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The 2003 Australian Wool Innovation On-Farm Fibre Measurement Instrument Evaluation Trial. Part 1: Accuracy and Precision Trials

By

J.W. Marler and P. Baxter*

AWTA Ltd PO Box 190, Guildford, NSW, 2161, Australia
* SGS Wool Testing Services PO Box 15062, Wellington, New Zealand

SUMMARY

The 2003 Australian Wool Innovation Ltd (AWI) On-Farm Fibre Measurement (OFFM) Instrument Evaluation Trial was a direct outcome of market research commissioned by AWI, which indicated an increasing need by wool producers for an independent and objective assessment of the commercial application of the two current OFFM technologies (OFDA2000 and Sirolan Fleecescan™). AWI established an Expert Advisory Group to provide assistance and guidance with the design and implementation of the trial and the analysis and interpretation of the trial results.

The trial design included sampling the whole fleece (Fleecescan) and two sampling sites (OFDA 2000 for the traditional midside and the less common pinbone) on-farm followed by laboratory testing to Australia/ New Zealand Fleece Testing Standards.

With respect to this report, the key objectives were to determine the Confidence Limits, relevant to the whole fleece rather than simply the sampling site, for the different fleece measurement systems as they are used commercially. The measured characteristics were: Mean Fibre Diameter (MFD); Standard Deviation of fibre Diameter (SDD), Coefficient of Variation of Fibre Diameter (CVD), Comfort Factor (CFR) and Mean Fibre Curvature (MFC).

The Overall Confidence Limits are presented below (Note: for a given parameter, values with the same letter are considered to be statistically equivalent ($p>0.05$)):

Parameter	Fleece	Pinbone Samples			Fleece	Midside Samples		
	Whole Flc Avg	Lab LSN	Lab OFDA100	OFDA -2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
MFD	**19.5**	**±1.19c**	**±1.25c**	**±1.39d**	**±1.17b**	**±1.24c**	**±1.05ab**	**±1.04**
SDD	**4.1**	±0.7**a**	±0.5**a**	±0.5**a**	±0.7**a**	±0.5**a**	±0.5**a**	±0.6**a**
CVD	**20.8**	±3.3**c**	±2.4**a**	±2.2**a**	±3.4**c**	±2.2**a**	±2.4**a**	±2.9**b**
CFR	**98.1**	±2.3**a**	±2.6**a**	±2.6**a**	±1.8**a**	±1.6**a**	±1.5**a**	±1.6**a**
MFC	**93**	±15**b**	±12**ab**	±13**b**	±13**ab**	±12**ab**	±10**a**	±13**ab**

The above Confidence Limits relate to the procedures that were common commercial practice in 2003. Where required, they can be improved, at an increased cost, by increasing the sampling and or testing regimes.

The key conclusions from this component of the trial were that:

- Midside sampling and laboratory testing gave the best and equivalent confidence limits of ±1.04μm for Laserscan and ±1.05μm OFDA100.; and
- The Fleecescan (±1.17μm) and OFDA2000 midside sampling (±1.24μm) were considered to be equivalent in precision.

The Overall Means and Biases (referenced to the Whole Fleece Average Value) are presented below (Note: for a given parameter values with the same letter are considered to statistically equivalent (p>0.05)):

Parameter	Whole Flc Avg	Pinbone Samples			Fleece	Midside Samples		
		Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
MFD Diff Wh Flc	**19.5**	**20.1cd 0.5**	**20.2d 0.7**	**20.3d 0.7**	**19.7bc 0.2**	**19.3ab -0.2**	**19.3ab -0.2**	**19.2a -0.4**
SDD Diff Wh Flc	**4.1**	4.0**cd** -0.1	4.0**d** -0.1	3.7**b** -0.3	4.0 **cd** -0.1	3.6**a** -0.5	3.9**c** -0.2	3.8**b** -0.3
CVD Diff Wh Flc	**20.8**	19.7**b** -1.0	19.7**b** -1.1	18.3**a** -2.4	20.1**b** -0.7	18.5**a** -2.2	20.1**b** -0.7	19.6**b** -1.2
CFR Diff Wh Flc	**98.1**	97.6**ab** -0.6	97.4**a** -0.7	97.6**ab** -0.6	98.0**abc** -0.2	98.8**c** 0.6	98.6**bc** 0.4	98.6**bc** 0.4
MFC Diff Wh Flc	**93**	94**c** 2	84**ab** -9	80**a** -13	99**c** 6	82**a** -11	88**b** -4	98**c** 5

