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EXAMINATION OF THE EFFECT ON FABRIC HANDLE OF SOFTENER TREATMENT USING THE CRC WOOL HANDLE METER

Part I: Single Jersey

CRC SII Project 2.3.1

R4.3.5.1

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Examination of Effect on Fabric Handle of Softener Treatment Using the CRC Wool Handle Meter

Part I: Single Jersey

Executive Summary

Two lightweight, knitted wool fabrics in single jersey were treated with fatty acid and silicone softeners at different concentrations. The fabrics were assessed by five judges and tested on the CRC Wool Handle Meter (WHM) against untreated and control fabrics.

The 20 treated fabrics all had similar fabric handle, though the untreated fabrics were assessed by the judges to be slightly softer, smoother and more preferred in Overall Handle than the treated fabrics. No consistent effect was assessed on fabric handle of softener type, concentration or fabric mean fibre diameter (mfd).

The WHM also predicted the untreated fabrics to be slightly softer, smoother and more preferred than the untreated fabrics. Unlike the subjective assessments, however, the WHM predicted:-

- that the treated fabrics were softer, smoother and more preferred than the control fabric (i.e., a sample given a blank (water-only) treatment), as would be expected;
- that the finer fabric (18.5µm) was smoother, cleaner, cooler, lighter and tighter than the coarser fabric (19.3µm); and,
- small, consistent differences between the fatty acid and silicone softeners.

The WHM provided a more precise prediction of the average assessment of the judges (average 95%CL = 0.7) than did an individual judge (average 95% CL = 1.2).

The increased sensitivity of the WHM compared to the judges was also reinforced by a Principal Component Analysis (PCA) which clearly demonstrated the ability of the WHM to differentiate between:

- the treated and untreated fabrics;
- the finer and coarser fabrics; and,
- the softener types.

1 Background

A major objective of Fabric Handle Project 2.3 in the Sheep CRC Wool Program is to develop simple instrumentation and an associated knowledge package to measure the fabric handle of next-to-skin knitted fabrics. The outcome will enable the engineering of predictable and desirable handle characteristics in garments made from lightweight knitted wool fabric.

A handle survey of the lightweight knitted fabrics in next-to-skin garments has shown that there are seven important handle attributes (Mahar and Wang, 2009). In order to predict these handle attributes, a prototype of the CRC Wool Handle Meter has been designed based on fabric extraction techniques (Alley et al., 1978, Pan and Yen, 1992). In conjunction with this fabric measurement, a series of models has been developed for the lightweight knitted fabrics in next-to-skin garments. The models have been validated for unwashed lightweight fabrics in single jersey (i.e. 140 – 210 g/m^2 in weight and less than 0.9mm in thickness).

In order to apply or extend the application of the CRC Handle Meter in other areas, this report examines the effect of the application of softeners to fabric. Subjective assessments from five judges are used to confirm the performance of the instrument and the associated models. Adjustments to the models will be made if required.

2 Experimental

2.1 Fabrics

Two knitted wool fabrics made from wool of different mfd in single jersey were selected for softening treatments carried out at Macquarie Textiles Group Ltd, Albury. The first fabric (SJ1), was made from wool with a nominal mfd of 18.5µm using 1/40Nm yarn with medium twist (520tpm). The wool came from Philip Attard and was processed to top by Sudwolle, China. The yarn was spun at Jingao, Beijing and the fabric was knitted and finished in China by Mengdi. It was given a scour-only finish so ‘it is unlikely that a softener would have been applied’.
The second fabric (SJ2) was made from wool with a nominal mfd of 20.5µm wool, 1/40 Nm yarn. The yarn was purchased from Shinhan and the fabric was knitted and finished with a blank dye at CSIRO. There was no softener applied.

2.2 Softener Treatments

A full width fabric strip approximately 40cm in length was prepared for each treatment. Five individual strips were padded with one of two different softeners from a bath at the concentrations of 0.5%; 1%; 2%; 4%; or 8%. The first softener used was a generic fatty acid type while the second softener (Rucofin SIQ) was silicone based. A wetting agent, Ricowet – VM, was added at 4ml/litre to each bath.

Roller pressure was set at 2 bar, which squeezed the excess liquid from the padded fabric.

A control sample was padded with water and wetting agent only. An untreated sample was also provided for comparison. All samples were air dried overnight at approximately 20°C.

Uptake of the softener suspension (after padding) as a percentage of initial fabric weight is listed in Table 1 for each of the treatments.

Table 1. Liquid Pickup by the Fabrics for Different Softeners

ID	Fatty Acid		ID	Silicone	
	Concentration (%)	Uptake (%)		Concentration (%)	Uptake (%)
SJ1 control	0	56	SJ1 control	0	56
SJ1-1	0.5	42	SJ1-6	0.5	59
SJ1-2	1	44	SJ1-7	1	72
SJ1-3	2	43	SJ1-8	2	79
SJ1-4	4	52	SJ1-9	4	78
SJ1-5	8	50	SJ1-10	8	76
SJ-2-Control	0	85	SJ-2-Control	0	85
SJ2-1	0.5	83	SJ2-6	0.5	85
SJ2-2	1	74	SJ2-7	1	91
SJ2-3	2	72	SJ2-8	2	97
SJ2-4	4	81	SJ2-9	4	95
SJ2-5	8	83	SJ2-10	8	92

2.3 Subjective Assessments

Five judges from three organisations were selected to assess the seven handle attributes plus Overall Handle quality. Four of them were from the previous panel set up during development of the models. No training was conducted for them prior to the assessments. The fifth judge was employed after some training.

A piece of approximately 25 x 25 cm fabric was prepared from each of the samples for the assessments. Each sample was randomly assigned a new ID in order to avoid any influence from the treatment strengths in the assessment.

The judges were asked to follow the instructions provided (Appendix 1), particularly to clean their hands using paper towelling and alcohol wipes before and during fabric assessment, because the softener material may deposit on the judge's hands.

A set of benchmark fabrics from the calibration set was provided with the average score from the previous 12 judges. The judges rated the samples for each of the

handle attributes against the benchmark fabrics. The same scale of 1 – 10 was used as for the calibration fabrics (Table 2). The assessed results are shown in Appendix 1.

Table 2. Rating scales for the fabric handle sensory assessments

Handle attribute	Ratings of the handle assessments	
	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	
Rough – Smooth (RS)	Rough ----------►	Smooth
Hard – Soft (HS)	Hard ----------►	Soft
Loose – Tight (LT)	Loose ----------►	Tight
Heavy – Light (HL)	Light ----------►	Heavy
Hairy – Clean (HC)	Clean ----------►	Hairy
Warm – Cool (WC)	Cool ----------►	Warm
Greasy – Dry (GD)	Greasy ----------►	Dry
Overall Handle (OH)	Poor ----------►	Excellent

2.4 Objective Measurement

The samples were tested on the CRC Handle Meter at AWTA Ltd. Before testing, the fabrics were conditioned overnight and three specimens were prepared. The testing was conducted according to the testing protocol (Wang, 2008) established for the development of the models. A single operator was employed and instructed to clean the testing accessories (i.e. samples mounting plate, pressure plate and extraction orifice) prior to each test using paper towelling and alcohol wipes.

The average curve of the three specimens was used to predict the handle attributes. The curves are showed in Appendix 2 for individual fabrics and softener treatments, respectively.

3 Analysis of Subjective Assessments

3.1 Assessment Scores and Agreement among the Judges

Table 3 lists the mean, standard deviation (SD) and range of the scores for each of the handle attributes from the individual judges. It indicates that the judges all graded the fabrics within narrow ranges (1 – 2) with average values in the middle to the low upper range of scores (5 – 7, on the 10 point scale).

Table 3 Means, standard deviations and ranges of scores for each attribute from the individual judges

Attribute		Judge 1	Judge 2	Judge 3	Judge 4	Judge 5
OH	Mean	5.7	5.5	6.6	5.7	5.6
	SD	0.7	0.3	0.4	0.2	0.6
	Range	2.5	1.0	1.0	1.1	1.8
RS	Mean	5.6	6.9	7.2	5.8	5.5
	SD	0.3	0.4	0.3	0.1	0.8
	Range	1.5	1.5	0.5	0.5	2.5
HS	Mean	4.9	6.4	7.0	5.4	5.5
	SD	0.8	0.3	0.8	0.3	0.5
	Range	2.0	1.2	2.0	1.0	1.7
HC	Mean	6.3	6.0	6.3	5.5	5.4
	SD	0.7	0.3	0.3	0.3	0.5
	Range	2.0	1.0	0.5	1.0	1.2
WC	Mean	5.2	5.2	5.7	5.0	6.0
	SD	0.8	0.2	0.3	0.0	0.4
	Range	2.0	0.5	0.5	0.0	1.0
HL	Mean	5.2	5.2	4.9	5.0	5.0
	SD	0.5	0.5	0.3	0.0	0.5
	Range	2.0	2.0	1.5	0.0	1.0
LT	Mean	5.0	4.3	5.0	5.4	4.9
	SD	0.0	0.2	0.0	0.7	0.5
	Range	0.0	0.5	0.0	2.0	1.5
GD	Mean	6.6	4.4	5.5	5.8	5.4
	SD	0.3	0.3	0.4	0.5	0.4
	Range	1.0	1.0	1.0	1.5	1.5
Average	Mean	5.6	5.5	6.0	5.4	5.4
	SD	0.5	0.3	0.3	0.3	0.5
	Range	1.6	1.1	0.9	0.9	1.5

Table 4 shows the poor agreement amongst the judges in their assessments of these fabrics, as indicated by the relatively low correlation coefficients between each judge's scores and the mean score of the other four (4) judges.

Table 4 Correlation coefficients between each judge's scores and the mean score of the other four (4) judges

Attribute	Judge 1	Judge 2	Judge 3	Judge 4	Judge 5
OH	0.12	0.07	0.15	0.29	0.13
RS	0.18	0.19	0.00	0.27	0.24
HC	0.60	0.13	0.00	0.19	0.57
HS	0.33	0.36	0.16	-0.15	-0.18
WC	0.05	0.14	0.05	-	0.17
HL	0.37	0.20	0.51	-	0.13
LT	-	0.60	-	0.48	0.25
GD	0.35	0.24	0.25	0.34	0.58
Average	0.29	0.24	0.16	0.24	0.24

Note: If a judge gave a constant score to all fabrics for an attribute no correlation coefficient is calculated for that attribute.

