RESEARCH RECORD NO: 246

REPORT TO MERITEX ON THE RESULTS OBTAINED FROM THE CARLO BOVETTI TRIAL

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DATE: MAY 1988

CLASSIFICATION: FABRICS/KNITTED/PROPERTIES

KEY WORDS: MERITEX, SINGLE JERSEY, 24G, 28G, TESTING, VARIATION SCOURING, MERCERISING, BLEACHING, DYEING, CALENDERING STENTERING, REFERENCE STATE, STARFISH

C O N T E N T S

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PREFACE

This report presents an analysis by the International Institute for Cotton of the results obtained by Meritex from the Carlo Bovetti trial.

The analysis has been approached and is presented in detail in three separate sections.

Part 1 presents the basic data and addresses the questions of testing reproducibility and internal self-consistency.

Part 2 addresses the main questions posed by the trial, e.g. the effect of processing and machine gauge on fabric quality and performance.

Part 3 undertakes a comparison of the results obtained with the current STARFISH model for mercerised single-jersey fabrics. Each section is self contained and includes individual summaries and conclusions.

Detailed tables and figures supporting each section are contained in separate appendices at the back of the report. However, individual summary tables and figures are provided where appropriate either within the body of the text or at the end of each section for easier reference.

The whole report is prefaced by an outline of the objectives of the trial and the experimental procedures as reported by Meritex, and an overall summary of the conclusions obtained from the individual sections.

1. OBJECTIVES OF THE CARLO BORETTI TRIAL

The objective of the trial was to answer four main questions. These were reported as being:

A) Does scouring prior to mercerising affect final fabric stability (quality)?

B) Is 28 gauge, 30" diameter, 16 tex single jersey fabric different in dimensional stability (quality) to 24 gauge, 30" diameter, 16 tex single jersey fabric?

C) What effect does the difference in the length of the dyeing cycle on the same dyeing machine have on the fabric quality (e.g. bleach against dark shade)?

D) What is the difference in open-width and tubular quality knitted from the same yarn on the same machine; mercerised together and dyed together in the same machine (same shade)?

2. EXPERIMENTAL PROCEDURE

Two fabric qualities were chosen; Quality XR02 knitted on a Vanguard, 24 gauge, 30" diameter, 2256 needle machine, nominal tex 16, stitch length 0.268cm; and Quality XD10 knitted on a Monarch 28 gauge, 30" diameter 2520 needle machine, nominal tex 16, stitch length 0.282cm.

Twenty four pieces of each quality were knitted and numbered according to the machine gauge, either 24/1 to 24/24 or 28/1 to 28/24. The following experimental procedure was then carried out on both sets of 24 pieces.

1. Piece Nos 1-6 and 13-18 were scoured in a winch, sent through a Ferraro padder with water but no softener, and dried on an Alea. (No Hydro).

2. Piece Nos 1-24 were then sewn back together and mercerised on the Omez mercerising range.

3. The pieces were then separated and batched for bleaching or dyeing on the Brazzoli dyeing machine, e.g.

Piece Nos	1-3	prescoured	)
	7-9	not scoured	) Bleach
	13-15	prescoured	)
	19-21	not scoured	)
Piece Nos	4-6	prescoured	)
	10-12	not scoured	) Dye, dark shade
	16-18	prescoured	)
	22-24	not scoured	)

4. All 24 pieces were then sent through the Airtex (no hydroextraction) and the Alea dryer.

5. Piece Nos 1-12 were then finished tubular through a Ferraro calender.

6. Piece Nos. 13-24 were slit, softened and finished open-width on a Bruckner stenter.

Measurements for tex, stitch length, courses, wales, weight and width were recorded on the fabrics off machine and for courses, wales, weight, length and width shrinkage in the reference state at each of the following stages of processing:-

1. Grey (as knitted)
2. After prescouring in the winch
3. After mercerising
4. After bleaching/dyeing and Airtex
5. After Alea drying
6. After Ferraro calender (tubular)
7. After Bruckner stenter (open-width)

All the individual test data plus details of the wet processing recipes and methods were reported to IIC and are contained within this report.

3. OVERALL SUMMARY CONCLUSIONS AND RECOMMENDATIONS

1. The results obtained from the analysis of the basic data reported by Meritex show that the grey fabrics were knitted with close attention to quality control

   Variation in knitted stitch length between pieces of the same quality was minimal, and variation in yarn count was within normal commercial tolerances.

2. Piece to piece variation in the measured reference dimensions of identically knitted and processed fabrics suggests that problems exist with the reliability and internal consistency of the measured data. This was confirmed both by a statistical analysis of the differences between measured and calculated properties and also by the calculation of the internal consistency factors.

3. It is recommended that an investigation is carried out in the Meritex laboratory in order to identify the source of the differences and the lack of reproducibility in measuring.

4. The introduction of a simple quality control procedure using the calculated internal consistency factors would improve testing reliability.

5. An indication of the influence of processing variables and machine gauge on the average dimensions and performance of identically knitted fabrics can be deduced from the measured data, although due to the uncertainty in the measured values the conclusions should be confirmed by further evaluations.

6. Scouring prior to mercerising appears to cause a reduction in fabric reference weight particularly in dyed fabrics but the data does not show any consistent differences in the delivered fabrics.

7. The 28 gauge fabrics were knitted with a different stitch length, consequently differences in reference courses and weight can be detected. After finishing the differences increased. The 28 gauge fabrics on average were finished with fewer courses and more length shrinkage and are lighter than the 24 gauge fabrics.

8. Dyed fabrics are heavier than bleached fabrics in the reference state and this is reflected in the delivered fabrics. Variation in the data does not allow conclusions regarding dimensions and stability to be drawn.

9. There is no difference in reference state dimensions between tubular and open-width processed fabrics. However, differences exist in the delivered fabrics. On average, the stentered fabrics were delivered with more courses and fewer wales than the calendered fabrics which

resulted in the stentered fabrics having less length shrinkage and more width shrinkage.

10. Comparisons with the existing STARFISH model for Dornier mercerised and Gyrostock dyed single jersey fabric indicate that on average, agreement between measured and predicted dimensions is sufficiently good to enable this model to be used to provide Meritex with practical guidelines for the setting of finishing targets and for the development of new fabric qualities.

11. The average percentage differences calculated in Part 3 could, in the absence of more precise comparions or models developed specifically for the processing routes found in the Meritex mill, be used as correction factors for use with the current STARFISH model when making predictions for fabrics of the type used in this study when they are tested in the Meritex laboratory.