The different measurement systems produced different biases compared to the whole fleece average. In the case of MFD, pinbone sampling was biased coarse (+0.6μm) and midside sampling was biased fine (-0.3μm). OFDA2000 underestimated the SDD (-0.2μm) and the CVD (-2.3%). The biases in MFC reflect the current lack of a calibration procedure for MFC.

The key conclusions from this component of the trial were that:

- For on-farm MFD measurements, OFDA2000 measured on midsides and Fleecescan measured on fleeces gave equivalent accuracy compared with the whole fleece average.
- For MFD, the pinbone samples measured on-farm or in a laboratory provided significantly higher results (average +0.6 μm) than the whole fleece average. The pinbone as a sampling site does not give as accurate a measure for MFD for the whole fleece.

INTRODUCTION

Since the late 1990s, both OFDA2000 (measurement based on imaging technology) and Sirolan Fleecescan™/Sirolan Laserscan™ (measurement based on laser technology) instruments have been regularly used to measure mean fibre diameter (MFD), but also other wool fibre traits, on samples taken from fleeces on-farm; in a race pre-shearing and in shearing sheds at shearing time.

In September 2001, Australian Wool Innovation (AWI) initiated a series of research projects to gain a greater understanding of the issues involved with the development and application of the on-farm fibre measurement (OFFM) technologies and systems. Nine research projects were initiated with respect to OFFM covering: market research, a world-wide search for new technologies, an assessment of potential enhancements to existing technologies, scoping of a Quality Assurance (QA) program, scoping of a wool grower extension program, a cost-benefit analysis, an assessment of the potential for electronic identification, an assessment of existing and future decision support systems and a comparison of existing technologies.

The market research commissioned by AWI, which was completed in June 2002, indicated an increasing need by woolgrowers for an independent and objective assessment of the commercial application of the two current OFFM technologies.

At that time, there had been little independent published information on the performance of the two instruments with respect to their use by woolgrowers for clip preparation, sheep breeding and/or flock management. There was also a scarcity of published data that used recognised and industry accepted statistical methods to determine the precision limits of each instrument and/or to compare their outcomes and their application methods.

In addition, there was only one published study (Marler *et al.,* 2002a, Marler *et al.,* 2002b) that had attempted to derive the precision limits as they related to the whole fleece instead of the more common practice of reporting the precision limits as they related to an individual site or a submitted sample.

By June 2002, AWI had established a draft protocol for an extensive trial that would address the above issues. AWI also established an OFFM Expert Advisory Group (EAG) to provide assistance and guidance with the implementation of the trial and the analysis and interpretation of the trial results. The OFFM EAG comprised the following:

- Mr Peter Baxter — SGS Wool Testing Services (New Zealand)
- Dr Ralph Behrendt — Department of Primary Industries (Victoria)
- Dr Kerry Hansford — Teckel Consulting Pty Ltd
- Dr Bill Humphries — CSIRO Textile and Fibre Technology
- Dr John James — Consultant Statistician
- Mr Jim Marler — AWTA Ltd
- Dr Paul Swan — AWI Ltd
- Mr George Waldthausen (Chair) — AWI Ltd

Dr John James was appointed to provide the primary analysis and interpretation of the results of the trial with advice and guidance from other EAG members. Mr Gary Macfarlane (GMAC Consulting Pty Ltd) was AWI's Project Manager responsible for the implementation of all aspects of the trial. Mr Russell Pattinson (Miracle Dog Pty Ltd) provided on-ground detailed management of each trial site.

