A Report for IWTO

A Study of the Effect of Grease Content on Staple Strength

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Abstract

Wool staple strength (SS) is one of the key raw wool characteristics. In commercial testing, SS is measured on greasy wool staples. Yet the strength of clean wool staples should be more accurate in reflecting the strength of individual wool fibres. In this study, staples from two fleeces of Australian Merinos were sampled to examine the effect of grease content (GC) on wool SS. Wool properties such as SS, fibre diameter (FD), and GC were measured before and after scouring. The results indicate wool SS differs significantly between washed and unwashed samples, as well as for samples scoured with different methods. GC has a negative correlation with SS ($r=-0.772$, $p<0.01$) and can explain about 60% SS in the linear regression equation.

Key words: staple strength (SS), fibre diameter (FD), scouring, grease content (GC)

1. Introduction

In 1985, the Australian Wool Corporation commenced objective pre-sale staple strength (SS) testing of Merino wools (Baird 1984), because some studies had found that staple strength of a greasy wool staple was a valuable commercial indicator of potential processing performance (Rottenbury and Andrews 1983; Douglas 1984; Ainsworth 1989), especially in predicting top properties such as mean fibre length (SL) (Hauteur) and the amount of noil removed. Staple strength is now measured objectively by determining the maximum force required to break a greasy staple (expressed in Newtons/kilotex (N/ktex)) (Gordon and Donnelly 1979; Heuer 1979; Rottenbury 1979).

Staple strength is affected by many environmental and physiological factors (Ryder and Stephenson 1968; Corbett 1979), which include seasonal variation in feed supply, higher nutritional requirements during pregnancy/lactation and high growth periods for young sheep, some physiological stress like flystrike or infection. A large reduction in the supply of nutrients absorbed by sheep will reduce fibre diameter and result in a weaker region of the staple because of the reduced amount of keratin material present (Reis 1992). The time of shearing also has an influence on the staple strength.

Wool staple strength can vary from 0 to 90 N/ktex. It is generally been regarded as “tender” when the staple breaking force is less than 25N/ktex (Hunter et al. 1983; Ralph

1986; Rogan 1988). Low staple strength has implications for processing as it may lead to increased fibre breakage and noil content.

Fibre diameter is the most important characteristic for wool fibres. For Merino wool, staple strength can be influenced by variations of fibre diameter both along and between fibres (McKinley et al. 1976; Denney 1990; Hansford and Kennedy 1990a; Ritchie and Ralph 1990). Hansford and Kennedy (1988, 1990a) found that the rate of change in diameter along fibres was more important in determining staple strength than minimum fibre diameter. The greater the variation is, the lower the strength. Hunter et al. (1983) concluded that tenderness in Merino wool was associated with reductions in both fibre diameter and the intrinsic strength of the fibres.

Raw or "greasy" wool contains impurities such as grease or wax, suint, vegetable matter and dust. Wool grease is produced by the sebaceous glands in the skin of sheep and it can protect wool from dust and water penetration (Thornberry et al. 1980). Wool grease is comprised principally of high molecular weight esters formed from a mixture of sterols and aliphatic alcohols with straight and branched chain fatty acids. There are many scouring methods to wash and remove the grease of wool. Most commonly used are neutral non-ionic detergent and organic solvent.

In current commercial wool testing, measurement of staple strength is conducted on greasy wool rather than clean wool. In this study, the effect of grease on wool staple strength was examined.

2. Experimental

2.1 Materials and Sample Preparation

Two fleeces were collected from the Gordon Institute of TAFE, named as coarse wool (CW) and fine wool (FW) in this study. The fleeces were spread on a large table and approximately 120 tufts of each fleece were randomly selected. Three staples were chosen from each tuft and then separated into Group A, Group B and Group C respectively. Staples in Group A were scoured for fibre diameter (FD) testing, Groups B and C were used for comparative experiments: 1) Group B was for testing greasy staple strength (SS) (by Lloyd Tensile Instrument), fibre diameter (FD) (by OFDA2000) and grease content (GC) (by Soxhlet Extractor), and the Group C was scoured and then tested like Group B except for the grease content (GC) measurement. Both greasy and washed staples were labelled and stored in trays to allow the staples to relax. All samples were kept in the conditioned laboratory for 24 hours prior to testing at the temperature of 20±2°C and relative humidity of 65±3%. Since every staple has different length, in order to simplify the measurement and ignore the effect of staple length, only 72mm length from tip was reserved for FW and 92mm for CW and the rest of the staple was cut off by a guillotine. Staples with a length less than 72mm or 92mm were removed from the trials.

2.2 Methods

2.2.1 Wool Scouring

All samples from Group A and half of Group C were scoured by organic solvent and the other half of Group C were scoured by neutral detergent.

