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by

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CORRELATION OF CERTAIN PROPERTIES OF RAW WOOL WITH THE DETERGENT REQUIREMENTS DURING SCOURING

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ABSTRACT

An attempt to correlate certain properties of raw wool with the detergent requirements during scouring was made during a study involving a wide range of South African fleece wools. It was shown that 77% of the variation in detergent requirements could be accounted for by measurement of five different parameters, viz. the solid dirt content, the particle size of the dirt, the entanglement of the tip portion of the staple, the pH of the suint and the yield.

INTRODUCTION

During a recent investigation which was carried out to study the processing performance during topmaking of wools from a range of breeds it was found that 35% of the variation in detergent requirements during scouring could be accounted for by crimp and yield[1]. Overcrimping led to a considerable increase in detergent requirements although the effect became slightly less pronounced as the wool became coarser. The reason for the dependence of detergent consumption on crimp was not clear. The poor fit, although statistically significant, was not very useful.

Scouring in the abovementioned investigation was carried out in a one-foot wide four-bowl Petrie & McNaught pilot scale scouring plant. Thirty different lots of raw wool, each of 70kg clean mass, were scoured, the total scouring time for each lot being 81 minutes.

The scouring bowls were charged with the same amount of non-ionic detergent (® Berol Lanco) and soda ash for each lot. After every 13,5 minutes of scouring time a specific amount of soda ash was added to the liquor in the first bowl. At the same time detergent was added to the liquors in the first, second and third scouring bowls so as to produce an average residual grease level of around 0,4% on the wool emerging from the dryer. The average amount of detergent added per 13,5 minute interval was found to vary from zero to 520 mℓ for the different wool lots and it was *this* value that was used in a multilinear regression analysis with mean fibre diameter, crimp, classing length and yield as independent variables. Only crimp and yield contributed significantly to the detergent consumption.

It was suggested that crimp may have been only a manifestation of certain other parameters which affect detergent consumption. It was decided to measure a number of additional parameters on twenty of the above lots in an attempt to throw some light on this anomaly and to obtain a more useful fit to the data.

EXPERIMENTAL

The following tests were carried out on the raw wool to supplement those carried out previously:

Grease content
Methanol-insoluble matter content
Suint content
pH of suint
Solid dirt content
Particle size of the dirt
Entanglement of the tip of the staple.

The particle size of the dirt and the dirt content of the wool were measured during a separate investigation into the particle size distribution of dirt in South African fleece wools, this information being required for effluent studies[2]. The particle size of the dirt was characterised by the pore size of the membrane which was required for 95% rejection of the dirt which had been removed from the wool and suspended in a suitable solvent mixture.

A test was devised to measure the entanglement of the tip of the staple as follows. A staple of wool was selected from a bulk sample at random, and after its greasy mass had been determined was clamped in the jaws of the SAWTRI withdrawal force tester[3] and a comb inserted into the staple next to the clamp in the normal way. The comb, however, consisted of only a single row of pins. (This row contained 4,5 pins/cm). Furthermore, the staple of wool was so clamped that the row of pins penetrated the staple 3 cm from the tip, the staple being in an unstretched condition. The maximum force of withdrawal was noted in the usual way but this force was expressed in relation to the bone dry clean mass of fibre in the staple calculated from values for the staple mass and scoured yield. A few initial tests were carried out prior to the commencement of this experiment and it was established that relative differences in the force required to disentangle the tip of 20% or more could be expected to be detected if 20 separate staples were submitted for test and the mean result taken. Accordingly, the above test was repeated 20 times. Very narrow or very wide staples were avoided.

All the other abovementioned tests were carried out in the normal manner.

RESULTS AND DISCUSSION

Results of the various tests which were carried out, together with the symbols used in the statistical analyses, are shown in Table I.