Rather than simply compare the OFDA2000 (incorporating both pinbone and midside sampling) and the Sirolan Fleecescan™ on-farm, it was considered appropriate to expand the trial to include a representation of Laboratory Fleece Measurement Systems. Hence, both midside sampling and pinbone sampling followed by laboratory preparation and measurement on both a Sirolan Laserscan and an OFDA100 were included.

The key objectives of the instrument evaluation project (trial) were to quantify:

(1) The precision/repeatability and accuracy of the commercially available sampling/measurement systems, with respect to an entire fleece; for the measured characteristics principally, Mean Fibre Diameter (MFD); but including: Standard Deviation of Fibre Diameter (SDD), Coefficient of Variation of fibre Diameter (CVD), Comfort Factor (CFR) and Mean Fibre Curvature (MFC).

(2) The ability of the sampling/measurement systems, principally the Fleecescan and the OFDA2000 (with midside sampling) to class a single mob wool clip into lines of distinctive MFD categories (minimum category of one micrometre (μm)); and

(3) The ability of the sampling/measurement systems, principally the Fleecescan and the OFDA2000 (with midside sampling) to rank individual sheep on the basis of MFD.

This report will cover the key objective (1) and a second report (Baxter and Marler, 2004) will cover key objectives (2) and (3) above.

The trial was specifically directed towards providing knowledge that could be used by woolgrowers (or their sheep and wool customers) to make informed decisions with respect to the use of these OFFM instruments for clip preparation, sheep breeding and/or flock management.

The trial provided an opportunity to benchmark one instrument against the other; and against the commercially accepted method of fleece measurement using on-farm midside sampling and off-farm laboratory measurement; and against IWTO certified results for on-farm prepared sale lots.

The trial also provided an opportunity to assess variability between operators and their instruments. As each operator had a separate instrument, these two components could not be separated in this trial; hence the variance for the operator-instrument effect was combined. It was expected that the majority of this variance would be due to operators, since experience suggests that there is little variation between instruments when used for diameter distribution measurement.

Scope of Trial Design

The trial was limited to providing information to woolgrowers specifically in relation to the classing and the ranking of the measures defined above. The trial did not assess:

- The other wool fibre measurements that may be provided by either instrument;
- The performance of either instrument in an in-store environment; or
- The two instruments in relation to issues such as ease of use, robustness, Occupational Health and Safety, after sales support, quality assurance, pricing, etc.

Factors Influencing the Performance of OFFM Instruments

Valid comparisons between OFFM instruments are difficult as the sample tested varies greatly. For example, usually the test specimen measured by OFDA2000 is sourced from a single staple, by Lab LSN and Lab OFDA100 is a sourced from a single site sample and for Fleecescan is sourced from an entire fleece. For this reason, the precision or repeatability of each instrument may not provide meaningful results in terms of the "best" instrument.

In addition, there are a number of other factors that influence the performance (precision and accuracy) of the instruments, which can subsequently affect any comparisons made. In terms of the equipment evaluated in this project, such factors include:

- Number of samplers i.e.
  - OFDA2000 – different samplers take staple from sampling site
  - OFDA2000 – different samplers prepare micro-staple from staple
  - Lab OFDA100 and LAB LSN – different samplers take sample from site
- Number of samples/test specimens i.e.
  - OFDA2000 – test more than one micro-staple per sample (eg. two test specimens from midside)
  - OFD2000 – test more than one site (eg. one test specimen from both midside and pin-bone)
  - Lab OFDA100 and LAB LSN – test more than one test specimen (eg. two test specimens from midside)
  - Lab OFDA100 and LAB LSN – test more than one site (eg. one test specimen from both midside and pin-bone)
  - Fleecescan – test more than one test specimen from the same fleece (eg. two test specimens (separate corings) from one fleece)
- Number of measurements i.e.
  - OFDA2000 – test more than one micro-staple per staple (eg. two micro-staples from midside)
  - Lab OFDA100 – test more than one slide per sample (eg. two slides from each sample)
  - LAB LSN – test more test specimens per sample (eg. two test specimens of 1000 snippets each)
  - LAB LSN – test more snippets per test specimen (eg. 600 to 1000 snippets)
  - Fleecescan – test more snippets per test specimen (eg. 600 to 1000 snippets)

The above list is not complete; however, it indicates the complexity of designing trials aimed at comparing different OFFM instruments.