Method 1-Organic Solvent Scour Method

The organic solvent used is comprised of 20% isopropanol and 80% hexane. Two glass beakers were used as scouring bowls, and one litre of solvent was filled into both beakers. The staple was clamped by a tweezers, wetted and swayed for about one minute in the solvent of beaker No.1 at room temperature; residual solvent was removed by a piece of large tissue paper after the staple was taken out of the first beaker; the procedures were then repeated for the staple in beaker No.2. After solvent scouring, the staples were laid in trays and left to recover in the fume hood to ensure the complete evaporation of solvent before the samples were conditioned in a controlled laboratory (20±2°C, 65±3% R.H.) for a minimum 24 hours. Solvent was recycled after certain sediment (dust and grease) had settled at the bottom of the beaker.

Method .2-Aquerous Scour Method with Neutral Detergent

Sorpol 4488 detergent, with a concentration of 1%, was used in the study. Four glass beakers were used as scouring bowls and liquors in these beakers were controlled at different temperatures: 65°C, 65°C, 50°C and 45°C respectively. The detergent was added to the first and the second beakers only for scouring, and water was used in the other two for rinsing. The tip of the staple was held by a pair of tweezers, and the staple was wetted and swayed for about 1 minute in the first beaker with detergent, then pressed by tissue papers to remove the extra liquor from the staple, and moved on to the remaining beakers. Samples were dried in air first and then conditioned in a controlled environment (20±2°C, 65±3% R.H.) for a minimum 24 hours.

2.2.2 Fibre Diameter Profile (FDP) Measurement

In Group A, 120 staples were scoured in a mixture of isopropanol and hexane as per the rations recommended by the OFDA2000 manual and measured by OFDA 2000 in the mode of standard fibreglass slide, at a scanning interval of 5mm with the grease content factor (GCF=1.1) off. Some measured properties of the staples included mean fibre diameter (MFD), coefficient of variation of fibre diameter (CVFD), comfort factor (CF) (percentage of fibres finer than 30μm), coefficient of variation of fibre diameter along staple (AL_CVD) and coarse edge microns (CEM).

2.2.3 Staple Strength (SS) Testing

Staple Strength (SS) measurements were performed on a Lloyd Tensile instrument, with Group B as “greasy staple” and Group C as “clean staple” (after washing). All tests were conducted in the conditioned laboratory (20±2°C, 65±3% R.H.). The staple was placed between two clips and was griped at both tip and base. The top clip moved up and the staple was extended to break (gauge length was set to 40mm for FW and 60mm for CW) at the extension rate of 50mm/s according to the standard IWTO-30-93. The peak force required to break the staple was recorded. Staple mass was weighed before and after strength testing. Linear density (ktex) is calculated by mass of per unit staple length. The value of peak force is divided by linear density to give a staple strength value (N/ktex). The extension-load curve was replotted from exported data points from the computer attached to the testing machine.

2.2.4 Grease Extraction

Grease content was measured for the Group B staples by a Soxhlet Extractor with ethanol as the solvent. Five groups of staples from both FW and CW were separated according to the fibre diameter measured by OFDA2000 to examine differences of grease content in different fibre diameter groups. Staples were dried in an oven at a temperature of 105°C and weighed as W_1. Then, each group of the staples was extracted off the grease according to the IWTO standard (IWTO-19-98). After extraction, oven-dried samples were weighted as W_2 to calculate the grease content:

$$Grease\,content = \frac{W_1 - W_2}{W_1} \times 100\%$$

3. Results and Discussion

3.1 Fibre Diameter Profile (FDP)

The FDPs of scoured FW and CW such as FD, CVFD, CEM, CF and AL_CVD are summarized in table 1.

Table 1. Scoured wool properties for FW and CW

Wool Type		FD (μm)	CVFD (%)	CEM (μm)	CF (%)	AL_CVD (%)	CUR (deg/mm)
FW	Mean	17.12	17.99	6.14	99.70	5.39	88.33
	Std. Deviation	0.93	1.53	0.77	0.29	1.12	7.42
	Minimum	15.70	14.20	4.80	98.50	3.24	68.40
	Maximum	19.70	21.10	8.00	100.00	8.05	107.10
	Variance	0.87	2.34	0.60	0.08	1.25	55.12
CW	Mean	24.33	17.84	7.86	91.77	5.88	52.79
	Std. Deviation	1.07	1.65	0.93	4.17	1.24	5.83
	Minimum	21.94	14.60	5.90	81.80	3.35	40.80
	Maximum	26.42	23.30	10.80	99.00	10.01	70.30
	Variance	1.14	2.73	0.86	17.38	1.53	33.96

Table 2. Mean difference and Sig. of scoured wool properties for FW and CW

	Mean Difference (FW-CW)	Significance (a)
FD(μm)	-7.208(*)	.000
CVFD(%)	.150	.506
CEM(μm)	-1.725(*)	.000
CF(%)	7.923(*)	.000
AL_CVD(%)	-.486(*)	.004
CUR(deg/mm)	35.540(*)	.000

* mean difference is significant at 0.05 level ($p<0.05$)

There are some significant differences among FD, CEM, CF and AL_CVD between fine wool and coarse wool ($P<0.05$), especially for MFD (7.21 μm) and CF (7.92%), but no evident difference was found for CVFD (See Table 2).