As Appendix 1 shows, the judges had different rankings and score ranges (i.e., different minimum and maximum values) for the same handle attributes. Therefore, normalisation of the scores was carried out when calculating the average score of the 5 judges. That is, the scores of each judge were normalised by his or her mean and standard deviation for each of the handle attributes. Then the average of the normalised scores of the five judges was calculated. Finally, the average of the normalised scores was transferred back to the scale of 1 – 10 using the grand mean and average range of the five judges. The normalised and transferred scores are listed in both Table 5 and Appendix 3.

3.2 Precision of the Subjective Assessments

The average of standard deviations (SD) between the five judges for each fabric was used to estimate the precision of the average assessment of the judges. The calculation is as follows:

95% Confidence Limit = 1.96 * SD / sqrt (number of judges)

The precision estimates for using either a single judge or 5 judges are listed in Table 6.

Table 5 Transferred Average Scores of 5 Judges for each of the Handle Attributes

Sample ID	OH	HS	RS	HC	WC	HL	LT	GD
SJ1 untreated	6.4	5.9	6.7	5.2	5.2	4.2	5.3	5.5
SJ1 control	6.0	5.7	5.9	5.8	5.4	5.3	5.1	5.6
SJ1 1	5.5	5.3	6.1	5.9	5.1	5.0	5.1	5.5
SJ1 2	5.7	5.5	5.7	5.9	5.5	5.0	5.3	5.6
SJ1 3	5.4	5.0	5.8	6.1	5.7	5.4	5.1	5.4
SJ1 4	5.6	5.0	6.2	6.0	5.4	5.5	5.0	5.6
SJ1 5	5.7	5.6	6.1	6.2	5.5	5.0	5.1	5.8
SJ1 6	5.6	6.0	6.1	6.0	5.7	5.5	4.9	5.4
SJ1 7	5.3	5.9	6.2	5.6	5.5	5.0	5.3	4.9
SJ1 8	5.6	5.8	6.3	5.8	5.0	5.3	4.8	5.3
SJ1 9	6.0	5.5	6.4	5.6	5.1	4.7	5.1	5.3
SJ1 10	6.0	5.1	6.0	5.9	5.5	5.0	4.8	5.4
SJ2 untreated	6.8	6.5	6.9	5.3	5.2	4.5	5.2	5.7
SJ2 control	6.3	6.4	6.2	6.0	5.4	5.0	4.7	5.5
SJ2 1	5.6	6.4	6.3	6.0	5.4	5.0	4.8	5.5
SJ2 2	5.3	5.8	5.6	6.3	5.8	5.1	4.5	6.1
SJ2 3	5.8	5.7	6.1	6.0	5.6	5.2	4.6	6.1
SJ2 4	5.6	6.4	6.1	6.0	5.5	5.1	4.5	5.5
SJ2 5	5.9	5.9	6.1	6.0	5.7	5.2	4.9	5.7
SJ2 6	5.9	5.9	6.1	6.1	5.3	5.1	4.9	5.4
SJ2 7	6.3	6.4	6.5	5.9	5.3	5.1	4.7	5.6
SJ2 8	5.7	6.0	6.3	6.0	5.5	5.0	4.6	5.8
SJ2 9	6.1	6.3	6.1	5.9	5.6	4.6	4.6	5.5
SJ2 10	5.8	6.3	6.5	5.5	5.5	5.0	5.0	5.3

Table 6 Precision Estimates of the subjective assessments for each of the attributes

	OH	HS	RS	HC	WC	HL	LT	GD
SD	0.60	0.98	0.88	0.55	0.55	0.33	0.50	0.85
1 judge	1.2	1.9	1.7	1.1	1.1	0.7	1.0	1.7
5 judges	0.5	0.9	0.8	0.5	0.5	0.3	0.4	0.7

3.3 Assessments of the Treatment Effects

Table 7 lists the differences in subjective scores between the treated and untreated fabrics. Unexpectedly the treated samples of the two fabrics were not consistently softer and smoother than the untreated fabrics. Moreover, the treated fabrics did not consistently show a clearly greasier handle than the untreated, even though a high bath concentration of up to 8% softener was used. Overall, the untreated fabrics were preferred by the judges in the Overall Handle assessment.

This preference by the judges may be due to the changes in fabric attributes following wet treatment. A treated fabric typically becomes thicker, heavier, tighter and hairier following treatment. As seen in Table 7, these effects may have been

detected by the judges. Therefore, the treated fabrics were not necessarily softer and smoother than the untreated fabrics in this case.

Table 7 Score Differences between the Treated and Untreated Fabrics (Treated – Untreated)

Sample	OH	RS	HS	HC	WC	HL	LT	GD
SJ1 control	-0.4	-0.8	-0.2	0.6	0.2	1.1	-0.2	0.1
SJ1 1	-0.9	-0.6	-0.6	0.7	-0.1	0.8	-0.3	0.0
SJ1 2	-0.7	-1.1	-0.5	0.7	0.2	0.8	0.0	0.1
SJ1 3	-1.0	-0.9	-1.0	0.9	0.4	1.2	-0.2	-0.1
SJ1 4	-0.8	-0.5	-1.0	0.8	0.2	1.3	-0.3	0.2
SJ1 5	-0.6	-0.6	-0.3	1.0	0.2	0.8	-0.3	0.3
SJ1 6	-0.7	-0.6	0.1	0.8	0.4	1.3	-0.4	-0.1
SJ1 7	-1.0	-0.5	0.0	0.5	0.2	0.8	0.0	-0.6
SJ1 8	-0.8	-0.4	-0.1	0.7	-0.2	1.1	-0.5	-0.2
SJ1 9	-0.3	-0.3	-0.4	0.4	-0.2	0.5	-0.3	-0.1
SJ1 10	-0.4	-0.7	-0.8	0.8	0.3	0.8	-0.5	-0.1
Average	-0.7	-0.6	-0.4	0.7	0.2	0.9	-0.3	0.0
SJ2 control	-0.5	-0.8	-0.1	0.6	0.2	0.5	-0.5	-0.2
SJ2 1	-1.2	-0.6	-0.2	0.7	0.2	0.5	-0.4	-0.2
SJ2 2	-1.5	-1.3	-0.8	1.0	0.6	0.6	-0.7	0.4
SJ2 3	-1.0	-0.8	-0.9	0.7	0.4	0.7	-0.6	0.4
SJ2 4	-1.2	-0.8	-0.1	0.7	0.3	0.6	-0.7	-0.2
SJ2 5	-0.9	-0.8	-0.7	0.6	0.5	0.7	-0.3	0.0
SJ2 6	-0.9	-0.8	-0.6	0.8	0.0	0.6	-0.3	-0.3
SJ2 7	-0.5	-0.5	-0.2	0.5	0.1	0.6	-0.5	-0.2
SJ2 8	-1.1	-0.6	-0.5	0.6	0.3	0.5	-0.6	0.0
SJ2 9	-0.7	-0.8	-0.3	0.6	0.3	0.1	-0.6	-0.2
SJ2 10	-1.0	-0.4	-0.3	0.2	0.2	0.5	-0.2	-0.5
Average	-1.0	-0.7	-0.4	0.6	0.3	0.5	-0.5	-0.1

3.4 Assessments of the Softener Effects

Table 8 lists the differences between the softener treatment and the control (i.e. the fabrics which was blank treated no softener added to the bath). For both fabrics, the differences in all the handle attributes were inconsistent and in dependent of the softener concentration in the bath. Moreover, the slight differences between the control and softener treated fabrics implied that the judges could not detect the effects of the softener treatments. As a result, the fabrics treated with the softeners were not consistently preferred by the judges, which was an unexpected result.

Table 8 Score Differences between the Treated and Control Fabrics (Treated – Control)

Sample	OH	RS	HS	HC	WC	HL	LT	GD
SJ1 1	-0.5	0.2	-0.4	0.1	-0.3	-0.3	-0.1	-0.1
SJ1 2	-0.3	-0.3	-0.2	0.1	0.0	-0.3	0.1	0.0
SJ1 3	-0.6	-0.1	-0.7	0.3	0.2	0.1	0.0	-0.2
SJ1 4	-0.4	0.3	-0.7	0.2	0.0	0.2	-0.1	0.0
SJ1 5	-0.2	0.2	-0.1	0.4	0.0	-0.3	-0.1	0.2
SJ1 6	-0.3	0.2	0.3	0.2	0.2	0.2	-0.2	-0.2
SJ1 7	-0.6	0.3	0.2	-0.1	0.0	-0.3	0.2	-0.7
SJ1 8	-0.4	0.4	0.1	0.0	-0.4	0.0	-0.3	-0.3
SJ1 9	0.1	0.5	-0.2	-0.2	-0.4	-0.6	-0.1	-0.3
SJ1 10	0.0	0.1	-0.6	0.2	0.1	-0.3	-0.3	-0.2
Average	-0.3	0.2	-0.2	0.1	0.0	-0.2	-0.1	-0.2
SJ2 1	-0.7	0.2	-0.1	0.0	0.0	0.0	0.1	0.0
SJ2 2	-1.0	-0.5	-0.7	0.4	0.4	0.1	-0.2	0.5
SJ2 3	-0.5	0.0	-0.8	0.0	0.2	0.2	-0.1	0.6
SJ2 4	-0.7	0.0	0.0	0.0	0.1	0.1	-0.2	-0.1
SJ2 5	-0.5	0.0	-0.6	0.0	0.3	0.2	0.2	0.2
SJ2 6	-0.4	-0.1	-0.5	0.1	-0.2	0.1	0.1	-0.2
SJ2 7	-0.1	0.3	-0.1	-0.1	-0.1	0.1	-0.1	0.0
SJ2 8	-0.6	0.1	-0.5	0.0	0.1	0.0	-0.1	0.2
SJ2 9	-0.3	0.0	-0.2	0.0	0.1	-0.4	-0.1	0.0
SJ2 10	-0.5	0.4	-0.2	-0.5	0.0	0.0	0.2	-0.3
Average	-0.5	0.0	-0.4	0.0	0.1	0.0	0.0	0.1

The differences in handle grades between the two softeners are listed in Table 9 for the two fabrics. On average, the silicone softener produced slightly softer, smoother, cleaner, more preferred but greasier handle than the fatty acid softener, though these differences are not statistically significant.