TRIAL DESIGN

The trial was conducted in two parts: Phase 1 (precision/repeatability - reported here) and Phase 2 (fleece classing and sheep selection – (Baxter and Marler, 2004)). The original trial protocol contains a detailed description of the methodology intended for application at each trial property. The following summarises trial protocols that are common to both Phase 1 and Phase 2.

The instruments evaluated in this trial were the OFDA2000 and the Sirolan Fleecescan™/Sirolan Laserscan™ (hereafter called the Fleecescan); which are both used to measure wool fibre characteristics on-farm. The on-farm sampling and measurement environments were at a race in the shed prior to shearing and in the shearing shed in conjunction with shearing, respectively. Note, OFDA2000s are often operated outside the shearing shed; however, for reasons of controlling the trial methodologies, the OFDA2000 testing was conducted inside the shearing shed.

The measurements from the on-farm instruments were also compared with measurements derived from laboratory testing using the OFDA100 and the Sirolan Laserscan™ (hereafter called the Lab LSN) instruments.

Other aspects of the trial methodology were:

- Each sheep was uniquely identified; with each fleece sampled, tested and shorn linked to the unique sheep identification.
- Commercial operators of the two instruments were engaged to provide the equipment, systems and operating personnel needed to carry out the trial in each location. Commercial rates were paid for the supply of these resources.
- The most recent standard operating procedures for the two instruments were used and they were operated to reflect normal commercial OFFM practice.
- An independent supervisor (Mr Russell Pattinson) oversaw each trial on the ten properties.

MATERIALS AND METHODS

General

The design involved trials on seven properties; however, the procedures used on the first three properties did not follow the prescribed sampling method exactly. As this inadvertently reduced the sampling variance for some of the methods, these three properties were not included in this report. The four remaining properties comprised two Victorian properties along with one from New South Wales and one from Western Australia.

To estimate the components of variance for the calculation of the confidence limits it was necessary to replicate the measurement systems. As far as was possible, all the operators were encouraged to operate independently of each other. However, once one operator located and sampled from a midside or pinbone site, the next operator had an opportunity to locate the exact same site. All operators were encouraged to make independent selection of the sites.

Sampling and Testing On-Farm

At each property, 160 sheep were sampled and shorn. Prior to each shearing, the sheep were examined for any obvious wool defects (e.g. badly cotted, fly strike, etc.). If identified, these sheep were removed.

Two OFDA2000s and two Fleecescans, operated using standard commercial protocols, were used on each trial property. Some operators were used at more than one property. Shed staff changed from shed to shed. The trial supervisor attended all properties.

Prior to measurement, the operator checked each instrument using the operating procedures recommended by the manufacturer.

Samples were taken from the left-hand side of all sheep.

While normal commercial practice was employed, the trial design required some key variations, as follows:

- Two separate tufts of wool were independently taken from each site area (i.e. 'midside' or 'pinbone') for measurement by the two OFDA2000s; and
- Two large (twice normal size) midside and two pinbone samples were taken from each sheep for laboratory measurement; and as a result, each skirted fleece had approximately 2% to 10% of its wool removed prior to skirting and measurement by Fleecescan.

During the trial, the methodology changed slightly due to shed layout, equipment changes and logistics.

Measurement Systems

OFDA2000

The following provides a brief description of Method A:

The grease correction factor (GCF) for each OFDA2000 instrument was determined using the standard commercial procedure. Based on greasy and clean measurements made on the first 30 sheep, four GCFs were calculated for each property (see Table 1).