Curves of fibre diameter distribution along staple length for both FW and CW are shown in Figure1. In common, breakage will occur under the external force at the thinnest point of fibre. Both wools show reduced FD near middle which probably is the location of position of break (POB). POB is the percentage of staples which break in the tip, middle and base of the staple. The worst case is a break in the middle, because it will reduce top Hauteur length. POB will not be discussed in this study, because staples were cut for the same length within each fleece.

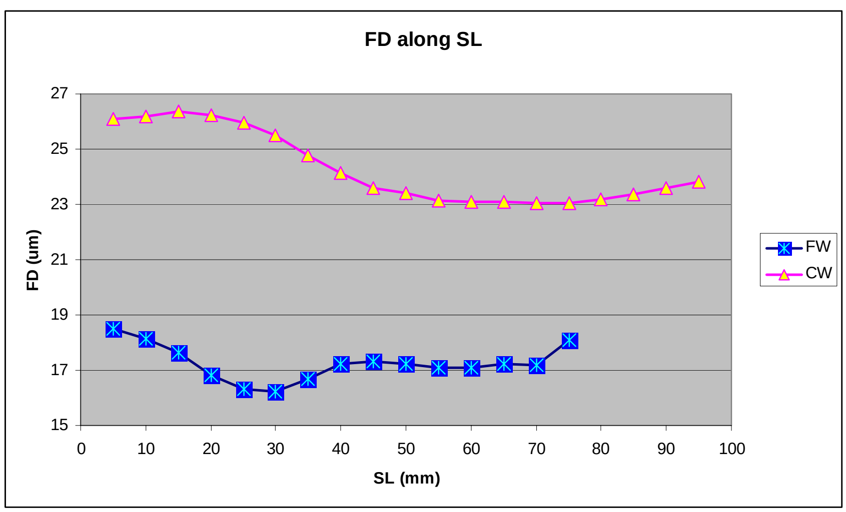


Figure1. FD along SL

3.2 Staple Strength (SS)

Mean Difference

Univariate analyses of variance were conducted, using the SPSS program, on staple strain and SS with different main factors as independent variables.

Both staple strain and strength show significant differences ($p<0.05$) among the two wool types (FW and CW). SS is increased with FD which is consistent with the result of Anderson and Cox (1950). Staple strain of FW is higher than that of CW. This would be expected because the curvature of FW is higher than that of CW.

Mean differences for staple strain and SS of FW and CW between washed and unwashed staples were summarized in Table3. There are significant differences for both of them at the 0.05 confidence level. Mean SS of the unwashed wool is lower than the washed one. After washing, grease, suint and some dust were removed and hence staple mass reduced, which would reduce the staple linear density. Because SS is the force per unit linear density, consequently, SS of the washed staple will be higher than that of unwashed staple. An evidently low staple strain was found for both FW and CW after washing.

Table3 Mean difference of staple strain and SS for FW and CW between washed and unwashed staples and different scouring regimes

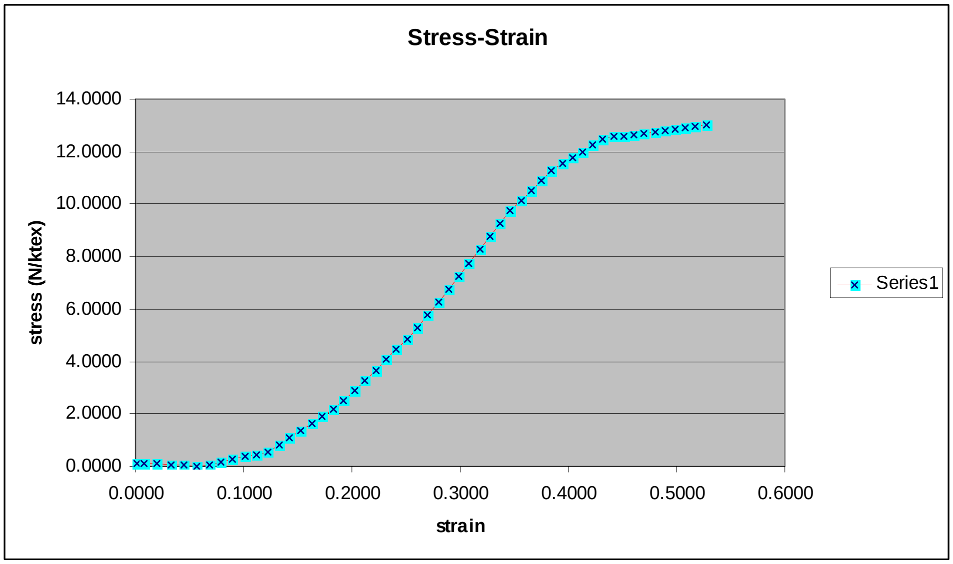
		Unwashed mean	Washed mean	Mean difference (unwashed-washed)	Sig.	Mean		Mean difference (SSM-ASM)	Sig.
						ASM	SSM		
FW	Strain	57.28	19.06	38.22(*)	.000	16.33	21.95	5.62(*)	.000
	SS	15.85	17.83	-1.97(*)	.000	16.27	19.48	3.21(*)	.000
CW	Strain	36.54	28.53	8.01(*)	.000	26.66	29.97	3.31(*)	.000
	SS	24.99	31.52	-6.53(*)	.000	28.65	33.73	5.08(*)	.000