Table 9 Score Differences between the Two Softeners (Fatty Acid – Silicone)

Fabric	Treatment	OH	RS	HS	HC	WC	HL	LT	GD
SJ1	0.50%	-0.2	0.0	-0.7	0.0	-0.5	-0.5	0.2	0.1
	1%	0.3	-0.5	-0.4	0.3	0.0	0.0	0.0	0.6
	2%	-0.2	-0.5	-0.9	0.3	0.7	0.1	0.3	0.1
	4%	-0.5	-0.2	-0.6	0.4	0.3	0.8	0.0	0.3
	8%	-0.2	0.1	0.5	0.3	0.0	0.0	0.2	0.4
	AV	-0.1	-0.2	-0.4	0.2	0.1	0.1	0.1	0.3
SJ2	0.50%	-0.3	0.2	0.4	-0.1	0.1	-0.1	-0.1	0.1
	1%	-1.0	-0.8	-0.6	0.5	0.5	0.0	-0.1	0.5
	2%	0.1	-0.1	-0.3	0.0	0.1	0.2	0.0	0.3
	4%	-0.4	0.0	0.1	0.1	-0.1	0.5	-0.1	-0.1
	8%	0.1	-0.4	-0.4	0.5	0.3	0.2	-0.1	0.5
	AV	-0.3	-0.2	-0.2	0.2	0.2	0.2	-0.1	0.3

3.5 Assessments of the Fibre Diameter Effect

Because of the inability of the judging panel to reliably differentiate between the finer and coarser fabrics a check measurement was made using a Laserscan of the wool mfd for each fabric. Four (4) test specimens were tested for each fabric and the simple average was obtained for the mean, SD and CV of each fabric. The results are shown in Table 10.

Table 10 Fibre diameter details of SJ1 and SJ2

	Mean (µm)	SD (µm)	CV (%)
SJ1 Untreated	18.5	3.5	19
SJ2 Untreated	19.2	3.9	20

Table 11 shows the differences between the nominal 18.5µm and '20.5'µm wool fabrics for each of the softeners. For the untreated and control fabrics the '20.5'µm samples were assessed to be softer, smoother and more preferred than their equivalent 18.5µm samples.

Table 11. Differences in the average handle grade between the 18.5µm and 20.5µm fabrics (18.5 – 20.5)

Softener	Treatment	OH	RS	HS	HC	WC	HL	LT	GD
	Untreated	-0.4	-0.2	-0.6	-0.2	0.0	-0.3	0.1	-0.3
	Control	-0.4	-0.3	-0.7	-0.2	0.0	0.3	0.4	0.1
Fatty Acid	0.50%	-0.2	-0.2	-1.0	-0.1	-0.2	0.0	0.3	0.0
	1%	0.3	0.0	-0.3	-0.4	-0.3	-0.1	0.8	-0.5
	2%	-0.5	-0.3	-0.7	0.1	0.1	0.2	0.5	-0.7
	4%	-0.1	0.1	-1.5	0.0	-0.1	0.4	0.5	0.1
	8%	-0.1	0.0	-0.2	0.2	-0.3	-0.2	0.2	0.0
	Average	-0.1	-0.1	-0.7	0.0	-0.2	0.1	0.4	-0.2
Silicone	0.50%	-0.3	0.0	0.1	-0.1	0.4	0.4	0.0	0.0
	1%	-0.9	-0.3	-0.5	-0.2	0.2	-0.1	0.6	-0.7
	2%	-0.2	0.0	-0.2	-0.1	-0.5	0.3	0.2	-0.5
	4%	-0.1	0.3	-0.7	-0.3	-0.5	0.1	0.4	-0.2
	8%	0.2	-0.5	-1.1	0.4	0.1	0.0	-0.1	0.1
	Average	-0.3	-0.1	-0.5	-0.1	-0.1	0.1	0.2	-0.3

4 Analysis of Objective Measurement and Prediction

4.1 Effect of Treatments on Curve Parameters

As shown in Appendix 2, the extraction curves for the treated and untreated, and for the two softeners were unexpectedly very similar.

The WHM curve parameters, plus fabric weight and thickness, are listed in Appendix 4 for each fabric. The differences of the curve parameters between the treated and

untreated are listed in Appendix 5. Consistent differences between the treated and untreated fabrics were observed for most of the parameters. This result implies that the WHM models may be able to predict differences between the treated and untreated fabrics.

Appendix 6 shows differences between the SJ1 and SJ2 fabrics when compared to their control fabrics. SJ1 showed consistently lower thickness, ‘a’ and ‘S1’, while SJ2 showed a consistent lower ‘weight’, ‘h’, and ‘S1’ while being higher in ‘thickness’, ‘pDp’, ‘Dp’, ‘S2’, ‘PHH’, ‘w’ and ‘work’.

Most of these differences were not dependent on the treatment concentration. The exceptions were the curve peak, ‘h’ for both SJ1 and SJ2, and the incline slope, ‘S1’, for SJ1. Figures 1 & 2 show the effect of the softener treatments on the curve peak, ‘h’, and incline slope, ‘S1’, respectively. They indicate that the fatty acid and silicone softeners had different effects on the SJ1 fabrics but a similar effect on the SJ2 fabrics. For treated SJ1 (i.e. 18.5µm) fabrics, the parameters ‘h’ and ‘S1’ decreased linearly with an increase in the softener bath concentration. For fabric SJ2, a slight increase was observed for ‘h’ but no effect on concentration was observed for ‘S1’.

In addition, the silicon softener had a stronger impact on the curve peak h and incline slope S1 for the fabric SJ1 than the fatty acid softener. However, this effect was not apparent for the fabric SJ2.

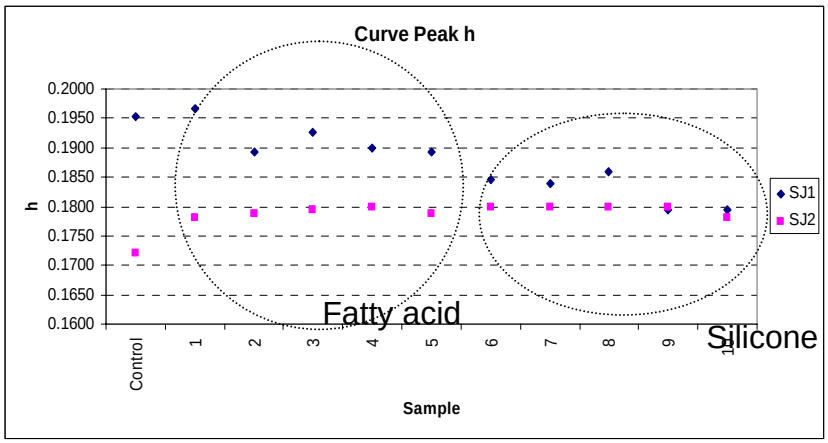


Figure 1. Effect of softeners on the Curve Peak, ‘h’.

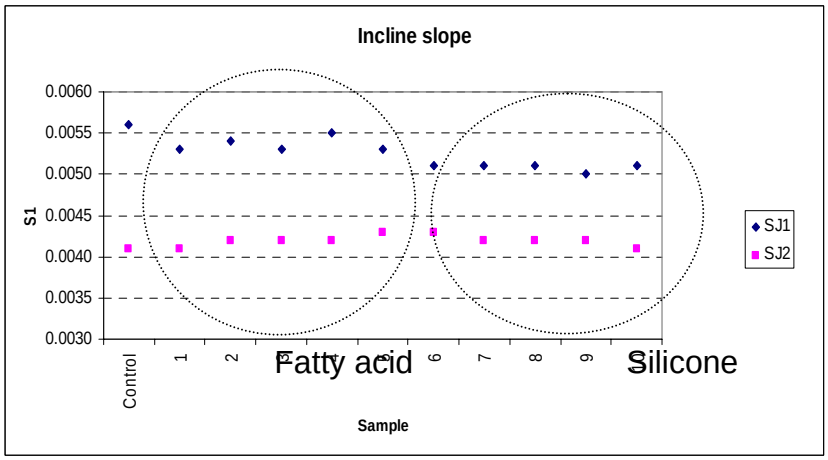


Figure 2. Effect of softeners on the Curve Incline Slope, ‘S1’.

4.2 Prediction Scores and Errors

The seven handle attributes and Overall Handle were predicted by the models using the curve parameters. The results are listed in Table 12. The differences between the predicted and assessed scores are listed in Table 13. Observations from these two Tables are summarised as follows:

- The average differences between the predicted and assessed values are less than one subjective unit for all handle attributes;
- The differences are not dependent on the softener concentration;
- For SJ1, the models consistently predicted slightly softer, tighter, lighter, cleaner and dryer than the assessors;
- For fabric SJ2, the models consistently predicted slightly softer, smoother, cleaner and warmer than the assessors.

Table 12 HWM predicted scores for each of the fabric handle

Sample ID	OH	HS	RS	HC	WC	HL	LT	GD
SJ1 untreated	6.2	6.6	6.6	4.4	4.8	4.0	5.3	6.0
SJ1 control	5.7	6.1	5.6	5.1	5.5	4.5	5.4	6.7
SJ1 1	6.0	6.4	6.1	5.0	5.3	4.3	5.4	6.3
SJ1 2	6.1	6.5	6.2	4.6	5.1	4.1	5.3	6.2
SJ1 3	5.9	6.3	5.9	5.0	5.4	4.4	5.4	6.5
SJ1 4	5.8	6.2	5.7	5.0	5.4	4.4	5.4	6.6
SJ1 5	6.3	6.6	6.1	5.1	5.3	4.2	5.3	6.2
SJ1 6	5.7	6.3	5.6	5.2	5.6	4.4	5.3	6.7
SJ1 7	5.9	6.3	5.7	5.1	5.6	4.3	5.2	6.6
SJ1 8	5.9	6.3	5.7	5.2	5.6	4.4	5.3	6.6
SJ1 9	6.0	6.4	5.6	5.2	5.6	4.3	5.2	6.6
SJ1 10	6.2	6.5	5.9	5.1	5.4	4.2	5.2	6.4
SJ2 untreated	7.2	7.1	6.7	4.7	5.3	3.6	4.6	5.6
SJ2 control	6.1	6.7	5.7	5.7	6.0	4.3	4.7	6.4
SJ2 1	6.3	6.7	5.9	5.5	5.9	4.3	4.7	6.4
SJ2 2	6.1	6.7	5.8	5.6	6.0	4.5	4.8	6.3
SJ2 3	6.3	6.7	5.9	5.6	5.9	4.4	4.8	6.2
SJ2 4	6.6	6.8	6.1	5.3	5.8	4.2	4.7	6.1
SJ2 5	6.1	6.6	5.7	5.6	6.0	4.5	4.8	6.4
SJ2 6	6.2	6.6	5.6	5.7	6.1	4.6	4.8	6.3
SJ2 7	5.7	6.4	5.4	5.9	6.2	4.8	4.8	6.6
SJ2 8	6.1	6.6	5.6	5.8	6.2	4.6	4.8	6.4
SJ2 9	5.7	6.4	5.3	5.9	6.3	4.7	4.8	6.7
SJ2 10	6.4	6.7	5.9	5.5	5.9	4.3	4.7	6.3