Table 1 OFDA2000 grease correction factors (GCF) calculated for each property

<table>
<tr><td rowspan="2">OFDA2000 (System1)</td><td>Midside (Sample 1)</td></tr>
<tr><td>Pinbone (Sample 1)</td></tr>
<tr><td rowspan="2">OFDA2000 (System 2)</td><td>Midside (Sample 2)</td></tr>
<tr><td>Pinbone (Sample 2)</td></tr>
</table>

For each OFDA2000, using surgical scissors, a tuft was removed from the midside and the pinbone. The samples taken and tests performed for each property are presented in Table 2.

Table 2 OFDA2000 samples taken and test performed on each property

<table>
<tr><td rowspan="4">Sheep 1</td><td rowspan="2">OFDA 2000 (Instrument 1)</td><td>Midside (1)</td><td>Test 1
Test 2</td></tr>
<tr><td>Pinbone (1)</td><td>Test 1
Test 2</td></tr>
<tr><td rowspan="2">OFDA 2000 (Instrument 1)</td><td>Midside (2)</td><td>Test 1
Test 2</td></tr>
<tr><td>Pinbone (2)</td><td>Test 1
Test 2</td></tr>
</table>

The measurements of MFD are made as the technology scans the length of the micro-staple. For Merino wools 16.5 – 24.0 µm, it is estimated that 600-3000 fibres are tested for MFD by the OFDA2000 during the measurement process, depending on staple length. Approximately 35% of these are tested for MFC.

Laboratory OFDA100 and Laboratory Laserscan

Laboratory midside testing using both the Laserscan and OFDA100 instruments conformed to Australian/New Zealand Standards, viz. AS/NZS 4492.4:2000 (AS/NZS 2000a) and AS/NZS 4492.5:2000 (AS/NZS 2000b). This is in contrast to OFFM techniques (Fleecescan and OFDA2000), which are not defined by such Standards.

For Laboratory testing, samples were taken from the midside and pinbone after sampling for the OFDA2000 measurement had been completed. The samples, twice the size of a normal midside, were removed with an electric handpiece.

Each sample was randomly split into two sub-samples and sent to the laboratory for the standard commercial fleece measurement test with one addition. Each sub-sample was tested twice by both the Lab LSN (1000 snippets) and the Lab OFDA100 (one slide). The eight laboratory measurements obtained for the trial properties are presented diagrammatically in Table 3:

Table 3 Lab LSN and Lab OFDA100 samples taken and tests performed on each property

Sheep 1	Midside Sample	Split	Lab LSN Test 1 Lab LSN Test 2 Lab OFDA Test 1 Lab OFDA Test 2
Sheep 1	Pin-bone Sample	Split	Lab LSN Test 1 Lab LSN Test 2 Lab OFDA Test 1 Lab OFDA Test 2

For both Lab LSN and OFDA100 the number of fibre snippets measured for MFC is less than that measured for MFD.

For Lab LSN, if 1000 snippets are tested during for MFD measurement, about 70-90% of these snippets (i.e. 800) are tested for MFC.

For OFDA100, approximately 5000 snippets are measured for MFD (Min = 3000 and Max = 6000). In these circumstances, for MFC approximately 1900 snippets are measured, which is, on average, 39% of the total.

<u>Fleecescan</u>

Following the sampling for OFDA2000, and midside and pinbone sampling for laboratory measurement, the sheep were then shorn. The Fleecescan measurements were undertaken as follows:

After shearing the fleece was skirted, rolled and then independently sampled and measured by the two Fleecescan operators in the shed. A test for MFD involved the successful measurement of 600 snippets. This level of snippets was used as it represented common commercial practice. However, some commercial providers may measure 1000 snippets.

The measurements obtained from the Fleecescan instruments for the trial properties are presented in Table 4.