Initially, before all the above results were known, a multilinear regression analysis was carried out in which the detergent additions (Y_1) were expressed as a function of X_1, X_2, X_3, X_4 and X_5. The diameter terms (X_1) was discarded in the early stages of the regression as making no significant contribution to the correla-

TABLE I

RESULTS OF VARIOUS TESTS CARRIED OUT ON THE RAW WOOL TOGETHER WITH THE RELEVANT SYMBOLS USED IN THE STATISTICAL ANALYSIS

Lot No.	Mean Fibre Diameter (μm)	Crimp/CM	IWTO Scoured Yield (%)	Solid Dirt content (%)*	Particle size of dirt (μm)	Total Grease (%)*	Suint (%)*	Methanol Insoluble matter (%)*	pH of Suint	Force to Disentangle the Tip (cN/g)*	Total grease on mass of raw wool (%)	Methanol insoluble fraction of the grease (%)	Suint on mass of raw wool (%)	Average classing length (months)	Reciprocal of average classing length	Detergent addition (ml per 13,5 min. interval)
1	19,4	6,2	65,4	9,9	2,1	41,8	11,7	19,7	6,3	201,7	23,4	47,0	6,5	12,0	0,083	156
2	20,1	5,2	67,6	8,2	1,8	32,9	11,8	14,3	6,2	152,5	19,0	43,5	6,8	12,0	0,083	260
3	20,1	4,4	73,0	6,2	1,2	24,3	14,6	10,4	6,8	109,0	15,2	42,9	9,1	12,0	0,083	416
4	20,6	5,8	68,2	8,5	0,6	29,4	7,7	12,8	6,7	201,8	17,1	43,4	4,5	11,5	0,087	520
5	21,3	4,6	69,9	5,9	1,5	36,2	7,9	20,8	5,5	96,8	21,6	57,4	4,7	12,0	0,083	312
6	21,4	4,8	64,6	10,0	0,8	29,9	11,7	12,4	8,3	176,8	16,5	41,5	6,5	12,0	0,083	52
7	21,6	4,8	67,3	7,9	2,1	19,4	19,9	8,4	7,4	107,0	11,2	43,2	11,4	12,0	0,083	104
8	21,8	3,8	70,3	11,9	4,4	27,3	11,7	12,3	6,6	103,3	16,4	45,1	7,0	12,0	0,083	26
9	22,0	6,5	68,7	8,0	2,0	21,9	10,4	6,0	6,8	163,6	12,9	27,5	6,1	12,0	0,083	156
10	22,2	3,5	73,8	6,2	1,9	25,4	8,1	11,2	5,8	134,1	16,0	44,0	5,1	12,0	0,083	312
11	22,9	5,3	65,0	12,1	1,8	31,1	7,1	14,6	6,1	153,5	17,3	41,1	3,9	11,5	0,087	104
12	24,3	4,8	66,9	10,6	0,8	28,8	11,9	13,5	7,2	158,9	16,4	46,9	6,8	14,0	0,071	156
13	24,4	3,3	67,9	15,7	3,5	17,8	13,6	8,1	6,3	101,4	10,3	45,7	7,9	11,5	0,087	52
14	24,6	3,0	74,0	7,4	3,7	25,8	8,3	12,1	5,9	119,7	16,3	46,8	5,3	10,0	0,100	26
15	25,1	4,1	70,9	6,4	3,2	24,4	12,9	7,3	7,1	142,5	14,8	30,1	7,8	14,0	0,071	208
16	25,4	3,8	65,1	22,2	5,4	41,5	8,2	19,2	5,9	126,2	23,1	46,3	4,5	10,0	0,100	39
17	25,7	3,0	74,6	7,7	1,6	22,0	8,1	8,9	6,2	108,2	14,0	40,3	5,2	14,0	0,071	260
18	26,7	2,6	70,6	11,4	2,6	30,0	10,3	10,5	6,7	144,6	18,1	34,9	6,2	11,0	0,091	130
19	27,8	3,6	66,6	14,5	6,9	19,9	19,7	8,6	8,1	147,6	11,3	43,4	11,2	10,5	0,095	78
20	28,8	2,9	68,9	12,0	2,1	33,0	16,0	15,4	6,9	122,7	19,4	46,7	9,4	14,0	0,071	0
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	Y_1

* Expressed on bone dry clean fibre

tion. The following equation was found to be significant at the 95% level of confidence:-

$$Y_1 = 85{,}88\ X_2 + 31{,}21\ X_3 - 2353{,}2 \quad \ldots\ldots (1)$$

$n = 20$; $r = 0{,}69$.