Table 13 Differences between the predicted and assessed scores for each of the fabric handle attributes (Predicted – Assessed)

Sample ID	OH	HS	RS	LT	HL	HC	WC	GD
SJ1 Untreated	-0.1	0.7	-0.1	0.0	-0.2	-0.8	-0.4	0.5
SJ1 control	-0.3	0.4	-0.3	0.3	-0.8	-0.7	0.1	1.1
SJ1 1	0.5	1.1	0.0	0.3	-0.7	-1.0	0.1	0.9
SJ1 2	0.4	1.0	0.5	0.0	-1.0	-1.4	-0.4	0.7
SJ1 3	0.5	1.3	0.0	0.3	-1.0	-1.2	-0.3	1.1
SJ1 4	0.2	1.3	-0.5	0.4	-1.2	-0.9	0.0	1.0
SJ1 5	0.6	1.0	0.0	0.2	-0.8	-1.1	-0.2	0.4
SJ1 6	0.1	0.3	-0.4	0.4	-1.2	-0.8	-0.1	1.3
SJ1 7	0.6	0.4	-0.5	0.0	-0.7	-0.5	0.1	1.7
SJ1 8	0.3	0.5	-0.6	0.4	-0.9	-0.6	0.6	1.3
SJ1 9	-0.1	0.8	-0.8	0.1	-0.4	-0.4	0.5	1.3
SJ1 10	0.2	1.3	-0.2	0.4	-0.8	-0.8	-0.1	1.0
AV-SJ1	0.2	0.8	-0.2	0.2	-0.8	-0.8	0.0	1.0
SJ2 untreated	0.4	0.6	-0.2	-0.6	-0.9	-0.6	0.0	-0.2
SJ2 control	-0.2	0.3	-0.4	0.0	-0.7	-0.3	0.6	0.8
SJ2 1	0.6	0.3	-0.4	-0.1	-0.7	-0.5	0.5	0.8
SJ2 2	0.8	0.9	0.1	0.3	-0.6	-0.7	0.2	0.3
SJ2 3	0.4	1.1	-0.2	0.1	-0.8	-0.4	0.3	0.1
SJ2 4	0.9	0.4	0.0	0.2	-0.9	-0.7	0.3	0.6
SJ2 5	0.2	0.7	-0.5	-0.1	-0.7	-0.3	0.3	0.7
SJ2 6	0.3	0.7	-0.5	-0.1	-0.6	-0.4	0.9	0.9
SJ2 7	-0.6	0.1	-1.1	0.2	-0.4	0.0	0.9	1.0
SJ2 8	0.3	0.6	-0.7	0.1	-0.4	-0.2	0.6	0.6
SJ2 9	-0.4	0.2	-0.8	0.2	0.1	0.0	0.7	1.1
SJ2 10	0.6	0.4	-0.6	-0.3	-0.7	0.0	0.5	1.0
AV-SJ2	0.3	0.5	-0.4	0.0	-0.6	-0.4	0.5	0.7
AV-All	0.3	0.7	-0.3	0.1	-0.7	-0.6	0.2	0.8

4.3 Precision of Predicted Scores

The precision of the predicted scores is shown in Table 14 for each fabric handle attribute. As can be seen the precision of the models in predicting the mean handle assessment of the five (5) judges is lower than a single judge, i.e., the models are more precise than an individual judge.

Table 14 The precision of the predicted scores for each fabric handle attribute

	OH	HS	RS	LT	HL	HC	WC	GD
SD	0.39	0.38	0.36	0.24	0.30	0.36	0.39	0.42
95%CL	0.76	0.74	0.71	0.47	0.58	0.71	0.75	0.82

4.4 Prediction of the Treatment Effects

The differences of the predicted scores between the untreated and treated fabrics are listed in Table 15. Observations from this Table are summarized as follows:

- The untreated fabrics were unexpectedly predicted to be slightly softer, smoother, hairier, warmer, heavier and drier than the treated fabric for both SJ1 and SJ2 fabrics, which is similar to the assessed results of the judges;
- The untreated fabrics were predicted to be preferred in Overall Handle, which is similar to the assessed results by the judge;
- The differences were not dependent on the softener concentration; and,
- The overall differences were slightly larger for SJ2 than for SJ1.

Table 15 Differences in the predicted scores between the untreated and treated fabrics (Treated – Untreated)

Sample ID	OH	HS	RS	HC	WC	HL	LT	GD
SJ1 control	-0.5	-0.5	-1.0	0.7	0.7	0.5	0.1	0.7
SJ1 1	-0.2	-0.2	-0.5	0.6	0.5	0.3	0.1	0.3
SJ1 2	-0.1	-0.1	-0.4	0.2	0.3	0.1	0.0	0.2
SJ1 3	-0.3	-0.3	-0.7	0.6	0.6	0.4	0.1	0.5
SJ1 4	-0.4	-0.4	-0.9	0.6	0.6	0.4	0.1	0.6
SJ1 5	0.1	0.0	-0.5	0.7	0.5	0.2	0.0	0.2
SJ1 6	-0.5	-0.3	-1.0	0.8	0.8	0.4	0.0	0.7
SJ1 7	-0.3	-0.3	-0.9	0.7	0.8	0.3	-0.1	0.6
SJ1 8	-0.3	-0.3	-0.9	0.8	0.8	0.4	0.0	0.6
SJ1 9	-0.2	-0.2	-1.0	0.8	0.8	0.3	-0.1	0.6
SJ1 10	0.0	-0.1	-0.7	0.7	0.6	0.2	-0.1	0.4
Average	-0.2	-0.2	-0.8	0.7	0.6	0.3	0.0	0.5
SJ2 control	-1.1	-0.4	-1.0	1.0	0.7	0.7	0.1	0.8
SJ2 1	-0.9	-0.4	-0.8	0.8	0.6	0.7	0.1	0.8
SJ2 2	-1.1	-0.4	-0.9	0.9	0.7	0.9	0.2	0.7
SJ2 3	-0.9	-0.4	-0.8	0.9	0.6	0.8	0.2	0.6
SJ2 4	-0.6	-0.3	-0.6	0.6	0.5	0.6	0.1	0.5
SJ2 5	-1.1	-0.5	-1.0	0.9	0.7	0.9	0.2	0.8
SJ2 6	-1.0	-0.5	-1.1	1.0	0.8	1.0	0.2	0.7
SJ2 7	-1.5	-0.7	-1.3	1.2	0.9	1.2	0.2	1.0
SJ2 8	-1.1	-0.5	-1.1	1.1	0.9	1.0	0.2	0.8
SJ2 9	-1.5	-0.7	-1.4	1.2	1.0	1.1	0.2	1.1
SJ2 10	-0.8	-0.4	-0.8	0.8	0.6	0.7	0.1	0.7
Average	-1.1	-0.5	-1.0	0.9	0.7	0.9	0.2	0.8

The differences of the predicted scores between the treated and control fabrics are listed Table 16. Observations from the Table follow:

- For SJ1, the fabrics treated by the two softeners were slightly softer, smoother, greasier, lighter and preferred in Overall Handle than the control;
- For SJ2, the fabrics treated by the two softeners were slightly tighter than the control; the other differences were not consistent with the softener concentrations.

Table 16 Differences between the treated and control fabrics (Treated – Control)

Sample ID	OH	HS	RS	HC	WC	HL	LT	GD
SJ1 1	0.3	0.3	0.5	-0.1	-0.2	-0.2	0.0	-0.4
SJ1 2	0.4	0.4	0.6	-0.5	-0.4	-0.4	-0.1	-0.5
SJ1 3	0.2	0.2	0.3	-0.1	-0.1	-0.1	0.0	-0.2
SJ1 4	0.1	0.1	0.1	-0.1	-0.1	-0.1	0.0	-0.1
SJ1 5	0.6	0.5	0.5	0.0	-0.2	-0.3	-0.1	-0.5
SJ1 6	0.0	0.2	0.0	0.1	0.1	-0.1	-0.1	0.0
SJ1 7	0.2	0.2	0.1	0.0	0.1	-0.2	-0.2	-0.1
SJ1 8	0.2	0.2	0.1	0.1	0.1	-0.1	-0.1	-0.1
SJ1 9	0.3	0.3	0.0	0.1	0.1	-0.2	-0.2	-0.1
SJ1 10	0.5	0.4	0.3	0.0	-0.1	-0.3	-0.2	-0.3
Average	0.3	0.3	0.3	0.0	-0.1	-0.2	-0.1	-0.2
SJ2 1	0.2	0.0	0.2	-0.2	-0.1	0.0	0.0	0.0
SJ2 2	0.0	0.0	0.1	-0.1	0.0	0.2	0.1	-0.1
SJ2 3	0.2	0.0	0.2	-0.1	-0.1	0.1	0.1	-0.2
SJ2 4	0.5	0.1	0.4	-0.4	-0.2	-0.1	0.0	-0.3
SJ2 5	0.0	-0.1	0.0	-0.1	0.0	0.2	0.1	0.0
SJ2 6	0.1	-0.1	-0.1	0.0	0.1	0.3	0.1	-0.1
SJ2 7	-0.4	-0.3	-0.3	0.2	0.2	0.5	0.1	0.2
SJ2 8	0.0	-0.1	-0.1	0.1	0.2	0.3	0.1	0.0
SJ2 9	-0.4	-0.3	-0.4	0.2	0.3	0.4	0.1	0.3
SJ2 10	0.3	0.0	0.2	-0.2	-0.1	0.0	0.0	-0.1
Average	0.1	-0.1	0.0	-0.1	0.0	0.2	0.1	0.0

4.5 Prediction of Softener Effects

The differences of the predicted scores between the fabrics treated by the two softeners are listed in Table 17 for each of the fabrics. Observations from Table 17 are summarized as follows:

- the fatty acid softener produced slightly smoother, cleaner and cooler predicted handle attributes than the silicon softener;
- The silicon softener produced slightly greasier predicted handle than the fatty acid softener; and;
- The fabrics treated with the fatty acid softener tended to be preferred in the prediction of Overall Handle.