Table 4 Fleecescan tests performed on each property

Sheep 1	Fleecescan-1	Test 1 Test 2
	Fleecescan-2	Test 1 Test 2

Note: if 600 snippets are tested during for fibre diameter measurement using Fleecescan, only about 70-90% of these snippets are tested for curvature.

On completion of testing the remaining fleeces were individually placed in plastic bags lightly pressed into wool packs and despatched to Newcastle for fleece coring.

<u>Whole Fleece Standard Laboratory Laserscan and Laboratory OFDA100 Tests</u>

Individual fleeces were cored at the Australian Cashmere Association in Newcastle, New South Wales using a coring machine, comprising two core tubes of approximately 2 cm diameter, which had been designed to sample single fleeces.

For each fleece, two core samples (70g minimum mass each) were taken based on approximately 100 corings per fleece. The two core samples were sent to the laboratory for measurement on both Lab OFDA100 and Lab LSN instruments.

In the laboratory, each core sample was measured twice on both Lab LSN and Lab OFDA100. A test was defined as the measurement of four test specimens of 1000 fibres for Lab LSN and four complete slides for Lab OFDA100.

Eight measurements were obtained for each fleece, with the replicate tests for each core/instrument combination being combined and reported as one test. Thus four test results in total were recorded (see Table 5).

Table 5 **Lab LSN and Lab OFDA100 "true value" tests performed on each property**

Fleece 1 Core 1	Lab LSN	Test 1 Test 2	Result 1
	Lab OFDA100	Test 1 Test 2	Result 2
Fleece 1 Core 2	Lab LSN	Test 1 Test 2	Result 3
	Lab OFDA100	Test 1 Test 2	Result 4

For both Lab LSN and Lab OFDA100 the number of fibre snippets measured for MFC is less than that measured for MFD.

For Lab LSN if 1000 snippets are tested during for MFD measurement, then approximately 70-90% of these snippets are tested for MFC.

For OFDA100, if 5000 snippets fibres are measured for MFD, then approximately 39% are measured for MFC.

For these trials, the best estimate of the whole-fleece value (nominally the "true" value) was taken to be the average of the Lab LSN and Lab OFDA results.

Table 6 summarises the measurements made for each instrument.

Table 6 **Summary of measurement schedules**

Instrument	Sample	No. Tests
On Farm		
OFDA2000 (1)	Midside sample	2
OFDA2000 (1)	Pin-bone sample	2
OFDA2000 (2)	Midside sample	2
OFDA2000 (2)	Pin-bone sample	2
Fleecescan (1)	Whole fleece	2
Fleecescan (2)	Whole fleece	2
Laboratory		
Lab LSN	Midside sample	2
Lab LSN	Pin-bone sample	2
Lab OFDA100	Midside sample	2
Lab OFDA100	Pin-bone sample	2
Wool Store		
Lab LSN	Whole fleece	2
Lab OFDA100	Whole fleece	2
Total		**24**

Data Summary

The wool traits that were studied and their respective measurement units were: MFD (μm), SDD (μm), CVD (%), CFR (%), and MFC (degrees/mm). Space constraints in the tables in the report have led to the measurement units not being included with every table.

Table 7 provides details of the properties, wool types and sheep numbers for Phase 1.

Table 7 **Summary of properties and sheep/wool used in Phase 1 trials**

No.	Date	Property Details	Sheep/Fleece Details	No. Sheep Analysed	Whole Flc Avg MFD
4 (AM)	10 Feb 2003	"Bernifay", Natimuk, VIC	MF4, FNF, 2½ yr old Merino ewes, sound, good colour, 106 mm midside	160	21.4
5 (WE)	5 Mar 2003	"Wallendbeen East", Cootamundra, NSW	MF4, 3 yr old medium Merino ewes, full wool, W2, good colour, 89 mm midside	160	18.0
6 (AE)	10 Mar 2003	"Glenara North", Horsham, VIC	MWF, 1.0% VM, 10 mth old superfine Merino hoggets, good colour, 70 mm midside	160	17.9
7 (MP)	22 May 2003	"Marbarrup" Kojonup, WA	MF5/4, 1.5% VM, adult medium Merino ewes, sound, good colour, 99 mm midside	162	21.4

Data Analysis Methods

Principles used to convert Within-Site Precision to Whole Fleece Precision

One key element of this trial was to estimate the 95% Confidence Limits of a single test as it pertained to the whole fleece rather than that related simply to the site on the sheep that has been sampled. The options that were considered by the EAG are detailed in Appendix 3. Note: Method C, as outlined below, was the agreed choice of analysis.