* $p<0.05$

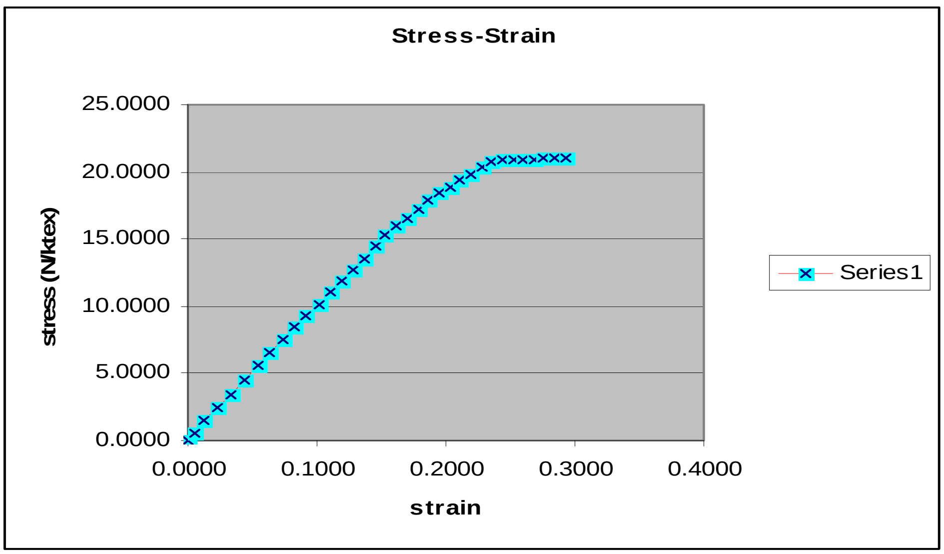
The aqueous scour method (ASM) using detergent removes part of wax, suint and dust in the staples while the solvent scour method (SSM) mostly removes wax.

Mean differences for staple strain and SS of FW and CW under different scour methods were also presented in Table3. Both staple strain and SS showed significant differences among different scour methods. A higher mass loss after washing occurred in SSM than ASM. Because FW and CW have different gauge length, both gauge length and loss of weight will affect linear density, hence the SS. Mean SS of SSM was larger than ASM, which also indicates a more efficient wash for solvent than detergent.

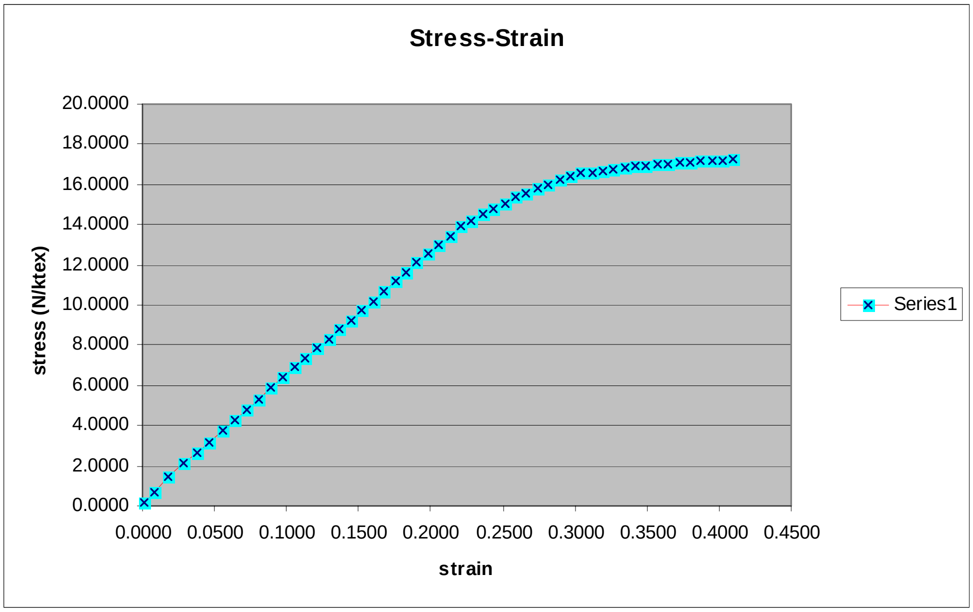
Figure2 shows stress-strain curve of some wool staples for FW and CW. Stress is expressed as the force per unit staple linear density while strain is the extension per unit length of the staple gauge length.