Table 17. Differences between the fabrics treated by the two softeners (Fatty Acid – Silicon)

Fabric	Treatment	OH	HS	RS	HC	WC	HL	LT	GD
SJ1	0.50%	0.3	0.1	0.5	-0.2	-0.3	-0.1	0.1	-0.4
	1%	0.2	0.2	0.5	-0.5	-0.5	-0.2	0.1	-0.4
	2%	0	0	0.2	-0.2	-0.2	0	0.1	-0.1
	4%	-0.2	-0.2	0.1	-0.2	-0.2	0.1	0.2	0
	8%	0.1	0.1	0.2	0	-0.1	0	0.1	-0.2
	AV	0.1	0.0	0.3	-0.2	-0.3	0.0	0.1	-0.2
SJ2	0.50%	0.1	0.1	0.3	-0.2	-0.2	-0.3	-0.1	0.1
	1%	0.4	0.3	0.4	-0.3	-0.2	-0.3	0	-0.3
	2%	0.2	0.1	0.3	-0.2	-0.3	-0.2	0	-0.2
	4%	0.9	0.4	0.8	-0.6	-0.5	-0.5	-0.1	-0.6
	8%	-0.3	-0.1	-0.2	0.1	0.1	0.2	0.1	0.1
	AV	0.3	0.2	0.3	-0.2	-0.2	-0.2	0.0	-0.2

4.6 Prediction of Diameter Effects

The differences of the predicted scores between the 18.5µm and ’20.5’µm fabrics made are shown in Table 18. Observations from this Table are summarised as follows:

- As in the case of the subjective assessments, the models consistently predicted the untreated and control SJ2 (20.5µm) fabrics to be softer, smoother and more preferred in Overall Handle than their SJ1 (18.5µm) equivalents; and,
- Unlike the subjective assessments, the models consistently predicted the SJ1 fabrics to be smoother, cleaner, cooler, lighter and tighter than the SJ2 fabrics.

Table 18 Differences between the Fabrics Made from Different Diameters (SJ1-SJ2)

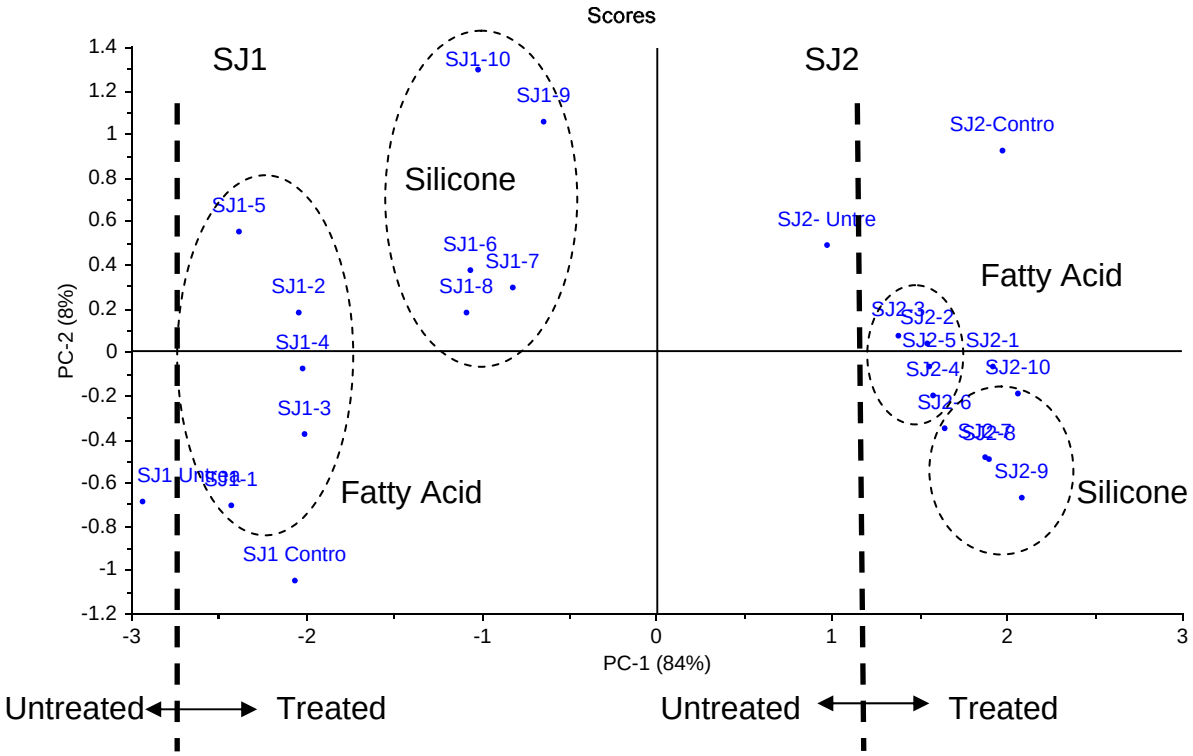
Softener	Treatment	OH	HS	RS	HC	WC	HL	LT	GD
	Untreated	-1.0	-0.5	-0.1	-0.3	-0.5	0.4	0.7	0.4
	Control	-0.4	-0.6	-0.1	-0.6	-0.5	0.2	0.7	0.3
Fatty Acid	0.50%	-0.3	-0.3	0.2	-0.5	-0.6	0.0	0.7	-0.1
	1%	0.0	-0.2	0.4	-1.0	-0.9	-0.4	0.5	-0.1
	2%	-0.4	-0.4	0.0	-0.6	-0.5	0.0	0.6	0.3
	4%	-0.8	-0.6	-0.4	-0.3	-0.4	0.2	0.7	0.5
	8%	0.2	0.0	0.4	-0.5	-0.7	-0.3	0.5	-0.2
	AV	-0.3	-0.3	0.1	-0.6	-0.6	-0.1	0.6	0.1
Silicone	0.50%	-0.5	-0.3	0.0	-0.5	-0.5	-0.2	0.5	0.4
	1%	0.2	-0.1	0.3	-0.8	-0.6	-0.5	0.4	0.0
	2%	-0.2	-0.3	0.1	-0.6	-0.6	-0.2	0.5	0.2
	4%	0.3	0.0	0.3	-0.7	-0.7	-0.4	0.4	-0.1
	8%	-0.2	-0.2	0.0	-0.4	-0.5	-0.1	0.5	0.1
	AV	-0.1	-0.2	0.1	-0.6	-0.6	-0.3	0.5	0.1

4.7 Principal Component Analysis of the Curve Parameters

In order to examine the sensitivity of the CRC WHM, Principal Component Analysis was carried out on the curve parameters. Figure 3 shows the sample scores from the first and second principal components (i.e. PC-1 & PC-2). The curve parameters h, S1, Dp and thickness were used. Approximately 92% of the variance was explained by the first two components. It shows that the fabrics were changed by the treatments, particularly for SJ1. Observations on the PCA are summarised as follows:

- Using PC-1 can differentiate between:
  - SJ1 and SJ2;
  - Untreated and Treated;
  - Fatty acid and Silicone softeners

- Using PC-1 and PC-2 can differentiate between:
  - Control and softened;
  - The softener's concentrations, particularly for the extremes.



5 Conclusion

The results of this trial confirm the sensitivity of the WHM compared to experienced fabric assessors, and will inform the Technical Manual.

The softener treatments in this trial failed to produce the expected levels of change in fabric handle.

The judges assessed differences in fabric handle between the treated and untreated fabric handle. But, whereas these subjective assessments failed to detect the expected increase in softness and smoothness of the treated fabrics, the WHM models predicted these expected increases.

Despite the agreed small differences amongst fabrics, the WHM was able to detect consistent differences in fabric handle attributes. The WHM predicted the untreated fabrics to be slightly softer, smoother and more preferred than the untreated fabrics. Unlike the subjective assessments, however, the WHM predicted:-

- that the treated fabrics were softer, smoother and more preferred than the control fabric (i.e., a sample given a blank (water-only) treatment), as would be expected;
- that the finer fabric (18.5µm) was smoother, cleaner, cooler, lighter and tighter than the coarser fabric (19.3µm); and,
- consistent, small differences between the fatty acid and silicone softeners.

The WHM provided a more precise prediction of the average assessment of the judges (average 95%CL = 0.7) than did an individual judge (average 95% CL = 1.2).

The increased sensitivity of the WHM compared to the judges was also reinforced by a Principal Component Analysis (PCA) which clearly demonstrated the ability of the WHM to differentiate between:

- the treated and untreated fabrics;
- the finer and coarser fabrics; and,
- the softener types.

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Appendix 1

1.1 Instructions to judges

Softener Trial
Fabric Handle Assessment
Next-to-skin fabrics – 2011

Instructions to assessors

Please wash & dry your hands prior to commencing these assessments. Note that some of these fabrics have been treated with commercial fabric softeners. Paper towelling and alcohol wipes have been provided for you to remove any softener material which may sometimes deposit on your hands and fingers during fabric assessment.
Assess the fabrics for handle for the next-to-skin market using your usual method and provide a grade according to the attached scales. Ignore the effects of fabric colour and pattern in your assessment.

1.2 Judges' scores

Judge 1

Fabric Handle Ranking	Fabric Handle Grade	Rough - Smooth Ranking	Rough - Smooth Grade	Hairy - Clean Ranking	Hairy - Clean Grade	Hard - Soft Ranking	Hard - Soft Grade	Warm - Cool Ranking	Warm - Cool Grade	Heavy - Light Ranking	Heavy - Light Grade	Loose - Tight Ranking	Loose - Tight Grade	Greasy - Dry Ranking	Greasy - Dry Grade
12	7	12	7	12	5	22	4	12	6	12	4	12	5	12	7
15	6.5	15	5.5	5	5	12	4	22	6	22	4.25	22	5	22	7
24	6.5	24	5.5	22	5	13	4	4	6	14	4.75	14	5	20	7
9	6.5	9	5.5	17	5	7	4	20	6	4	4.75	4	5	8	7
7	6.5	7	5.5	1	5	24	4	14	6	18	4.75	18	5	15	7
20	6.5	20	5.5	20	6.5	16	4	5	6	10	5	10	5	7	7
22	6	22	5.5	7	6.5	23	4	3	6	11	5	11	5	18	6.75
23	6	23	5.5	6	6.5	20	4	16	6	21	5	21	5	4	6.75
3	6	3	5.5	2	6.5	15	4	1	6	23	5	23	5	9	6.75
8	6	8	5.5	4	6.5	5	5	6	5.5	9	5	9	5	3	6.75
4	6	4	5.5	8	6.5	21	5	8	5.5	1	5.25	1	5	6	6.75
5	6	5	5.5	3	6.5	14	5	15	5.5	16	5.25	16	5	19	6.75
2	6	2	5.5	23	6.5	2	5	19	5.5	3	5.25	3	5	14	6.5
6	6	6	5.5	14	6.5	17	5.5	2	5.5	5	5.25	5	5	24	6.5
1	5	1	5.5	10	6.5	1	5.5	10	5.5	2	5.25	2	5	10	6.5
21	5	21	5.5	18	6.5	9	5.5	13	4.5	19	5.25	19	5	13	6.5
11	5	11	5.5	16	6.5	11	5.5	23	4.5	15	5.25	15	5	21	6.25
19	5	19	5.5	13	6.5	18	5.5	21	4.5	8	5.25	8	5	11	6.25
17	5	17	5.5	11	6.5	10	5.5	18	4.5	13	5.25	13	5	2	6.25
13	5	13	5.5	21	6.5	3	5.5	11	4.5	20	5.25	20	5	17	6.25
16	5	16	5.5	9	6.5	19	5.5	7	4.25	17	6	17	5	23	6.25
18	5	18	5.5	24	7	8	6	24	4	6	6	6	5	16	6
14	5	14	5.5	15	7	4	6	9	4	7	6	7	5	1	6
10	4.5	10	5.5	19	7	6	6	17	4	24	6	24	5	5	6

