1344.9	1.93
	Error	70	48768.9	6966.9	

**Significant at 1% level.

TABLE 4.—ANALYSIS OF VARIANCE SOUTHDOWN (AMPLITUDE) TREATED WITH DIFFERENT LIQUIDS.

Fibres	Source of variation	Degree of freedom	Sum of squares	Mean square	F
12 fibres	Treatment	7	0.0721	0.0103	2.38**
	Fibres	11	0.1890	0.0172	
	Error	77	0.3328	0.0043	
	Total	95	0.5939		
6 high values	Treatment	7	0.1311	0.0186	5.46**
	Fibres	5	0.0582	0.0166	
	Error	35	0.1191	0.0034	
	Total	47	0.3084		
6 low values	Treatment	7	0.0142	0.0020	0.50
	Fibres	5	0.0475	0.0095	
	Error	35	0.1416	0.0040	
	Total	47	0.2033		
Interaction	Fibre groups	1	0.0835	0.0835	
	Fibre within groups	10	0.1055	0.0105	
	Treatments	7	0.0721	0.0103	2.77**
	Interaction (treatment x group)	7	0.0721	0.0103	2.77**
	Error	70	0.2606	0.0037	

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

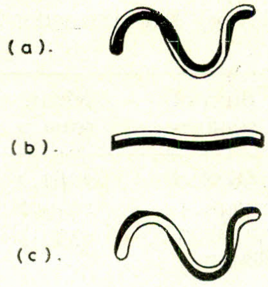

Fig. 1.—White=Orthocortex
Black =Para-cortex

crimp score results. The compressional load drops in Merino wool and increases in Southdown in formic acid treatment, probably due to variations in the stability of orthocortex fraction in the different samples.

Relationships among Crimp Form, Felting and Compressional Load.—In drawing overall conclusions about the interrelationships of these variables, a number of limitations should be kept in mind. The crimp form (score) is only approximate owing to the limited number of fibres measured. Felting and particularly compression are much more reliable measures, but there are definite problems, involved in preparing comparable "random assemblies" after chemical treatments. In addition, in the case of felting sine form fibres, we are clearly approaching a felting limit (for example a solid ball of keratin (specific gravity of 1.31) should have a diameter of 0.45 mm which could not be expected to be very sensitive to small changes in parameters. This does not apply to fibres of helical form. In Southdown wool, larger fluctuations in form do not result in appreciable changes in felting. It is also clear that crimp score is not related to felting and compressional load in all the treatments. However, using the two most reliable estimates and not restricted by any approach to a felting "limit", the large variations in felting and compressional load do follow similar trends as suggested elsewhere.[15]

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