The above equation showed that 47% of the variation in detergent requirements could be accounted for by variation in the crimp frequency and the yield, compared with the 36% which was accounted for by these same two parameters when all the original 30 lots were studied in the earlier investigation[1]. The particle size of the dirt did not make a sufficiently high contribution to the correlation to form part of the regression equation, but when a further regression was carried out in which Y_1 was regressed against X_2, X_3, X_5, X_3X_5 and X_2X_5 it played a significant rôle and a much improved fit to the data was obtained.

The following equation was derived, and was found to be significant at the 99% level of confidence:-

$$Y_1 = 204{,}2\ X_2 + 70{,}9\ X_3 + 1453{,}1\ X_5 - 17{,}94\ X_3X_5 - 68{,}74\ X_2X_5 - 5459{,}3 \quad \ldots\ldots (2)$$

$n = 20$; $r = 0{,}84$.

The above equation accounted for 71% of the variation in detergent requirements.

At this stage the results for the remaining additional tests were at hand and it was decided to substitute each in turn for crimp and to carry out the same regressional procedure as for equation (2). When Y_1 was regressed against X_6, X_3, X_5, X_3X_5 and X_6X_5 or against X_7, X_3, X_5, X_3X_5, and X_7X_5 or against X_8, X_3, X_5, X_3X_5 and X_8X_5 the terms involving the grease and suint contents of the raw wool, and the methanol insoluble matter content of the raw wool were rejected as not making a significant contribution to the regression. When Y_1 was regressed against X_9, X_3, X_5, X_3X_5 and X_9X_5 the following equation was found to be significant at the 99% level of confidence:

$$Y_1 = -126{,}98\ X_9 + 19{,}374\ X_3 - 4{,}723\ X_3X_5 + 38{,}178\ X_9X_5 - 149{,}135 \quad \ldots\ldots (3)$$

$n = 20$; $r = 0{,}78$

This equation gave a 60% fit to the data and was, therefore, not as good as equation (2), but when Y_1 was regressed against X_{10}, X_3, X_5, X_3X_5 and $X_{10}X_5$ the following equation was found to be significant at the 99% level of confidence, and gave a fit which could be regarded as more or less equivalent to that obtained in equation (2).

$$Y_1 = 1{,}7805\ X_{10} + 63{,}625\ X_3 + 1146{,}45\ X_5 - 17{,}510\ X_3X_5 - 4320{,}85 \quad \ldots\ldots (4)$$

$n = 20$; $r = 0{,}82$;

It seemed likely, therefore, that as far as detergent requirements were

TABLE II
CORRELATION COEFFICENT 'r' BETWEEN X_2 (CRIMP) AND VARIOUS OTHER PARAMETERS OF THE RAW WOOL.

Parameter	r
X_1 Diameter	–0,73
X_2 Crimp	1,00
X_3 Yield	–0,51
X_4 Dirt content	–0,23
X_5 Particle size	–0,42
X_6 Grease content	0,24
X_7 Suint content	–0,10
X_8 Meth insol. content	0,17
X_9 pH of suint	0,09
X_{10} Force to disentangle the tip	0,63

concerned, crimpiness in the wool played a rôle which could more or less be equated with the rôle played by the degree of entanglement of the tip. It is clear, in fact, from the correlation coefficient values given in Table II, that apart from diameter which was obviously correlated well with crimp over the wide range of wools studied here, the entanglement of the tip was the most highly correlated parameter. It is also of interest to note from these correlations that higher values for crimp were correlated with smaller particle size of the dirt, i.e. with finer dust. The reasons for this have not yet been investigated.