Judge 2

Fabric Handle Ranking	Fabric Handle Grade	Rough - Smooth Ranking	Rough - Smooth Grade	Hairy - Clean Ranking	Hairy - Clean Grade	Hard - Soft Ranking	Hard - Soft Grade	Warm - Cool Ranking	Warm - Cool Grade	Heavy - Light Ranking	Heavy - Light Grade	Loose - Tight Ranking	Loose - Tight Grade	Greasy - Dry Ranking	Greasy - Dry Grade
12	6	22	7.5	12	5.5	16	7	22	5	10	5	9	4	18	4
22	6	19	7.5	22	5.5	10	6.8	12	5	22	5	10	4	5	4
16	6	17	7.5	19	5.5	11	6.8	8	5	19	5	14	4	2	4
14	6	24	7.3	7	5.5	12	6.8	24	5	12	5	18	4.2	20	4
3	5.8	13	7.3	24	5.8	14	6.8	15	5	16	5	16	4.2	6	4
21	5.8	4	7.3	13	5.8	3	6.8	9	5	9	5	19	4.2	1	4.3
18	5.8	1	7	8	5.8	19	6.5	23	5	18	5	11	4.2	14	4.3
19	5.8	18	7	18	6	18	6.5	17	5	7	5.2	21	4.2	11	4.3
11	5.6	14	7	14	6	21	6.5	6	5.2	3	5.2	1	4.2	4	4.3
9	5.6	2	7	2	6	6	6.5	21	5.2	1	5.2	3	4.2	13	4.3
1	5.6	23	7	23	6	22	6.5	3	5.2	13	5.2	4	4.2	17	4.3
10	5.6	15	7	9	6	9	6.5	20	5.2	21	5.2	6	4.2	23	4.3
4	5.6	9	7	15	6	4	6.3	2	5.2	14	5.2	12	4.5	24	4.3
7	5.6	6	6.8	6	6.2	7	6.3	13	5.2	11	5.2	22	4.5	7	4.5
6	5.3	5	6.8	5	6.2	5	6.3	4	5.2	5	5.2	20	4.5	19	4.5
5	5.3	16	6.8	16	6.2	1	6.3	16	5.2	2	5.2	2	4.5	16	4.5
17	5.3	12	6.8	17	6.2	17	6.2	5	5.5	20	5.2	5	4.5	3	4.5
15	5.3	20	6.5	4	6.2	13	6.2	11	5.5	8	5.5	13	4.5	21	4.5
23	5.3	7	6.5	20	6.3	15	6.2	14	5.5	17	5.5	7	4.5	9	4.5
2	5.3	3	6.5	3	6.3	2	6	18	5.5	24	5.5	23	4.5	15	4.5
13	5	21	6.5	21	6.3	8	6	19	5.5	6	5.5	15	4.5	8	4.5
8	5	11	6.5	11	6.3	23	6	7	5.5	15	5.5	24	4.5	10	5
20	5	8	6	1	6.3	20	5.8	1	5.5	4	5.5	17	4.5	12	5
24	5	10	6	10	6.5	24	5.8	10	5.5	23	5.5	8	4.5	22	5

Judge 3

Fabric Handle Ranking	Fabric Handle Grade	Rough - Smooth Ranking	Rough - Smooth Grade	Hairy - Clean Ranking	Hairy - Clean Grade	Hard - Soft Ranking	Hard - Soft Grade	Warm - Cool Ranking	Warm - Cool Grade	Heavy - Light Ranking	Heavy - Light Grade	Loose - Tight Ranking	Loose - Tight Grade	Greasy - Dry Ranking	Greasy - Dry Grade
3	7	4	7.5	4	6	12	8	23	5.5	22	4	1	5	23	5
19	7	9	7.5	9	6	9	8	3	5.5	14	4.5	2	5	21	5
21	7	21	7.5	21	6	6	8	21	5.5	23	4.5	3	5	9	5
9	7	6	7.5	6	6	21	8	18	5.5	6	5	4	5	18	5
8	7	22	7.5	22	6	7	8	22	5.5	20	5	5	5	5	5
16	7	1	7.5	1	6	18	8	5	5.5	7	5	6	5	22	5
12	7	5	7.5	5	6	11	8	14	5.5	12	5	7	5	3	5
20	7	23	7.5	23	6	13	7	19	5.5	11	5	8	5	17	5.5
14	7	11	7.5	11	6	17	7	1	5.5	4	5	9	5	12	5.5
23	7	18	7.5	18	6	5	7	4	5.5	13	5	10	5	13	5.5
13	6.5	16	7.5	16	6	8	7	11	5.5	21	5	11	5	16	5.5
4	6.5	17	7	17	6.5	16	7	13	5.5	19	5	12	5	11	5.5
11	6.5	12	7	12	6.5	15	7	17	5.5	3	5	13	5	4	5.5
10	6.5	13	7	13	6.5	10	7	12	5.5	2	5.5	14	5	1	5.5
7	6.5	19	7	19	6.5	14	7	9	6	24	5	15	5	6	5.5
6	6.5	20	7	20	6.5	23	7	8	6	15	5	16	5	7	5.5
22	6.5	3	7	3	6.5	4	7	20	6	10	5	17	5	8	5.5
1	6	8	7	8	6.5	1	7	6	6	16	5	18	5	14	5.5
18	6	14	7	14	6.5	19	6	16	6	8	5	19	5	20	5.5
5	6	7	7	7	6.5	20	6	7	6	9	5	20	5	19	6
17	6	15	7	15	6.5	3	6	15	6	17	5	21	5	15	6
15	6	10	7	10	6.5	2	6	2	6	5	5	22	5	2	6
24	6	2	7	2	6.5	22	6	24	6	1	5	23	5	24	6
2	6	24	7	24	6.5	24	6	10	6	18	5	24	5	10	6