12. A more profitable approach would be to firstly upgrade the accuracy of testing and then to carry out another calibration exercise on a new set of fabrics taken at random from standard production.

P A R T   1

THE BASIC DATA; TESTING REPRODUCIBILITY AND INTERNAL SELF-CONSISTENCY

PART 1 : The basic data; testing reproducibility and internal self-consistency.

1. THE BASIC DATA

The basic results reported by Meritex were tex, stitch length, courses, wales, weight and width measured in the "off machine" or before wash state, and courses, wales, weight, length and width shrinkage measured in the reference state.

For the purpose of this analysis the results reported for stitch length in mm/100 wales have been converted to stitch length in cm, and the values for courses and wales per inch have been converted to courses and wales per cm.

The reported results are contained in tables A1-1 to A1-14 for Quality XR02, 24 gauge and in tables A1-15 to A1-28 for Quality XD10, 28 gauge. Plots of the measured tex and stitch length values off machine and those for courses, wales and weight in the reference state are included in Figures A1-1 to A1-33 for Quality XR02 and Figures A1-34 to A1-66 for Quality XD10.

2. GREY FABRIC AS KNITTED (OFF MACHINE)

2.1. Tex

The reported values for yarn tex measured in the grey fabric "off machine" illustrate the variation in the grey yarn as delivered.

The yarn used for the 24 gauge quality XR02 had an average tex of 15.8 with a coefficient of variation (CV) of 1.4%; the yarn used for the 28 gauge quality XD10 had an average tex of 15.5 with a coefficient of variation (CV) of 1.2%. The grand mean over both qualities was tex 15.6 with a CV of 1.7%.

For both qualities the average delivered count was slightly lighter (finer) than specified (nominal tex 16) although individually the variation is within acceptable limits. On average the mean delivered tex is approximately 2.5% lighter than specified and the level of variation is marginally on the high side.

A common UK specification for yarn allows an overall variation on yarn count of ±2.5% (CV% = 1.25). This is considered to be a strict specification if yarn is sourced from several spinners, although it should be achievable by an individual spinner. If more than one spinner is being used a range of ±3.0 to 3.5% (CV% 1.5 to 1.75) would probably be a more realistic commercial target.

Given the relatively low level of variation measured in the yarn taken from samples within a given fabric quality, there is just a suspicion that the yarns used may have come from two different lots or deliveries of yarn. On the other hand the overall variation could be a true reflection of the proficiency of the spinner, or the results of testing variation, e.g. if the two sets of fabrics were tested by two different technicians.

2.2. Stitch length

The reported values for measured stitch length in the grey fabric "off machine" illustrate the level of quality control during knitting.

For both qualities the measured values indicate a very high level of quality control with a very low level of piece to piece variation.

The 24 gauge quality XR02 had an average stitch length of 0.267cm with a CV of 0.4%, and the 28 gauge quality XD10 had an average stitch length of 0.283cm with a CV of 0.3%.

This low level of variation is not unusual between consecutive pieces of the same quality produced on a properly maintained machine, correctly set up and incorporating positive feed, course length control. A higher level of variation, between 1 and 1.5%, would not be unreasonable for fabrics of the same `quality produced on different machines or at different times on the same machine.

3. PROCESSED FABRIC (OFF MACHINE)

3.1. Tex

The mean and coefficient of variation (CV) for the yarn tex measured in the "off machine" fabric after each stage of processing are compared below;

		24g		28g	
Process	N	Mean	CV%	Mean	CV%
Grey	24	15.8	1.4	15.5	1.2
Winch scoured	12	16.1	2.8	15.6	1.3
Mercerised	24	16.0	1.4	16.1	1.1
Bleached/dyed	24	16.1	1.6	16.4	1.2
Alea dried	24	16.0	3.3	16.2	1.7
Calendered	12	16.2	1.6	16.1	0.8
Stentered	12	16.0	1.4	16.2	0.4

For the 24 gauge quality XR02 the variation in the measurements increases for the part processed fabrics, although is similar to the grey for the fully finished samples.

Given that, after mercerising, both bleached and dyed fabrics are included in the data sets this is a somewhat surprising result. An increase in the level of variation after bleaching/dyeing would normally have been expected reflecting the differences in tex which would be expected between samples that had been bleached compared to those which had been dyed to a dark shade. However, as this is not apparent, the increase in the coefficient of variation after drying may therefore reflect variation in the moisture content of the samples at the end of the drying stage.

3.2. Stitch length

The mean and coefficient of variation for the stitch length measured in the fabric off machine after each stage of processing are compared below:

Process	N	24g Mean	24g CV%	28g Mean	28g CV%
Grey	24	0.267	0.4	0.283	0.3
Winch scoured	12	0.267	0.5	0.283	0.2
Mercerised	24	0.252	0.3	0.260	0.2
Bleached/dyed	24	0.250	0.4	0.260	0.2
Alea dried	24	0.250	0.7	0.267	0.3
Calendered	12	0.250	0.3	0.260	0.2
Stentered	12	0.250	0.3	0.260	0.1

On average the variation in the stitch length measured on the part processed fabrics remains similar to that found in the grey fabric and improves for the fully finished samples. The one major exception are those results recorded on the Alea dried samples. For the 24 gauge quality the variation almost doubles and for the 28 gauge quality the average measured stitch length apparently increases. This is a surprising result.

Once a fabric has been mercerised, the stitch length does not usually change significantly during further processing, and there is no reason to suppose that the variation in the stitch length should increase. These results therefore suggest some problem in the measurement of these particular samples.

4. FABRIC DIMENSIONS REFERENCE STATE

The results for courses, wales and weight measured in the reference state have been identified on the plots in Appendix 1 according to the processing sequence followed by the individual samples. In the reference state of relaxation differences between pieces reflect either real differences in the original grey construction or in the influence of the different processing routes. The results reported from the measurements of grey yarn tex and stitch length have indicated that all the pieces of each nominal quality were knitted to the same actual construction with low variability. Therefore the differences observed in processed fabrics should be reflecting the influence of the individual processing procedures. Those samples which have followed the same processing sequence should tend to yield similar results.

If the plots for courses, wales and weight are examined it becomes apparent that within each group of samples which have followed the same processing sequence there are apparently large variations in the measured values. These are particularly apparent for courses and to a lesser extent for wales. The results for weight are usually more consistent.