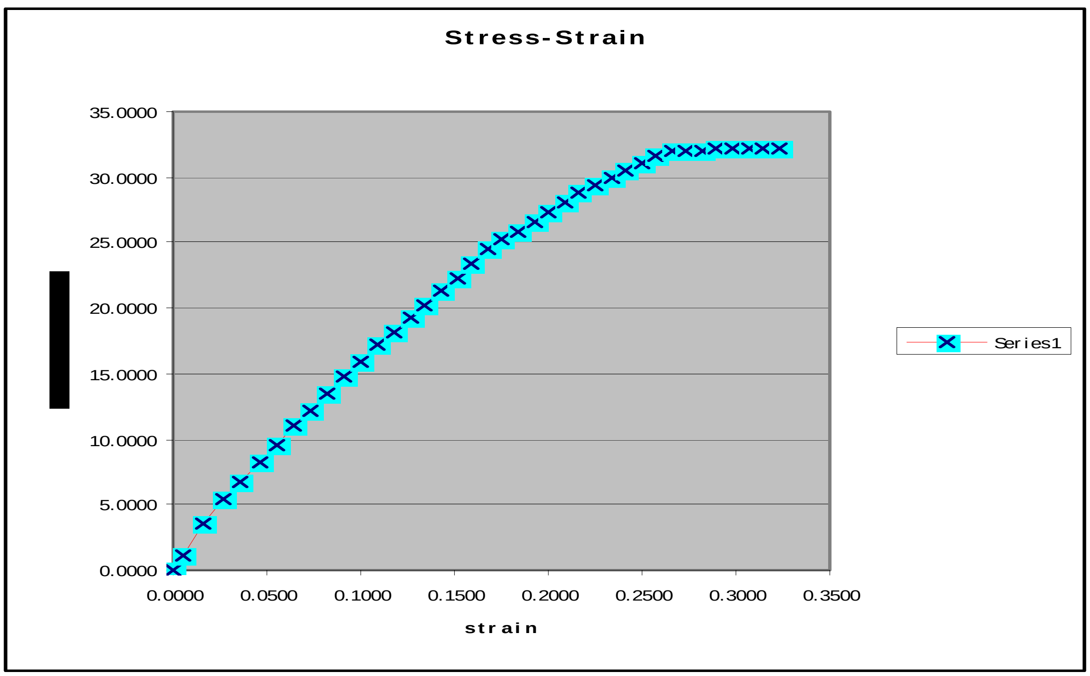
Unwashed fine wool staple



Washed fine wool staple



Unwashed coarse wool staple



Washed coarse wool staple

Figure2 Stress- strain curve for FW and CW

Correlations

General correlations between FD, AL_CVD, GC, SS and strain of the two fleeces are presented in Table 4.

Positive good correlations occurred between FD with SS, Max.load, GC, and between SS and Max.load. Correlations between SS and other factors were significant, except for the variance of fibre diameter along staple. GC had a strong negative correlation with FD ($r=-.935$, $p<0.01$) and SS ($r=-.772$, $p<0.01$), which indicated that wool with higher GC has lower FD and SS. Linear density was found to be correlated with other factors especially with Max.load ($r=.897$, $p<0.01$).

Table 4 Correlations between characteristics of wool staples

	GC	CVFD	CEM	CF	AL_CVD	CUR	strain	SS	Ini.M	MAXLOAD	lineardensity
FD	-.935(**)	.004	.784(**)	-.889(**)	.208(**)	-.932(**)	.003	.686(**)	-.102(*)	.873(**)	.799(**)
GC		-	-	-	-	-	.795(**)	-.772(**)	-.781(**)	-.866(**)	-.854(**)
CVFD			.580(**)	-.174(*)	.551(**)	-.054	-.213(**)	-.157(*)	-.037	-.012	.089
CEM				-.824(**)	.480(**)	-.753(**)	.424(**)	.565(**)	-.011	.635(**)	.593(**)
CF					-.269(**)	.833(**)	-.553(**)	-.782(**)	.033	-.768(**)	-.626(**)
AL_CVD						-.191(**)	.053	.127	-.080	.168(*)	.191(**)
CUR							-.666(**)	-.819(**)	-.086	-.823(**)	-.705(**)
Strain								-.272(**)	-.690(**)	-.058	.098(*)
SS									.190(**)	.706(**)	.364(**)
Ini.M										-.104(*)	-.256(**)
Max.LOAD											.897(**)

** p<0.01; * p<0.05

	GC	CVFD	CEM	CF	AL_CVD	CUR	strain	SS	Ini.M	MAXLOAD	lineardensity
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Ini.M										-.104(*)	-.256(**)
Max.LOAD											.897(**)

Correlations between the above properties with the influence of wool type are shown in Table 5.