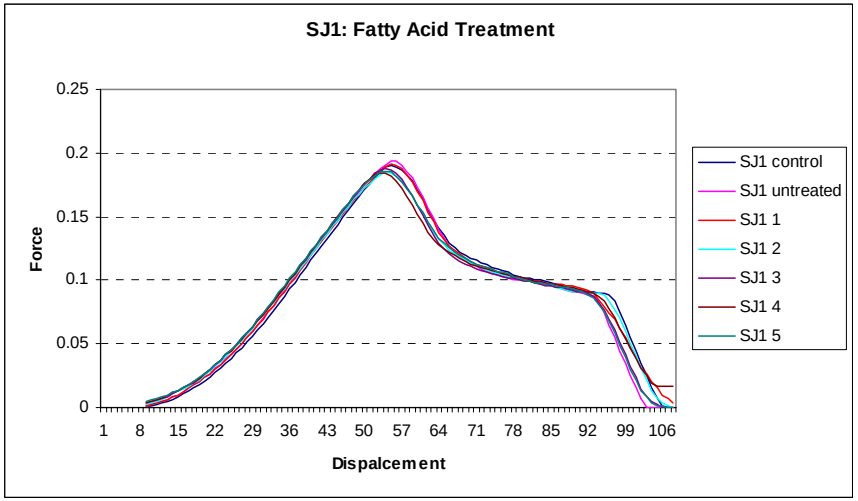
Judge 4

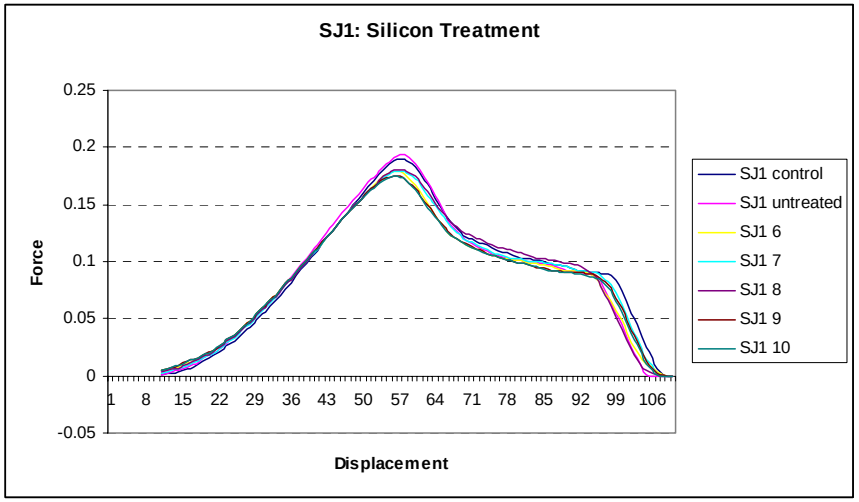
Fabric Handle Ranking	Fabric Handle Grade	Rough - Smooth Ranking	Rough - Smooth Grade	Hairy - Clean Ranking	Hairy - Clean Grade	Hard - Soft Ranking	Hard - Soft Grade	Warm - Cool Ranking	Warm - Cool Grade	Heavy - Light Ranking	Heavy - Light Grade	Loose - Tight Ranking	Loose - Tight Grade	Greasy - Dry Ranking	Greasy - Dry Grade
12	6.1	12	6	15	6	5	5.0	1	5	1	5	22	6.5	19	4.5
9	6	9	5.9	21	5.9	7	5.0	2	5	2	5	5	6.5	9	4.5
3	5.9	3	5.9	18	5.9	13	5.0	3	5	3	5	12	6.5	4	4.5
19	5.9	19	5.9	17	5.8	8	5.0	4	5	4	5	8	6.5	16	4.5
22	5.9	22	5.9	5	5.8	21	5.0	5	5	5	5	7	6	10	4.5
1	5.9	1	5.9	13	5.7	2	5.0	6	5	6	5	2	6	23	5
23	5.9	23	5.8	7	5.7	10	5.0	7	5	7	5	1	6	21	5
20	5.8	20	5.8	8	5.6	6	5.0	8	5	8	5	15	6	18	5
18	5.8	18	5.8	2	5.6	17	5.0	9	5	9	5	17	5.5	14	5
16	5.8	16	5.8	10	5.6	14	5.6	10	5	10	5	6	5.5	13	5
24	5.8	24	5.8	6	5.5	4	5.6	11	5	11	5	20	5.5	3	5
11	5.8	11	5.8	4	5.5	15	5.6	12	5	12	5	3	5.5	24	5
15	5.7	15	5.7	11	5.5	11	5.6	13	5	13	5	24	5	11	5
4	5.7	4	5.7	9	5.5	24	5.6	14	5	14	5	13	5	20	5.5
14	5.7	14	5.7	16	5.4	16	5.6	15	5	15	5	23	5	6	5.5
17	5.7	17	5.7	14	5.4	18	5.6	16	5	16	5	21	5	1	5.5
6	5.7	6	5.7	19	5.4	20	5.6	17	5	17	5	16	5	7	5.5
10	5.6	10	5.7	20	5.3	23	5.6	18	5	18	5	19	4.5	17	5.5
2	5.6	2	5.6	1	5.3	12	5.6	19	5	19	5	18	4.5	2	5.5
21	5.6	21	5.6	23	5.2	19	5.6	20	5	20	5	14	4.5	15	5.5
8	5.6	8	5.6	24	5.2	9	5.6	21	5	21	5	11	4.5	12	5.5
13	5.6	13	5.6	3	5.1	22	5.6	22	5	22	5	10	4.5	22	6
7	5.5	7	5.6	22	5.1	12	5.6	23	5	23	5	9	4.5	8	6
5	5	5	5.5	12	5	3	6.0	24	5	24	5	4	4.5	5	6

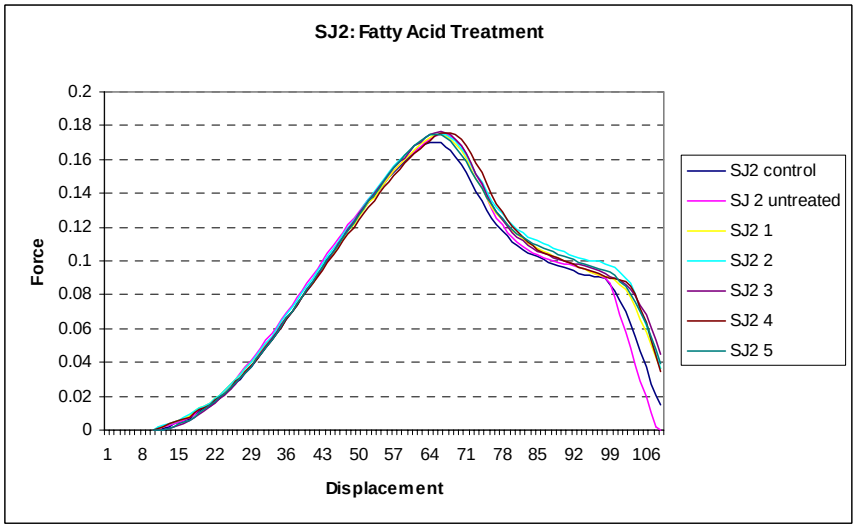
Judge 5

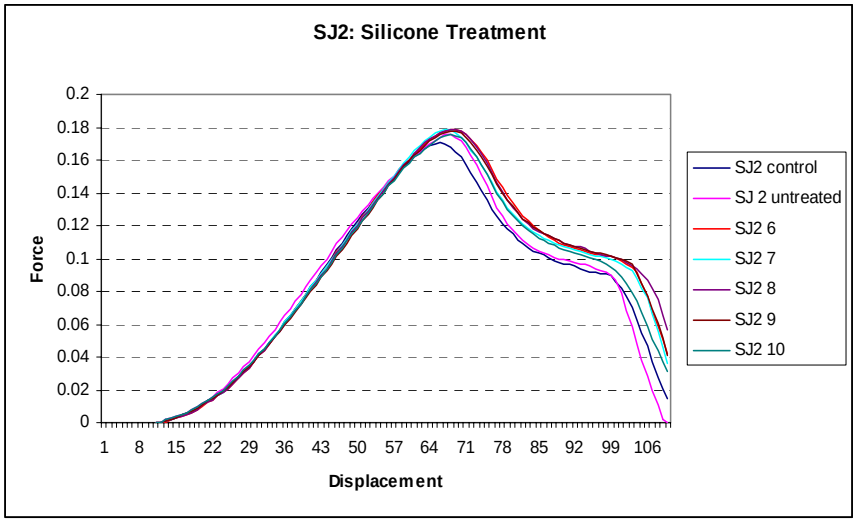
Fabric Handle Ranking	Fabric Handle Grade	Rough - Smooth Ranking	Rough - Smooth Grade	Hairy - Clean Ranking	Hairy - Clean Grade	Hard - Soft Ranking	Hard - Soft Grade	Warm - Cool Ranking	Warm - Cool Grade	Heavy - Light Ranking	Heavy - Light Grade	Loose - Tight Ranking	Loose - Tight Grade	Greasy - Dry Ranking	Greasy - Dry Grade
22	6.5	22	6.5	19	6	22	6.5	22	5.5	22	4.5	22	5.5	19	6.5
5	6.4	12	6.4	10	6	5	6.3	5	5.5	5	4.5	5	5.4	16	6.2
12	6.4	5	6.4	16	6	12	6.3	12	5.5	12	4.5	12	5.3	18	6
1	6.3	17	6.3	24	5.8	1	6	17	5.5	17	4.5	15	5.3	10	6
17	6.3	1	6.2	11	5.8	17	6	1	5.5	1	4.5	8	5.3	4	5.8
7	6.1	15	6.1	6	5.8	7	5.8	7	5.5	7	4.5	23	5.3	15	5.5
3	6.1	14	6	4	5.8	3	5.8	23	5.5	23	4.5	20	5.2	14	5.5
14	6	3	6	2	5.8	14	5.6	20	5.5	20	4.5	17	5.2	8	5.5
13	6	7	6	21	5.6	13	5.6	13	5.5	13	4.5	24	5.2	3	5.5
15	5.8	13	5.9	9	5.6	15	5.5	8	6	8	4.5	9	5.1	11	5.5
21	5.8	21	5.9	18	5.6	21	5.5	14	6	14	4.5	1	5	2	5.3
20	5.7	23	5.8	3	5.4	20	5.5	15	6	15	4.5	7	5	21	5.3
23	5.6	20	5.7	15	5.2	23	5.5	3	6	3	4.5	13	5	6	5.3
18	5.5	9	5.7	14	5.2	18	5.3	18	6	18	5.5	6	5	7	5.3
9	5.5	18	5.3	8	5.2	9	5.3	9	6	9	5.5	11	5	24	5.3
8	5.4	24	5.2	13	5	8	5	21	6	21	5.5	2	4.8	23	5.3
24	5.3	8	5.1	20	5	24	5	2	6.5	2	5.5	14	4.7	13	5.2
11	5.2	4	5	23	5	11	5	4	6.5	4	5.5	10	4.5	1	5.2
6	5.1	11	4.8	7	4.8	6	5	6	6.5	6	5.5	18	4.5	12	5.2
4	5	2	4.6	1	4.8	4	5	11	6.5	11	5.5	4	4.5	9	5.2
2	4.9	6	4.5	17	4.8	2	5	24	6.5	24	5.5	2	4.3	17	5
10	4.8	16	4.3	12	4.8	10	4.9	10	6.5	10	5.5	10	4.1	20	5
16	4.8	10	4.3	5	4.8	16	4.9	16	6.5	16	5.5	16	4	5	5
19	4.7	19	4	22	4.8	19	4.8	19	6.5	19	5.5	19	4	22	5

Appendix 2. Average Extraction Curves for Individual fabrics and Softener Treatments









Appendix 3. Average Normalised and Transferred Scores of Five Judges

	OH	HS	RS	HC	WC	HL	LT	GD
SJ1 Untreated	0.8	0.1	1.0	-1.5	-0.5	-2.0	1.3	-0.2
SJ1 control	0.2	-0.1	-0.5	-0.2	0.0	0.7	0.7	0.1
SJ1 1	-0.5	-0.6	-0.1	0.1	-0.8	-0.1	0.5	-0.1
SJ1 2	-0.2	-0.4	-1.0	0.1	0.1	-0.1	1.1	0.0
SJ1 3	-0.7	-0.9	-0.6	0.5	0.6	0.9	0.5	-0.3
SJ1 4	-0.4	-0.9	0.0	0.2	-0.1	1.2	0.4	0.2
SJ1 5	-0.1	-0.2	-0.1	0.7	0.1	-0.1	0.5	0.5
SJ1 6	-0.3	0.2	-0.2	0.2	0.6	1.2	-0.1	-0.3
SJ1 7	-0.7	0.0	0.0	-0.5	0.1	-0.1	1.2	-1.4
SJ1 8	-0.4	0.0	0.2	-0.1	-1.2	0.7	-0.3	-0.6
SJ1 9	0.3	-0.3	0.4	-0.5	-1.0	-0.8	0.5	-0.5
SJ1 10	0.2	-0.7	-0.3	0.1	0.2	-0.1	-0.3	-0.3
SJ2 untreated	1.5	0.7	1.3	-1.2	-0.5	-1.3	0.9	0.4
SJ2 control	0.8	0.6	0.0	0.2	0.0	-0.1	-0.6	0.0
SJ2 1	-0.3	0.5	0.3	0.2	-0.1	-0.1	-0.4	-0.1
SJ2 2	-0.7	-0.1	-1.0	0.9	1.0	0.2	-1.2	1.2
SJ2 3	0.0	-0.2	-0.1	0.3	0.5	0.4	-0.9	1.3
SJ2 4	-0.3	0.6	-0.1	0.2	0.2	0.2	-1.2	-0.1
SJ2 5	0.1	0.0	-0.1	0.2	0.8	0.4	-0.1	0.4
SJ2 6	0.1	0.1	-0.1	0.5	-0.5	0.2	-0.1	-0.4
SJ2 7	0.7	0.5	0.5	0.0	-0.4	0.2	-0.8	0.1
SJ2 8	-0.2	0.2	0.2	0.2	0.3	-0.1	-0.9	0.5
SJ2 9	0.4	0.4	-0.1	0.1	0.4	-1.1	-0.9	0.0
SJ2 10	0.0	0.4	0.6	-0.8	0.1	-0.1	0.2	-0.6