This unusually high level of variation in the results obtained from identically knitted and processed fabrics suggests that there is another reason for the apparent variation between pieces which cannot be totally due to differences in the processing. The most likely reason for these apparent dissimilarities is that the relaxation procedure or the measuring techniques employed by Meritex are themselves subject to variation and inconsistency. For example, unusually low levels for courses and wales could indicate that a particular sample has been incompletely relaxed or relaxed by a different degree to another sample. Alternatively, they could reflect excessive stretching during handling and measuring of the samples. In both cases, however, low recorded values for courses and wales would also normally be reflected in a correspondingly low value for fabric weight or conversely high values for courses and wales would normally be reflected by a correspondingly high value for fabric weight. More often than not however, this is actually not the case. Therefore, in order to investigate further, the following two sets of comparisons were carried out;

1) A statistical comparison of the measured values compared to the equivalent calculated values. (calculated from other reported test data).

2) Calculation of the internal consistency factors.

4.1. Measured vs Calculated

For each data set, the reported test values were used to calculate equivalent values for the various properties. The following formulae were used:-

1) Fabric weight gsm $= \dfrac{\text{tex. SLcm. c/cm. w/cm}}{10}$

2) Tubular fabric width cm BW $= \dfrac{\text{cylinder needles}}{\text{wales/cm BW}} \cdot 0.5$

3) Full open width cm BW $= \dfrac{\text{cylinder needles}}{\text{wales/cm BW}}$

4) Reference courses/cm $= \dfrac{\text{100. c/cm BW}}{\text{100 - length shrinkage}}$

5) Reference wales/cm $= \dfrac{\text{100. w/cm BW}}{\text{100 - width shrinkage}}$

6) % length shrinkage $= \dfrac{c/cm\ AW - c/cm\ BW}{c/cm\ AW} \cdot 100$

7) % width shrinkage $= \dfrac{w/cm\ AW - w/cm\ BW}{w/cm\ AW} \cdot 100$

The calculated values are tabulated together with the equivalent measured values for each data set (fabric quality and process stage) in tables A1-1 to A1-28 (Appendix 1).

The results of the statistical comparisons carried out for each data set are summarised in Appendix 2, tables A2-1 to A2-7 for Quality XR02 and tables A2-8 to A2-14 for Quality XD10. Plots illustrating the measured versus calculated values are also included. Figures A2-1 to A2-33 display the results for quality XR02 and Figures A2-34 to A2-66 display the results for quality XD10. These results show that most of the time statistically significant differences exist between the measured and equivalent calculated values. In other words, the measurements of the individual properties recorded on each individual sample are incompatible.

Tables summarising these results are included as Tables 1 and 2 at the end of Part 1. In these tables the mean differences and the standard deviations of the differences for each property and each data set are tabulated together. The mean differences indicate the average size of the discrepancy between the two sets of values, the standard deviations indicate the size of the sample to sample variation.

These results can be further summarised by calculating the average values over all the data sets for both fabric qualities in order to obtain an estimate of the overall discrepancy and the sample to sample variation.

	Mean difference	Mean SD of the differences
Weight gsm BW	-2.3	4.5
Width cm BW	+0.7	1.7
Courses/cm AW	+0.8	0.8
Wales/cm AW	+0.04	0.6
Weight gsm AW	-9.2	7.8
% Length shrinkage	-3.8	3.6
% Width shrinkage	-0.3	3.1

From these averaged results it would appear that the main problem lies in the measurement of courses or length shrinkage. Courses calculated from length shrinkage overestimate measured courses by approximately 4.3% based on the average measured values for fully finished fabrics. Variation is ±4.3%. Conversely, length shrinkage calculated from the change in courses (off machine to reference state) underestimates measured length shrinkage by approximately 3.8%. Variation is ±3.6%.

The discrepancies in courses, and marginally also in wales, are confirmed by the fabric weight results. Fabric weight calculated from measured tex, stitch length, courses and wales underestimates measured weight by approximately 6%. Variation is ±5%. Taken together, the differences in calculated courses and wales compared to measured courses and wales accounts for about 4.5% of the discrepancy between measured and calculated weight. Most of the remaining 1.5% can probably be accounted for by the fact that the values for tex and stitch length reported by Meritex were obtained from off machine fabrics, not reference state fabrics. With the exception of grey fabric where changes in tex and stitch length from grey to grey reference can be in the order of 1.5 to 2.5%, the changes in tex and stitch length in processed fabrics brought about by relaxation are normally no more than 0.5-1.0%.

However, although on the average these results would appear to indicate a systematic offset, there are large variations in the offset from sample to sample. An investigation of testing procedures and measuring techniques, especially if more than one technician has carried out the testing, should be initiated in order to identify the reasons for the discrepancies and to improve reliability and consistency.

4.2. Internal Consistency Factors

In addition to the statistical evaluation of the measured and calculated data the results were used to calculate the internal consistency factors for each data set. These values are used on a routine basis by the IIC laboratory in order to catch rogue results, which from time to time are inevitable, and to maintain a minimum standard of quality control over the results obtained by the laboratory technicians.

The individual internal consistency factors are a set of ratios as follows:

$$C1 = \frac{\text{Calculated weight BW}}{\text{Measured weight BW}}$$

$$C2 = \frac{\text{Calculated weight AW}}{\text{Measured weight AW}}$$

$$C3 = \frac{\text{Calculated courses AW}}{\text{Measured courses AW}}$$

$$C4 = \frac{\text{Calculated wales AW}}{\text{Measured wales AW}}$$

The individual results for each data set are included in Appendix 3, tables A3-1 to A3-7 for Quality XR02 and tables A3-8 to A3-14 for quality XD10. A summary table giving the means and standard deviations for each data set is included as Table 3 at the end of this section.

The results obtained by calculating the internal consistency factors serve only to confirm the results of the statistical analysis. The individual results illustrate the problem of variation within and between samples since values a long way outside of the acceptance range 0.95 - 1.05 appear regularly. In addition, it can be seen that on average calculated courses are overestimating measured courses and that calculated weight is underestimating measured weight. The results for wales in the reference state are much more secure on average although the sample to sample variation is still high. Calculated weight off machine is also underestimating measured weight and although the problem is probably less severe than for the after wash results it still reflects inconsistencies and variations in the measurement of courses and wales and perhaps also yarn tex.

5. SUMMARY AND CONCLUSIONS

1. The grey fabrics for both qualities were apparently knitted with close attention to quality control. Variation in stitch length is minimal; variation in yarn count is within normal commercial tolerances.