Table 5 Correlations between main characteristics of wool staples for FW and CW

		GC	AL_CVD	Staple strain	SS	Max.load
FW	FD	.630(**)	.211(*)	.649(**)	-.277(**)	.206(**)
	GC			-0.012	-0.012	.150
	AL_CVD			-.075	-.185	-.025
	Staple strain				-.286(**)	.283(**)
	SS					.340(**)
CW	FD	-.270(**)	-.105	.243(**)	-.123	.582(**)
	GC			.191(*)	-.079	-.018
	AL_CVD			-.249(*)	-.029	.005
	Staple strain				-.385(**)	.310(**)
	SS					.145(*)

For FW, there are medium correlations between FD with staple strain (r=0.649, p<0.01) and GC (r=0.630, p<0.01), whereas poor correlation between GC and SS, and also has a negative correlation between FD and SS (r=-0.277, p<0.01).

For CW, a negative correlation was found between FD and GC (r=-0.270, p<0.01), but no significant correlation between SS with FD and GC, it indicated that FD and GC have hardly influence on SS for CW.

Therefore, SS is more likely influenced by FD rather than GC.

Regression Analysis

Stepwise linear model of regression was used to determine which factor is the important contributor to the SS regression. Use FD, CVFD, AL_CVD and CUR to predict SS under washed condition for two fleeces, with the four factors, it can explain 77.1% of SS (Table 6):

$$SS = 19.236 + 1.363FD - 1.044CVFD + 0.440AL\_CVD - 0.093CUR$$

Table 6 ANOVA for the regression

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	9801.120	4	2450.280	164.850	.000(a)
	Residual	2913.280	196	14.864		
	Total	12714.400	200			

FD alone can explain 73.7% of SS; while combined FD with CVFD, it can explain 76.3% of SS; and with CUR, 76.8% can be explained. AL_CVD was excluded from the regression equation which showed AL_CVD is the least important to predict SS and FD has the most contribution to SS in this study.

When regression was done to both FW and CW respectively, it showed that CVFD was the most important factor for FWSS (r^2=0.137), while FD for CWSS (r^2=0.201), but were both significant.

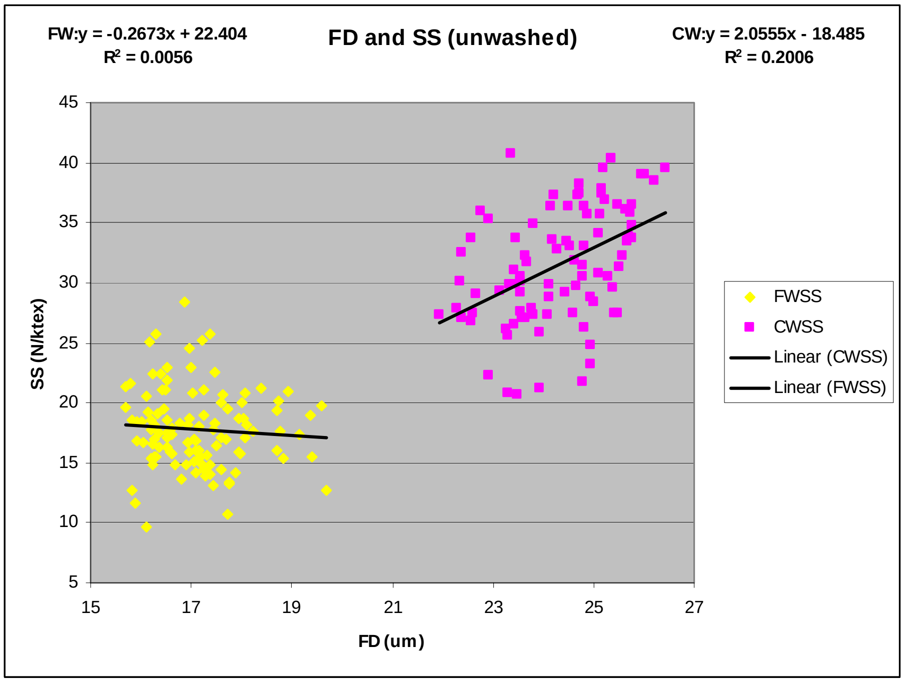


Figure 3 FD vs SS (unwashed)

For the two fleeces under unwashed condition, regression was done by using FD and GC to predict SS. Combining the two factors together can explain 64.9% of SS, r^2=64.3% for FD and 59.6% for GC respectively. FD contributes more to SS than GC. GC alone can not predict SS very well (Figure 4b).