Although yield, particle size and tip entanglement provided a fairly good fit to the data as seen in the above equation, still some 32% of the variation in detergent requirements were not accounted for. Modifications to the model were made in an attempt to improve the fit without making the model too complex. The pH of the suint was obviously of some importance, as seen in equation (3), and it was found that by bringing in an interaction term involving the pH of the suint and the dirt content, i.e. by regressing Y_1 against X_9X_4, X_{10}, X_3, X_5 and X_3X_5 the following equation was found to be significant at the 99% level of confidence and gave a 76% fit to the data:-

$$Y_1 = -3{,}003\,X_9X_4 + 1{,}572\,X_{10} + 54{,}458\,X_3 + 1361{,}158\,X_5 - 20{,}292\,X_3X_5 - 3315{,}45 \qquad (5)$$

$n = 20$; $r = 0{,}87$.

A further improvement in the fit to 77% was obtained by substituting X_{10}^2

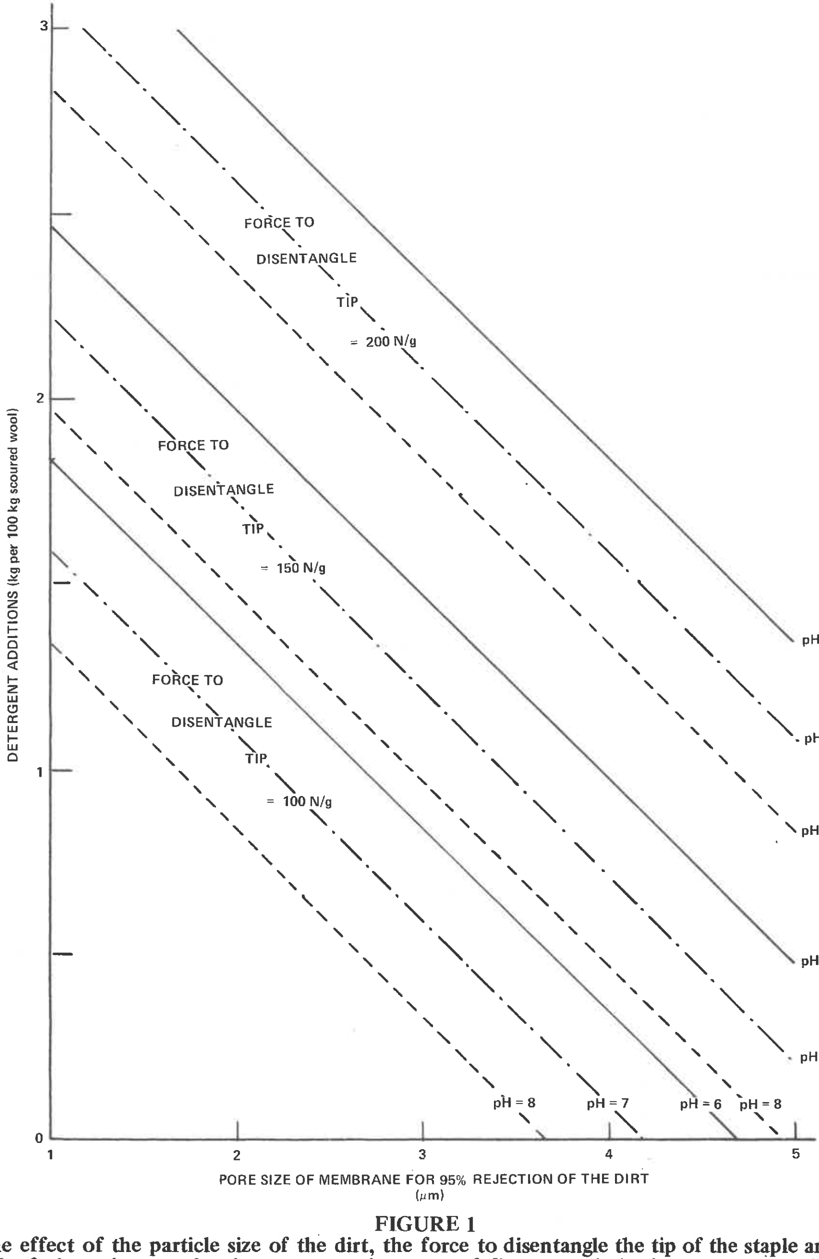

FIGURE 1

The effect of the particle size of the dirt, the force to disentangle the tip of the staple and the pH of the suint on the detergent requirements of fleece wools having an average yield of 70% and a dirt content of 10%.

for X_{10} in the above regression, the following equation being obtained:-

$$Y_1 = -2{,}911\,X_9X_4 + 0{,}0058\,X_{10}^2 + 55{,}608\,X_3 + 1360{,}09\,X_5 - 20{,}263\,X_3X_5 - 3502{,}61 \qquad (6)$$

$n = 20$; $r = 0{,}88$.