2. Piece to piece variation in the measured reference dimensions of identically knitted and processed fabrics suggests problems with the reliability and internal consistency of the test data.

3. Statistical analysis of the differences between measured and calculated properties indicates that problems do exist with the measurements, and in particular courses and/or length shrinkage.

4. The differences between measured and calculated weights can on average largely be explained by the apparently low measured values for courses and wales.

5. The average discrepancies between measured and calculated values are aggrevated by the high levels of variation and lack of reproducibility between samples. This could prejudice the interpretation of results obtained from an individual sample in other factory evaluations.

6. The internal consistency factors confirm the results of the statistical analysis and illustrate how if a simple quality control procedure were to be adopted by the Meritex laboratory, rogue results, which from time to time occur, could be quickly identified and retesting initiated.

7. It is recommended that an investigation into testing procedures and measuring techniques is initiated in the Meritex laboratory, in order to improve the reliability and reproducibility of test data.

TABLE 1

MERITEX: CARLO BOVETTI TRIAL

SUMMARY : Statistical Comparisons of Measured Vs Calculated Values
Mean Differences and Standard Deviations of the Differences

FABRICS MEASURED AS DELIVERED (OFF MACHINE)

Process	Weight gsm	sd	Width cm	sd
24g Quality XR02				
Grey	1.6	4.2	0.3	2.7
Prescoured	6.3	4.8	0.8	0.9
Mercerised	n.a.	n.a.	0.6	1.4
Bleach/Dye	n.a.	n.a.	0.3	0.9
Dried	-8.2	6	1.4	0.9
Calendered	-3.4	3.7	0.7	1.4
Stentered	-5.2	2.8	n.a.	n.a.
mean	-1.78	4.3	0.68	1.37
28g Quality XD10				
Grey	-3.2	4.6	-3	2.9
Prescoured	2.6	3.3	0.5	0.9
Mercerised	n.a.	n.a.	2.3	2.3
Bleach/Dye	n.a.	n.a.	1.5	2.7
Dried	-1.2	6.2	1.4	1.8
Calendered	-5.5	4.3	1	1.8
Stentered	-6.4	5.3	n.a.	n.a.
mean	-2.74	4.74	0.62	2.07
24+28g mean	-2.26	4.52	0.65	1.72

(+) means calculated greater than measured
(-) means calculated less than measured

NB 1) Weights after mercerising and bleach/dye measured wet, therefore a direct comparison with calculated weights is not applicable.

NB 2) Widths after Stenter are trimmed, therefore a direct comparison with calculated widths is not applicable.

MERITEX: CARLO BOVETTI TRIAL

SUMMARY : Statistical Comparisons of Measured Vs Calculated Values
Mean Differences and Standard Deviations of the Differences

FABRICS MEASURED IN REFERENCE STATE

Process	C/cm	sd	W/cm	sd	Wtgsm	sd	LS%	sd	WS%	sd
24g Quality XR02										
Grey	1.6	0.9	-0.3	0.5	-5.3	6.2	-6.9	3.9	1.3	2.4
Prescoured	0.9	0.4	-0.3	0.3	1.6	4	-4	1.7	1.6	2.1
Mercerised	0.9	0.6	0.5	0.8	-9.2	5.8	-3.7	2.7	-2.8	3.9
Bleach/Dye	0.9	0.8	0.6	0.5	-12.9	8.3	-3.8	3.5	-2.9	2.5
Dried	0.3	0.7	-0.1	0.6	-10.6	8.6	-1.5	3	0.6	3.2
Calendered	0.4	0.5	-0.1	0.4	-6.7	6.5	-1.9	2.2	0.3	1.9
Stentered	0.4	0.7	0.4	0.5	-11.3	6.4	-2.1	3.2	-1.8	2.5
mean	0.77	0.66	0.1	0.51	-7.77	6.54	-3.41	2.89	-0.53	2.64
28g Quality XD10										
Grey	1.2	1	0.02	0.5	-10.8	8.9	-5.8	5.4	-0.1	2.3
Prescoured	1.1	0.7	-0.3	0.4	-4.9	4.2	-5.3	3.2	2	2.4
Mercerised	0.7	0.7	-0.02	0.9	-14.5	4.1	-3.1	3	0.04	5.4
Bleach/Dye	1.6	1.2	-0.05	0.9	-13.4	15.9	-7	5.3	0.2	4.8
Dried	0.7	1	-0.1	0.5	-8	11.8	-3.3	5.3	0.3	2.8
Calendered	0.3	1	0.1	1	-8.7	12.8	-1.7	4.9	-0.5	4.6
Stentered	0.5	0.7	0.3	0.6	-14.5	5	-2.6	3.4	-1.7	2.7
mean	0.87	0.9	-0.01	0.69	-10.69	8.96	-4.11	4.36	0.03	3.57
24+28g mean	0.82	0.78	0.04	0.6	-9.23	7.75	-3.76	3.62	-0.25	3.11

(+) means calculated greater than measured
(-) means calculated less than measured

TABLE 3

MERITEX: CARLO BOVETTI TRIAL

MERITEX Test Data : Internal Consistency Factors

SUMMARY: Means and Standard Deviations

Process	N	C1	sd	C2	sd	C3	sd	C4	sd
24g Quality XR02									
Grey	24	1.02	0.04	0.96	0.04	1.07	0.04	0.98	0.03
Prescoured	12	1.05	0.04	1.01	0.03	1.05	0.02	0.98	0.02
Mercerised	24	n.a.	n.a.	0.94	0.04	1.05	0.03	1.03	0.04
Bleach/Dye	24	n.a.	n.a.	0.92	0.05	1.05	0.04	1.03	0.03
Dried	24	0.94	0.04	0.93	0.05	1.02	0.03	0.99	0.03
Calendered	12	0.97	0.03	0.96	0.04	1.02	0.03	1	0.02
Stentered	12	0.96	0.02	0.93	0.04	1.02	0.04	1.02	0.03
28g Quality XD10									
Grey	24	0.97	0.04	0.93	0.06	1.06	0.06	1	0.03
Prescoured	12	1.02	0.03	0.96	0.03	1.06	0.04	0.98	0.02
Mercerised	24	n.a.	n.a.	0.91	0.03	1.04	0.04	1	0.05
Bleach/Dye	24	n.a.	n.a.	0.92	0.1	1.09	0.07	1	0.05
Dried	24	0.99	0.05	0.95	0.07	1.04	0.06	1	0.03
Calendered	12	0.96	0.03	0.94	0.08	1.02	0.06	1.01	0.05
Stentered	12	0.95	0.04	0.91	0.03	1.03	0.04	1.02	0.03