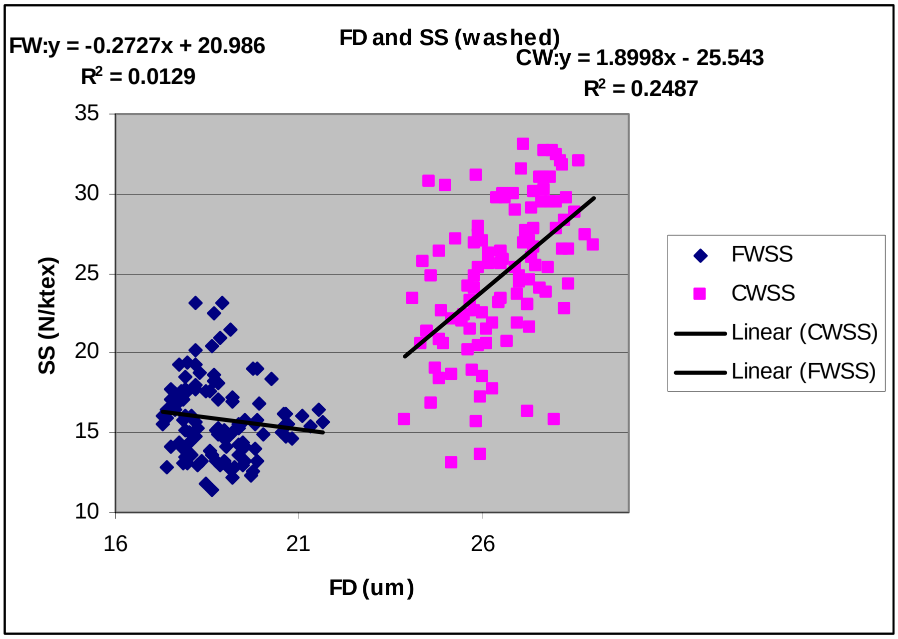


Figure 4 (a) FD vs SS (washed)

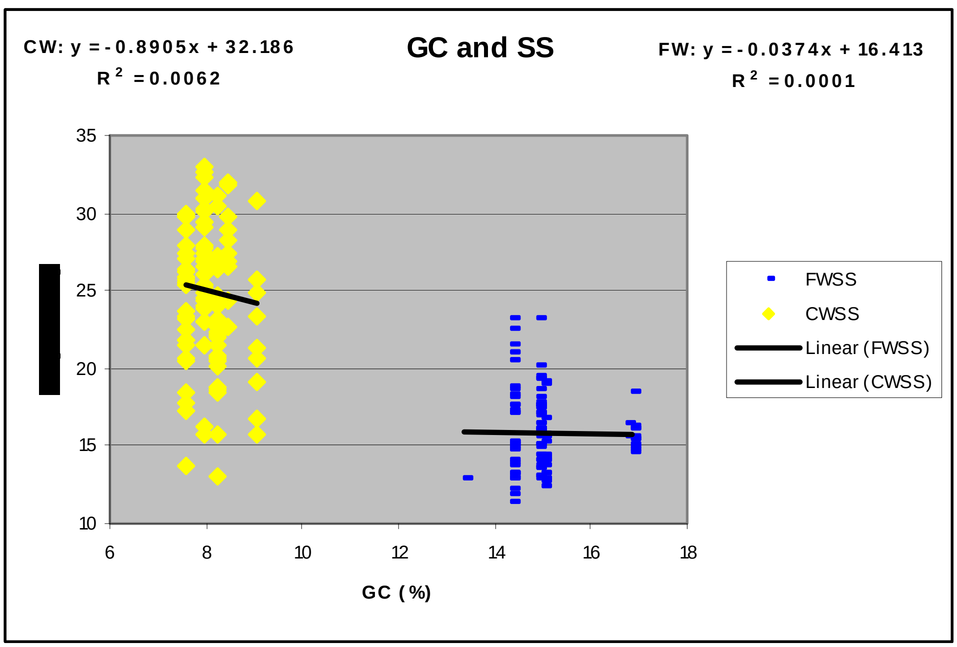
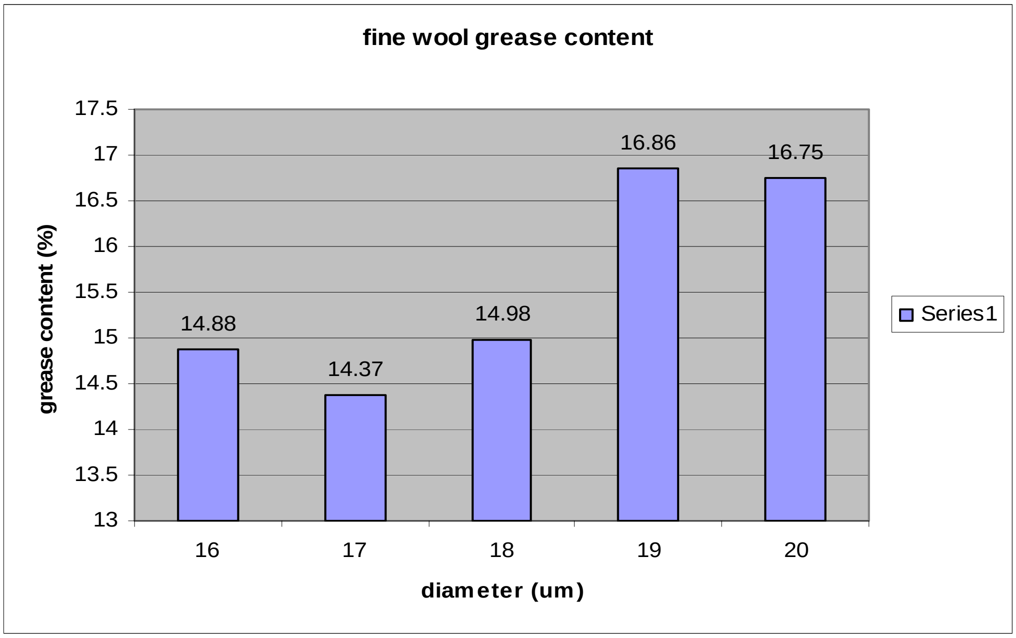