Appendix 4. Curve Parameters and Weight and Thickness for 24 Fabrics

Sample ID	Mass (gm-2)	Thickness (mm)	h	a	S1	pDp	Dp	S2	PPH	w	Work
SJ1 Untreated	173	0.56	0.20	16	0.0054	18	55	-0.0117	0.0127	3.43	7.29
SJ1 Control	179	0.64	0.20	17	0.0056	23	54	-0.0089	0.0111	3.24	7.29
SJ1-1	177	0.59	0.20	16	0.0053	23	54	-0.0088	0.0064	1.93	6.61
SJ1-2	176	0.59	0.19	16	0.0054	19	54	-0.0111	0.0162	4.46	7.86
SJ1-3	180	0.61	0.19	15	0.0053	22	53	-0.0092	0.0107	3.17	7.17
SJ1-4	179	0.62	0.19	15	0.0055	23	52	-0.0089	0.0115	3.38	7.13
SJ1-5	178	0.56	0.19	15	0.0053	28	52	-0.0073	0.0117	3.81	8.04
SJ1-6	180	0.63	0.18	15	0.0051	23	53	-0.0082	0.0073	2.32	6.38
SJ1-7	179	0.64	0.18	15	0.0051	23	54	-0.0086	0.0140	4.36	8.00
SJ1-8	181	0.63	0.19	16	0.0051	25	54	-0.0079	0.0102	3.29	7.27
SJ1-9	180	0.63	0.18	15	0.0050	25	53	-0.0077	0.0119	3.93	7.51
SJ1-10	180	0.60	0.18	15	0.0051	24	53	-0.0081	0.0131	4.17	7.59
SJ2- Untreated	153	0.61	0.18	17	0.0043	21	65	-0.0098	0.0275	9.20	15.83
SJ2-Control	167	0.67	0.17	17	0.0041	32	62	-0.0057	0.0125	5.26	9.70
SJ2-1	169	0.68	0.18	17	0.0041	27	64	-0.0072	0.0143	5.46	9.95
SJ2-2	172	0.67	0.18	17	0.0042	32	63	-0.0060	0.0134	5.42	10.28
SJ2-3	169	0.66	0.18	17	0.0042	32	63	-0.0061	0.0135	5.45	10.34
SJ2-4	170	0.66	0.18	17	0.0042	26	65	-0.0077	0.0194	7.13	12.38
SJ2-5	169	0.68	0.18	18	0.0043	31	63	-0.0062	0.0138	5.45	10.15
SJ2-6	168	0.68	0.18	18	0.0043	36	64	-0.0055	0.0189	7.83	14.30
SJ2-7	171	0.70	0.18	17	0.0042	36	63	-0.0053	0.0118	5.03	10.28
SJ2-8	168	0.69	0.18	18	0.0042	36	65	-0.0055	0.0162	6.79	12.60
SJ2-9	169	0.72	0.18	18	0.0042	35	64	-0.0055	0.0120	5.05	10.19
SJ2-10	169	0.68	0.18	17	0.0041	27	65	-0.0072	0.0182	6.96	12.12

Appendix 5. Differences in Parameters between Treated and Untreated Fabrics (Treated – Untreated)

	Weight (gm-2)	Thickness (mm)	h	a	S1	pDp	Dp	S2	PPH	w	Work
SJ1 Control	7	0.01	0.00	1	0.0002	5	-1	0.0028	-0.0015	-0.19	0.00
SJ1 1	4	0.00	0.00	0	-0.0001	5	-1	0.0029	-0.0063	-1.51	-0.68
SJ1 2	3	0.00	-0.01	0	0.0000	0	-1	0.0006	0.0035	1.03	0.57
SJ1 3	7	0.01	-0.01	-1	-0.0001	4	-2	0.0025	-0.0020	-0.26	-0.12
SJ1 4	6	0.01	-0.01	0	0.0001	5	-3	0.0028	-0.0012	-0.05	-0.16
SJ1 5	6	0.00	-0.01	-1	-0.0001	9	-2	0.0044	-0.0010	0.38	0.75
SJ1 6	7	0.01	-0.01	0	-0.0003	5	-2	0.0035	-0.0054	-1.11	-0.91
SJ1 7	7	0.01	-0.01	0	-0.0003	5	-1	0.0031	0.0013	0.93	0.71
SJ1 8	8	0.01	-0.01	0	-0.0003	7	-1	0.0038	-0.0025	-0.14	-0.02
SJ1 9	7	0.01	-0.02	-1	-0.0004	7	-2	0.0040	-0.0008	0.50	0.22
SJ1 10	8	0.00	-0.02	0	-0.0003	6	-2	0.0036	0.0004	0.74	0.30
AV-all	6	0.01	-0.01	0	-0.0001	5	-1	0.0031	-0.0014	0.03	0.06
AV-FA	5	0.00	-0.01	0	0.0000	5	-2	0.0026	-0.0014	-0.08	0.07
AV-S	7	0.01	-0.02	0	-0.0003	6	-1	0.0036	-0.0014	0.18	0.06
SJ2 Control	-5	0.01	-0.03	1	-0.0013	14	7	0.0060	-0.0001	1.83	2.41
SJ2 1	-3	0.01	-0.02	1	-0.0013	9	9	0.0045	0.0016	2.03	2.66
SJ2 2	-1	0.01	-0.02	1	-0.0012	14	8	0.0057	0.0007	1.99	2.99
SJ2 3	-4	0.01	-0.02	1	-0.0012	14	8	0.0056	0.0009	2.01	3.05
SJ2 4	-3	0.01	-0.02	2	-0.0012	8	10	0.0040	0.0067	3.70	5.09
SJ2 5	-4	0.01	-0.02	2	-0.0011	13	8	0.0055	0.0012	2.02	2.86
SJ2 6	-4	0.01	-0.02	2	-0.0011	18	9	0.0062	0.0062	4.40	7.01
SJ2 7	-2	0.01	-0.02	2	-0.0012	18	8	0.0064	-0.0009	1.60	2.99
SJ2 8	-5	0.01	-0.02	2	-0.0012	18	10	0.0062	0.0035	3.36	5.31
SJ2 9	-4	0.02	-0.02	2	-0.0012	17	9	0.0062	-0.0007	1.62	2.90
SJ2 10	-4	0.01	-0.02	1	-0.0013	9	10	0.0045	0.0055	3.53	4.83
AV-all	-4	0.01	-0.02	2	-0.0012	14	9	0.0055	0.0022	2.55	3.83
AV-FA	-3	0.01	-0.02	2	-0.0012	11	9	0.0051	0.0022	2.35	3.33
AV-S	-4	0.01	-0.02	2	-0.0012	16	9	0.0059	0.0027	2.90	4.61

Appendix 6. Differences in Parameters between Softener Treated and Control Fabrics (Treated – Control)

	Mass (gm-2)	Thickness	h	a	S1	pDp	Dp	S2	PPH	w	Work
SJ1 1	-2	-0.01	0.00	-1	-0.0003	0	0	0.0001	-0.0048	-1.32	-0.68
SJ1 2	-3	-0.01	-0.01	-2	-0.0002	-5	0	-0.0022	0.0051	1.22	0.57
SJ1 3	0	0.00	0.00	-2	-0.0003	-1	-1	-0.0003	-0.0005	-0.07	-0.11
SJ1 4	0	0.00	-0.01	-2	-0.0001	-1	-2	0.0000	0.0004	0.14	-0.16
SJ1 5	-1	-0.01	-0.01	-3	-0.0003	4	-2	0.0016	0.0005	0.57	0.75
SJ1 6	1	0.00	-0.01	-2	-0.0005	0	-1	0.0007	-0.0038	-0.92	-0.91
SJ1 7	0	0.00	-0.01	-2	-0.0005	0	0	0.0003	0.0028	1.12	0.72
SJ1 8	2	0.00	-0.01	-2	-0.0005	2	0	0.0010	-0.0009	0.05	-0.01
SJ1 9	1	0.00	-0.02	-2	-0.0006	2	-1	0.0012	0.0008	0.69	0.23
SJ1 10	1	0.00	-0.02	-2	-0.0005	1	-1	0.0008	0.0019	0.93	0.30
AV-all	0	0.00	-0.01	-2	-0.0004	0	-1	0.0003	0.0001	0.24	0.07
AV-FA	-1	0.00	0.00	-2	-0.0002	0	-1	-0.0002	0.0001	0.11	0.07
AV-S	1	0.00	-0.01	-2	-0.0005	1	-1	0.0008	0.0001	0.37	0.06
SJ2 1	-10	0.00	-0.02	0	-0.0015	4	10	0.0017	0.0031	2.22	2.66
SJ2 2	-8	0.00	-0.02	0	-0.0014	9	9	0.0029	0.0022	2.18	3.00
SJ2 3	-10	0.00	-0.02	0	-0.0014	8	9	0.0028	0.0024	2.20	3.05
SJ2 4	-10	0.00	-0.02	0	-0.0014	3	11	0.0012	0.0082	3.89	5.09
SJ2 5	-10	0.00	-0.02	1	-0.0013	8	9	0.0027	0.0027	2.21	2.87
SJ2 6	-11	0.00	-0.02	1	-0.0013	13	10	0.0034	0.0078	4.59	7.01
SJ2 7	-8	0.01	-0.02	0	-0.0014	13	9	0.0036	0.0006	1.79	2.99
SJ2 8	-11	0.01	-0.02	1	-0.0014	12	11	0.0034	0.0050	3.55	5.31
SJ2 9	-11	0.01	-0.02	1	-0.0014	12	10	0.0034	0.0009	1.81	2.90
SJ2 10	-11	0.00	-0.02	0	-0.0015	4	11	0.0017	0.0070	3.72	4.84
AV-all	-10	0.00	-0.02	0	-0.0014	9	10	0.0027	0.0040	2.81	3.97
AV-FA	-10	0.00	-0.02	0	-0.0014	6	9	0.0023	0.0037	2.54	3.33
AV-S	-10	0.01	-0.02	0	-0.0014	11	10	0.0031	0.0043	3.09	4.61