C1 = Calculated Weight BW / Measured Weight BW
C2 = Calculated Weight AW / Measured Weight AW (Tex & SL BW)
C3 = Calculated Courses AW / Measured Courses AW
C4 = Calculated Wales AW / Measured Wales AW

N = Number of samples; sd = Standard Deviation

NB Weights BW after Mercerising and Bleach/Dye measured Wet, therefore a direct comparison with calculated Weights is not applicable

P A R T 2

THE EFFECT OF PROCESSING VARIABLES AND MACHINE GAUGE ON THE DIMENSIONS AND PERFORMANCE OF THE FINISHED FABRICS

PART 2: The effect of processing variables and machine gauge on the dimensions and performance of the finished fabrics.

1. INTRODUCTION

The main objectives of the Carlo Bovetti trial were to identify differences in the fully finished fabrics which could be attributed to differences in the processing procedures to which the individual samples were subjected.

In order to discover whether real differences exist between the various processing sequences it is the reference state dimensions of the samples which have to be compared. If no differences exist between reference dimensions, then differences in finished fabric performance (shrinkage) will be due to differences in the "as delivered" dimensions. Conversely, if differences do exist between the reference dimensions and the fabrics are delivered to the same dimensions, then differences in finished fabric performance (shrinkage) will be observed. Therefore once the reference dimensions have been compared the "as delivered" dimensions of the samples must also be scrutinised.

However, in order to be able to establish that it is the processing variables which have caused apparent differences in the finished fabrics it is first necessary to establish that the original grey fabrics were produced to the same quality (and can therefore be treated as identical) and that normal variations in the fabric caused by processing are taken into account.

The basic results reported by Meritex have shown that the grey fabric pieces were knitted with a high level of quality control. Variation in stitch length between pieces of the same quality is minimal and the variation in the knitted tex is within normal commercial tolerances. Therefore we would normally be reasonably confident that any differences which are observed in the reference dimensions of fabrics which have followed different processing sequences could probably be attributed to the influence of the different procedures and not to real differences in the grey fabrics. However, in the analysis of the basic data it was discovered that large variations exist in the measured dimensions of fabrics which had followed identical processing routes. The probable source of these apparent variations was identified as inconsistency and variation in the measurement of the individual parameters during testing. This makes the identification of processing influences more difficult to detect with certainty because the reliability of the measured data is in question. Consequently, in order to be able to draw any conclusions from the data it is necessary to erect a criterion which takes some account of the variation in the data, with which to judge the results.

The following outlines such a criterion and presents the conclusions which can be drawn by applying it to the available data. For the purposes of this analysis only those results obtained from the fully finished samples have been considered, as it is differences in the delivered fabrics which are the main concern of the trial. The results obtained from the samples at an intermediate stage of processing have therefore been ignored. In addition, intermediate stage of processing have therefore been ignored. In addition, it is also probably worth noting that the problems associated with the individual test results are less severe in the fully finished samples than on the part processed fabrics.

2. A CRITERION FOR JUDGEMENT

For each fabric quality, the same processing sequence was followed by three individual samples. Each set of results can therefore be treated as a replication and the results from all three samples averaged in order to discover the average dimensions obtained after a particular processing sequence. Variation between the individual samples is indicated by the standard deviation.

Given that there are problems with the reproducibility of the individual measurements and knowing that the grey fabrics in each set were knitted to the same quality, there is no reason to suppose that the level of variation indicated between one set of three samples should, on average, be any more or less than that found between another set of three samples. Therefore, the standard deviations obtained for each set of three samples, for each property measured, and for each quality were averaged. The results for the reference state values are given in the following table:

PROPERTY	AVERAGED STANDARD DEVIATION
Tex	0.16
Stitch Length cm	0.0007
Courses/cm	0.55
Wales/cm	0.27
Weight gsm	1.29

Using the averaged standard deviations as the basis for comparisons between the data sets, the 95% confidence limits can be calculated using the formula:

$$CL = \frac{t.s}{\sqrt{N}}$$

where: t is the students t statistic for N-1 degrees of freedom
s is the averaged standard deviation for the samples
N is the number of samples

For a set of three samples the 95% confidence limit is calculated to be 2.5 standard deviations. Using this value the 95% confidence limits for each property in the reference state can be calculated. These are given in the following table:

PROPERTY	AVERAGED 95% CL
Tex	±0.4
Stitch length cm	±0.002
Courses/cm	±1.4
Wales/cm	±0.7
Weight gsm	±3.2

These values provide a criterion for judging the apparent differences which are observed between the various processing sequences. Differences which are found to be larger than the 95% confidence limits are unlikely to have occurred simply by chance, and can therefore be considered to indicate a potentially real or significant difference between the samples.

For each processing variable there are eight parallel comparisons which can be made. If there is a real influence of a processing variable on a given property then significant differences should appear consistently in all or at least in the majority of cases. If a significant difference is indicated only once or in a minority of cases, then the effect is not proven.

If, in a particular set of comparisons, no consistent significant differences are found, then it is permissible to average over the two data sets. This provides a basic data set containing six samples. The averaged standard deviations and confidence limits for a set of six samples are different from a set of three, but can be calculated in a similar way. For a set of six samples the calculation for confidence limits indicates that a significant difference will probably exist if the differences between the two sets of values are greater than approximately 1 standard deviation.

Similar values can be calculated for the finished as delivered or off machine fabric properties, as those given above for the reference state. These provide a similar criterion for judging whether fabrics processed through the different sequences have actually been delivered to the same dimensions.

The averaged standard deviations for the finished as delivered fabrics are given in the following table:

PROPERTY	AVERAGED STANDARD DEVIATION
Courses/cm	0.33
Wales/cm	0.24
Weight gsm	2.0
Width cm	0.5
Length shrinkage %	0.9
Width shrinkage %	0.93

From the averaged standard deviations the 95% confidence limits (2.5s) were calculated and are given in the following table:

PROPERTY	AVERAGED 95% CL
Courses/cm	±0.8
Wales/cm	±0.6
Weight gsm	±5.0
Width cm	±1.3
Length shrinkage %	±2.3
Width shrinkage %	±2.3

3. PRESENTATION OF RESULTS

The detailed comparisons for each data set are contained in Appendix 4. Tables A4-2 to A4-12 give the reference state comparisons, Tables A4-14 to A4-24 give the as delivered or off machine comparisons. Significant differences based on the appropriate condfidence limits are indicated on the tables by an asterisk. Tables A4-1 and A4-13 summarise the averaged standard deviations and confidence limits used for the comparison.