Attempts to improve the fit still further by carrying out the same regression as the above, but with an additional term introduced into the analysis, failed. Those parameters which were selected as the sixth independent variable were X_6, X_7, X_8, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_9X_{14} and finally, X_2. It was concluded that equation (6) therefore represented the data as best as could reasonably be obtained. It was shown furthermore, that as crimp (X_2) did not significantly improve the fit, its rôle had been successfully equated by other variables with which it had been manifested.

A practical interpretation of equation (6) can be obtained by considering an average fleece wool yield of 70% and an average dirt content of 10%. Under these conditions equation (6) reduces to:-

$$Y_1 = -29{,}11\,X_9 + 0{,}0058\,X_{10}^2 - 58{,}32\,X_5 + 389{,}95 \qquad (7)$$

This equation can be re-written:

$$Y_2 = -0{,}25\,X_9 + 0{,}00005\,X_{10}^2 - 0{,}50\,X_5 + 3{,}34 \qquad (8)$$

where Y_2 represents the detergent additions made in kg per 100 kg of clean wool.

Equation (8) has been graphically represented in Fig 1 for a practical range of staple tip entanglement, practical range of pH of the suint, and a practical range of particle size. It must be remembered that the duration of the scouring period was comparatively short and that the rates of addition of detergent shown apply specifically to this period. It does not necessarily imply that equilibrium conditions have been reached. The graph does serve to illustrate, however, the importance of the particle size of the dirt, the entanglement of the tip, and the pH of the suint in the consumption of detergent.

SUMMARY AND CONCLUSIONS

An attempt to correlate certain properties of raw wool with its detergent requirements during scouring was made during a study involving a wide range of S.A. fleece wools. Initially the parameters mean fibre diameter, crimp, classing length and yield were used as independent variables in a multilinear regression analysis and it was shown that crimp and yield accounted for 35% of the detergent requirements. (The detergent used was Berol Lanco). It was suggested that crimp may have been a manifestation of other parameters which affect detergent consumption and a number of additional properties of the raw wool were measured to throw some light on this anomaly and to improve the percentage fit.

It was shown that 77% of the variation in detergent requirements could be accounted for by the following parameters, listed roughly in their order of importance in the average case:-

1. Solid dirt.
2. Particle size of the dirt in the fleece characterised by the pore size of the membrane required for 95% rejection of the dirt.
3. Entanglement of the tip portion of the staple.
4. pH of the suint.
5. Yield.

Higher values for crimp were significantly correlated with higher entanglement of the tip portion of the staple and were also correlated with finer particle size of the dirt.

THE USE OF PROPRIETARY NAMES

® Berol Lanco is the proprietary name of Messrs Berol Kemi Sweden. The fact that chemicals with proprietary names have been mentioned in this report does not in any way signify that SAWTRI recommends them or that there are not substitutes which are of equal or better value.

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REFERENCES

1. Turpie, D. W. F., The Processing Characteristics of South African Wools, Part XIV : The Processing Performance during Topmaking of Wools from a Range of Breeds. *SAWTRI Techn. Rep.* No. 374 (Oct. 1977).
2. Turpie, D. W. F., and Mozes, T. E., Treatment of Wool Scouring Liquors, Part VIII : The Particle Size Distribution of Solid Dirt Particles in a range of South African Fleece Wools, *SAWTRI Techn. Rep.* No. 384 (Dec. 1977).
3. Kruger, P. J., The SAWTRI Withdrawal Force Tester. *SAWTRI Bulletin,* **6**, 1, 9 (March, 1972).

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