Figure 4 (b) GC vs SS

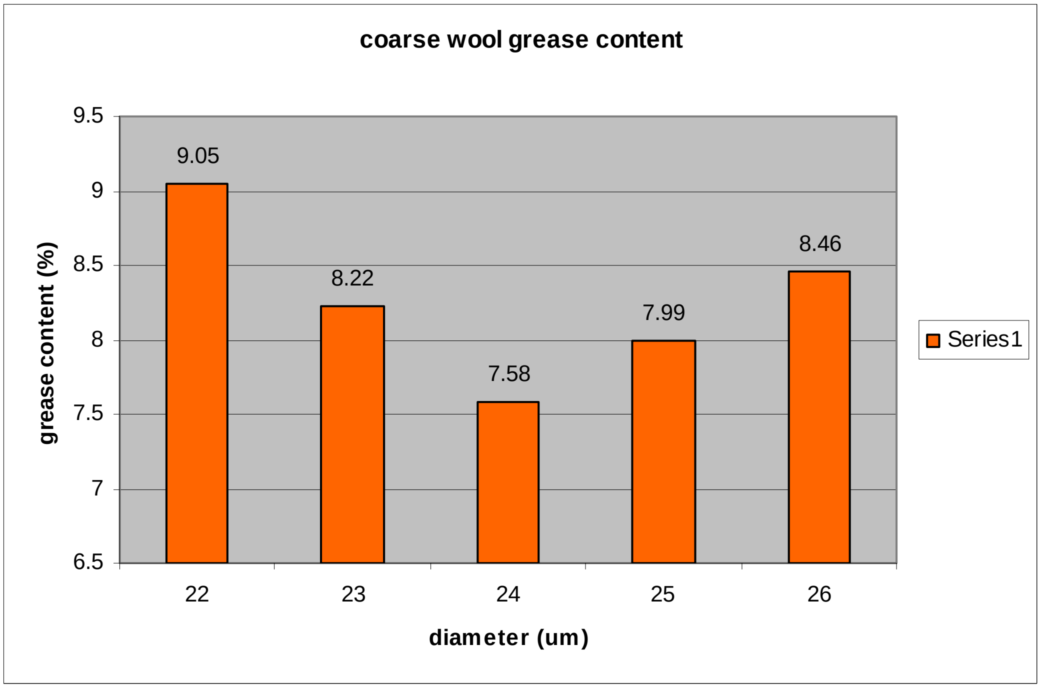
3.3 Grease Content

Grease content of greasy wool staples was tested for different ranges of fibre diameter. Groups for FW are: 15.6-16.5(μm), 16.6-17.5(μm), 17.6-18.5(μm), 18.6-19.5(μm) and 19.6-20.5(μm) and groups for CW are: 21.6-22.5(μm), 22.6-23.5(μm), 23.6-24.5(μm), 24.6-25.5(μm) and 25.6-26.5(μm). Results are shown by histogram in Figure 5.

Generally, grease content will reduce as the fibre diameter increases. The Figure showed that grease content of FW (14.37-16.86%) is higher than CW (7.58-9.05%). This would be expected, since higher-crimp-frequency wools tend to be greasier (Stevens 1994). However, in this study, it does not show a clear trend within diameter groups (FW and CW), probably due to the size of wool staples (not enough samples were collected for each diameter group).



Fine Wool



Coarse Wool

Figure5 Relationship between FD and GC

4. Conclusion

This study has demonstrated that the staple strength of scoured wool is higher than that of the corresponding greasy staple. Different scouring methods also affect the staple strength of the scoured samples.

Grease content (GC) has a negative medium correlation with greasy wool staple strength (SS) ($r=-0.772$, $p<0.01$). Fibre diameter (FD) has the strongest relationship with SS among other factors.

Further work is warranted to confirm the findings from this study with a large sample size covering a wide range of fibre diameters.

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