4. DISCUSSION

4.1. Reference State Comparisons

4.1.1 Calendered vs Stentered

On the average, there are no consistent significant differences between the calendered and stentered fabrics in the reference state. Consequently the two data sets can be averaged in order to provide a second level of comparison between the remaining data sets.

4.1.2 Prescoured vs Not Scoured

On the average there are no consistent significant differences between the prescoured and not scoured bleached fabrics. For the dyed fabrics however there is an indication (3 out of 4) that the fabrics which have not been prescoured prior to mercerising and dyeing may be heavier. There are no consistent significant differences in the other properties.

When the calendered and stentered data sets are averaged and compared the significant weight difference is confirmed for the dyed fabrics and in addition a significant difference is shown for the 28 gauge bleached fabrics, although not for the 24 gauge fabrics.

On balance therefore there is an indication that prescouring prior to mercerising, bleaching or dyeing may be reducing the finished reference weight of the fabrics by an average 2%.

4.1.3 Bleached vs Dyed

The dyed fabrics are consistently and significantly heavier than the bleached fabrics although consistent significant differences in the other properties are not apparent. This is confirmed by the comparison of the averaged calendered and stentered data sets.

The prescoured dyed fabrics are on average 5.3% heavier than the prescoured bleached fabrics; the not scoured fabrics are on average 7.0% heavier than the not scoured, bleached fabrics. Overall, the dyed fabrics are heavier than the bleached fabrics by approximately 6.2%.

4.1.4 24 gauge vs 28 gauge

The individual comparisons show statistically significant differences between stitch length and courses. The 28 gauge fabrics have a longer stitch length and fewer courses/cm in the reference state. There is also an indication from the dyed fabric results that the reference weight of the 28 gauge fabrics is lighter than the 24 gauge fabrics.

These results are confirmed by the comparison of the averaged calendered and stentered data sets.

The 28 gauge fabrics have on average stitch lengths 4% longer than the 24 gauge fabrics and 7.7% fewer courses. From the dyed fabrics there is also an indication that the 28 gauge fabrics are lighter by approximately 3%, although this is not repeated in the bleached fabrics. Taken overall the 28 gauge fabrics are approximately 1.5% lighter than the 24 gauge fabrics.

4.2. <u>As Delivered (off machine) Comparisons</u>

4.2.1 Prescoured vs Not Scoured

There are no consistent significant differences in the delivered dimensions of the prescoured and not scoured fabrics. Consequently the two data sets can be averaged in order to provide a second level of comparison between the remaining data sets.

4.2.2 Calendered vs Stentered

From the individual comparisons there is an indication that the dyed fabrics which have been stenter finished have less length shrinkage than the calendered fabrics; the results from the bleached fabrics on balance support this. In addition, there is also an indication that the stenter finished fabrics have higher width shrinkages. The individual differences are with one exception not significant but 7 out of 8 comparisons show a positive trend.

If the averaged prescoured and not scoured data sets are compared the difference in length shrinkage for dyed fabrics is confirmed and also the overall difference in width shrinkage.

The results from the reference state comparisons showed that there was no difference between calendered and stentered fabrics in the reference state. Therefore differences in shrinkage found in the delivered fabrics should normally be supported by differences in the delivered courses and wales. Lower recorded values for length shrinkage would suggest that the fabrics were delivered with more courses. Higher recorded values for width shrinkage would suggest that the fabrics had been delivered with fewer wales.

Looking at the results from the averaged prescoured and not scoured data sets, this trend is not shown consistently, although on the average more courses and fewer wales are indicated which confirms the trend in the shrinkage results.

4.2.3 Bleached vs Dyed

The individual comparisons show that the dyed and bleached fabrics were not consistently delivered to the same dimensions, and that the dyed fabrics were delivered heavier than the bleached fabrics.

This is confirmed by the comparison of the averaged prescoured and not scoured data sets. On average the dyed fabrics are 4% heavier than the bleached fabrics. Variation in the other properties however makes further conclusions impossible.

4.2.4 24 gauge vs 28 gauge

The 28 gauge fabrics were on average delivered with fewer wales and more length shrinkage than the 24 gauge fabrics. The 28 gauge bleached fabrics were also delivered with more wales. On average the 28 gauge fabrics were also delivered lighter than the 24 gauge fabrics.

On the average the 28 gauge fabrics were delivered with approximately 9% fewer courses than the 24 gauge fabrics and with an average greater length shrinkage of 1.6%. The comparison of the reference state data indicated that in the reference state the 28 gauge fabrics had 7.7% fewer courses than the 24 gauge fabrics. Therefore the increased level of length shrinkage is confirmed by the increased difference in courses between the two sets of fabrics.

On average the 28 gauge fabrics were delivered approximately 3.3% lighter than the 24 gauge fabrics. The comparison of the reference data indicated that the overall difference in weight was approximately 1.5%. The increased difference in weight is therefore also supported by the differences in delivered courses.

Significant differences in reference wales were not confirmed in the comparison of the reference data and therefore if both sets of fabrics were delivered to the same wales/width then differences in width shrinkage should not be apparent. Although individually significant differences in measured delivered wales and width shrinkage can be identified they are not consistent over all the data sets, and on average there is no difference either in delivered wales or width shrinkage. Fabric widths cannot be directly compared between the two gauges because the number of needles and therefore the delivered widths were different.

5. SUMMARY AND CONCLUSIONS

1. From the reference state comparisons there is firm evidence that:

   1) dyed fabrics are heavier than bleached fabrics by approximately 6.2% overall.

   2) 28 gauge fabrics were knitted with a 4% longer stitch length and have 7.7% fewer courses in the reference state than the 24 gauge fabrics.

2. There is also an indication that prescouring may reduce the finished reference weight of the fabric (especially after dyeing) compared to not scoured fabrics by approximately 2%.

3. There are no consistent differences between calendered and stentered fabrics.

4. The comparison of the delivered dimensions showed that there was no difference between prescoured and not scoured fabrics, but that on average the stentered fabrics were delivered with more courses and fewer wales which resulted in less length shrinkage and more width shrinkage compared to the calendered fabrics.

5. The dyed fabrics were delivered heavier than the bleached fabrics by approximately 4% but variation in the other properties did not allow further conclusions to be drawn.

6. The 28 gauge fabrics were delivered with fewer courses and more length shrinkage than the 24 gauge fabrics. The size of the differences were compatible with the differences in reference state dimensions. The 28 gauge fabrics were also on average delivered lighter than the 24 gauge fabrics which was also supported by the differences in weight between the two data sets.

P A R T 3

COMPARISON WITH STARFISH V87:4.3

PART 3 : Comparison with STARFISH V87:4.3

1. INTRODUCTION

The current STARFISH model for mercerised single jersey fabric was developed from the results obtained on fabrics which had been piece mercerised on a Dornier tubular mercerising range and dyed to a medium shade in a Gyrostock dyeing machine. Theoretically therefore we would not necessarily expect the predictions obtained from this model to accurately predict the behaviour of the fabrics produced by Meritex which were mercerised on an Omez mercerising range and dyed both white and to a dark shade on a Brazzoli dyeing machine. In addition, the measured values reported by Meritex show inconsistencies and variations which not only detract from the reliability of the data but also may obscure any real differences in the relaxation procedures between laboratories or any real differences in finished dimensions which may actually be present.

However, these points notwithstanding, the practical, commercial utilisation of the STARFISH model does not necessarily require absolute agreement between predicted and measured values, if the predicted values can be used to provide relevant guidelines for the production/processing/testing conditions prevailing in an individual mill. For this reason therefore, it is useful to examine the degree of fit between STARFISH and the results reported by Meritex in order to establish whether from a practical/commercial point of view the current STARFISH model can provide useful information in the actual production environment.

2. A CRITERION FOR JUDGEMENT

As in the case of the comparison between different processing sequences reported in Part 2, we need to establish a criterion with which to judge the goodness of fit between the measured values and the STARFISH model predictions. For these comparisons however, we are more concerned with practical differences rather than statistical ones. Therefore an appropriate criterion is one which takes account of whether the prediction is near enough to be useful rather than whether it is significantly different.

A reasonable basis on which to build such a criterion might be one which is established from common commercial tolerance levels. In the UK, typical tolerances are:

Courses/cm	± 2.5%
Wales/cm	± 2.5%
Weight gsm	± 5.0%

Using these values as a starting point therefore, we might reasonably arrive at the following scheme for assessing the practical usefulness of any STARFISH predictions.

Assessment	% Differences	
	Courses/Wales	Weight
Excellent	0 - 1.5	0 - 2.5
Acceptable	1.6 - 2.5	2.6 - 5.0
Poor	2.6 - 4.0	5.1 -10.0
Worthless	4.1 +	10.1 +

3. PRESENTATION OF RESULTS

In Appendix 5, detailed comparisons of the dimensional data obtained from the Carlo Bovetti trial have been made with those values which would have been predicted by the STARFISH model. Tables A5-1 and A5-2 compare the results for grey fabric; Tables A5-3 and A5-4 the results for winch scoured; Tables A5-5 to A5-8 the finished reference state dimensions, and Tables A5-9 and A5-10 the finished as delivered results. In each case both the absolute and the percentage differences between the measured and the predicted values have been calculated.

4. DISCUSSION

The STARFISH model predicts the average dimensions and performance (shrinkage) of knitted fabrics from a knowledge of the yarn count and stitch length as knitted, the knitting machine on which the fabrics were produced and the finishing route through which the fabrics were processed.

Predictions can be obtained for both reference state dimensions and finished as delivered or off machine dimensions. As delivered dimensions are calculated from the reference state dimensions by specifying the two target parameters for the finished fabrics which are required to be achieved, e.g. length and width shrinkages, or course and wale densities, or weight and width.

For the purposes of this analysis, comparisons have been made between measured and predicted values in the reference state for both grey and processed fabrics, and in the finished as delivered state for processed fabrics. Input values for each quality were the average measured values for tex and stitch length, and the average measured values for length and width shrinkage as finishing targets.

For the processing routes which were used in this exercise, STARFISH does not contain an exactly appropriate model, therefore the nearest available match was used, as follows:-

Actual process	STARFISH Model Used
Grey	Grey
Prescour	Winch Bleach
Omez, Brazzoli, white, tubular	Dornier, Gyrostock, dyed, tubular
Omez, Brazzoli, white, stenter	Dornier, Gyrostock, dyed, tubular
Omez, Brazzoli, dyed, tubular	Dornier, Gyrostock, dyed, tubular
Omez, Brazzoli, dyed, stenter	Dornier, Gyrostock, dyed, tubular

Note that:-

1. The actual dyeing reported by Meritex was to a dark shade, whereas the model predictions are for a medium shade. This will affect mainly the weight predictions.

2. Provided that the yarn type and especially the yarn twist of the yarns used in the trial is similar to that modelled by STARFISH then we would not expect to see large differences for the grey fabrics between the STARFISH predictions and the measured dimensions.

3. Previous trials have indicated that, for single jersey fabrics, the differences between fabrics processed on Gyrostock and Brazzoli dyeing machines, and through tubular and stenter finishing are not large.

4. The influence of different mercerising machines/conditions on fabric dimensions can be significant. Therefore we would not be surprised to see relatively large differences between fabrics processed on Omez and Dornier mercerisers.

A study of the detailed comparisons in Appendix 5 yields a rather confusing picture with many contradictions. Much of this confusion is probably as a result of the known variability in the test data. Therefore in order to simplify the picture and smooth out the variations, the data were averaged over processing routes into four broad categories, namely, Grey, Prescoured, Finished white and Finished dyed. Initially the 24g and 28g samples were kept separate since they are two distinct basic qualities (different stitch lengths) and because a comparison between these two qualities would give an indication of the consistency of the conclusions.

4.1. Reference State Fabrics

4.1.1 Tex and Stitch Lengths

Changes in yarn tex and stitch length from as knitted to the finished reference state have been found to be fairly consistent over all fabric types (rib, interlock and single jersey) and for a very wide range of yarn counts. Changes in yarn tex are primarily dependent on the type of processing, e.g. mercerising and the depth of shade to which the fabric is produced. Changes in stitch length are primarily dependent on the type of processing, e.g. mercerising but are not influenced further by the depth of shade.

The following tables compare the values used by STARFISH to those reported by Meritex for the fabrics from the Carlo Bovetti trial.

Tex	STARFISH	% Change (As Knitted to Finished Reference) Meritex 24g	28g	Mean
Grey	-2.3	-	-	-
Winch bleach	-3.5	+1.9	+0.9	+1.4
Merc., Bleached white	+2.1	+1.3	+4.5	+2.9
Merc., Medium dyed	+3.7			
Merc., Deep dyed	+7.3	+2.4	+4.7	+3.6

Stitch Length	STARFISH	Meritex 24g	28g	Mean
Grey	-1.4	-	-	-
Winch Bleach	-1.8	0	0	
Merc, Bleached white	-7.4	-6.4	-8.1	-7.3
Merc., Medium dyed	-7.4			
Merc., Deep dyed	-7.4	-6.4	-8.1	-7.3

On average the change in stitch length in the fully finished fabrics is predicted by STARFISH, although no change was reported after prescouring. For tex, the changes reported by Meritex are similar for the bleached white fabrics but the change in dyed fabrics are better predicted by the medium dyed model than the deep dyed model. An increase in tex after prescouring is an unusual result and would not have been predicted.

The results for the prescoured fabrics suggest that there may have been a problem with the measurements.

4.1.2 Dimensions

The following figures summarise the average pecentage differences found in the reference state samples. Percentage difference is defined as:-

$$D\% = 100 \ \frac{(\text{Predicted-Measured})}{\text{Measured}}$$

Reference State % Differences

		Courses	Wales	Weight	C + W
Grey	24g	1.4	3.8	-2.0	5.2
	28g	5.1	0.6	-5.5	5.7
	Mean	3.3	2.2	-3.8	5.5
Prescour	24g	3.5	1.2	-1.4	4.7
	28g	3.7	0.6	-5.1	4.3
	Mean	3.6	0.9	-3.3	4.5
White	24g	2.6	3.7	3.3	6.3
	28g	2.2	1.6	-2.0	3.8
	Mean	2.4	2.7	0.7	5.1
Dyed	24g	0	3.2	-3.7	3.2
	28g	1.7	1.6	-5.7	3.3
	Mean	0.9	2.4	-4.7	3.3

From these figures, the following observations can be made:-

1. There is a clear trend for predicted courses and wales to be greater than the measured values with a corresponding and opposite difference in the weights. In theory, the sum of the differences in courses and wales given in the fourth column should be equal and opposite to the difference in weight.

2. There is often a relatively large disagreement between the 24g and 28g fabric. In theory these two should be identical. The source of this discrepancy must therefore be in the measured values.

3. From the practical point of view, using the criteria for judgement outlined in 2.0, there are no cases where both 24g and 28g results agree that the predictions are worthless, and there is only one case where both 24g and 28g agree that the predictions are poor. If we take the mean of the 24g and 28g results then there are three cases where the predictions are poor but in the vast majority of cases these results indicate that STARFISH can provide a useful level of prediction.

However, in spite of averaging across samples, there are three facts which lead to the conclusion that the basic unreliability of the data is again clouding the issue. These are:

1. There is no reason to expect a difference between measured and predicted values for the grey fabrics, since, unless the grey yarn was substantially different from those used in building the model, we know that grey fabrics are adequately modelled by STARFISH.

2. There is no reason to expect a difference between the percentage differences for 24g and 28g qualities within a given processing route. This would indicate an independent influence of machine gauge which has not been proven in all our previous trials. Even if a given processing route is not adequately modelled by STARFISH there should be a constant offset for these fabrics.

3. The sum of the differences for courses and wales should always be equal and opposite to the difference for weight. Even for the mean values this is not true of these results.

Notwithstanding these reservations and difficulties, however, STARFISH has more often than not provided practically useful predictions.

4.2. As Delivered Fabrics

The following table summarises the average percentage differences found in the samples measured in the as delivered or off machine state, compared with the STARFISH predictions. The predictions were obtained using the measured length`and width shrinkage values as finishing targets.

As Delivered State % Differences

		Courses	Wales	Weight	C + W
Prescour	24g	-1.1	3.1	0	1.0
	28g	-2.4	2.5	-3.4	0.1
	Mean	-1.7	2.8	-1.7	0.5
White	24g	1.4	3.7	3.2	5.1
	28g	0.6	-0.8	-2.4	0.1
	Mean	1.1	1.5	0.4	2.6
Dyed	24g	-3.3	2.0	-4.5	0.6
	28g	-1.2	2.0	-5.9	0.4
	Mean	-2.3	2.0	-5.2	-0.3

On the whole, the trends in these data and the conclusions which can be drawn from them are the same as for the Reference State comparisons.

The only additional point which may perhaps be worthy of note is that, in theory, the offset between predicted and measured values should be about the same for the as delivered results as it is for the Reference State results. This is clearly not the case, especially for the courses, as can be seen from the following summary:

Mean % Difference

		Courses	Wales	Weight	C + W
Prescour	Ref.	3.6	0.9	-3.3	4.5
	As Del.	-1.7	2.8	-1.7	0.5
	Mean	0.9	1.8	-2.5	2.7
White	Ref.	2.4	2.7	0.7	5.1
	As Del.	1.1	1.5	0.4	2.6
	Mean	1.7	2.1	0.5	3.8
Dyed	Ref.	0.9	2.4	-4.7	3.3
	As Del.	-2.3	2.0	-5.2	-0.3
	Mean	-0.7	2.2	-4.4	1.5

In principle the mean values in this summary table could be used as correction factors for use with the currnt STARFISH model when making predictions for fabrics of the type used in this study when they are tested in the Meritex laboratory. However, their value is limited by the underlying accuracy of testing. A much more profitable approach would be firstly to upgrade the accuracy of testing and then to carry out a calibration exercise on a new set of samples taken at random from current production.

5. SUMMARY AND CONCLUSIONS

1. Given that the current STARFISH model for mercerised fabrics was developed on fabrics processed through a different mercerising and dyeing route to that used by Meritex, and that there are some problems with the reliability of the measured data, the results of the comparisons of measured and predicted values have shown that practically useful information can be obtained from STARFISH for use by Meritex within their processing and testing environment.

2. The averaged percentage differences which have been calculated could, in the absence of more precise comparisons or models developed specifically for the processing routes found in the the Meritex mill, be used as correction factors for use with the current STARFISH model. However, a more profitable approach would be to improve the accuracy of testing and then to carry out a new calibration exercise on a new set of samples.