For both the Lab OFDA100 and Lab LSN measurements of whole-fleece values, an analysis of variance of the same form as for the laboratory measurements, described below, was conducted to obtain estimates of the between-sheep and replicate variances. The best estimate of the whole-fleece value (nominally the "true" value) was taken to be the average of the two, and an appropriate error variance was calculated from the variance of differences between the whole-fleece means obtained by the two methods. For mean fibre curvature, there were large systematic differences between all instruments, and consequently, it is doubtful that the analyses will yield reliable results.

For the prediction of a "whole-fleece" value from an on-farm sample, the error variance of the on-farm measurement of, for example, a mid-side sample does not account for the total variance of estimating the whole fleece. This means that a confidence limit calculated in relation to a site underestimates the error with which a whole fleece value is predicted. It is thus desirable to assess the error variance of the predicted "whole-fleece" value. To estimate this error variance, it is necessary to have independent estimates of the "whole-fleece" value and the sampling variance of this estimated "whole-fleece" value.

For both OFDA2000 (midside and pinbone) and Fleecescan, the mean of all records on each fleece was calculated. For each of the measurements, there were approximately 160 OFDA2000 midside, 160 OFDA2000 pinbone, 160 Fleecescan and 160 retained whole-of-fleece mean values. The co-variances of the three on-farm measurements with the retained fleece measurements were then calculated in the usual way. The co-variances of the laboratory measurements and the whole-of-fleece measurements were calculated similarly. The rationale for this approach is that the on-farm measurements are essentially attempts to estimate the average of the whole fleece, and thus their error variance is best estimated by the variance of differences between the on-farm or laboratory value and the "true" whole-fleece value, adjusted for the variance of errors in the "whole fleece mean".

The variance of a difference between on-farm measurement and "true" whole-fleece value can be calculated as follows. Let X denote the on-farm measurement and Y the whole-fleece measurement. Then the total fleece variance (VT) is VX + VY – 2Cov(X,Y). Here Cov(X,Y) is the appropriate covariance as calculated above. VX is the value of (VS + VT) for the on-farm measurement at a site. VX is the value of (VS + VT) for the on-farm measurement at site. Here Cov(X,Y) is the appropriate covariance as calculated above. VX is the value of (VS + VT) for the on-farm measurement. VS is the variance between sheep and VT is the within-site measurement error variance. VY is the VS component for the whole-fleece average, with no error variance included, since it is the true value which is relevant.

The variances thus obtained were used to calculate 95% confidence interval estimates (1.96 times square root of VT for the Whole Fleece) for the three on-farm methods and the four laboratory methods, and in addition, the correlations of these methods with "true" whole fleece values were calculated.

The analytical methods described in IWTO-0, Appendix B were used to determine the regression parameters for each property.

Within-Site Precision Estimates

OFDA2000 (Midside), OFDA2000 (Pinbone) and Fleecescan

For each of the five fibre parameters measured by the three on-farm methods (OFDA2000 midside, OFDA2000 pinbone and Fleecescan) the variance components were estimated as follows. In Table 10, it is assumed that 160 sheep are measured, but the number varied slightly among properties as indicated in the Table 9 above. The analysis of variance was done using the computer package LSLMMW of Dr Walter Harvey fitting a model including terms for sheep (S), operators (O) which included instrument effects, their interaction (SO) and replicates (R). The structure of the analysis of variance is shown in Table 8.

Table 8 **Analysis of variance for on-farm measurements**

Source	D.F.	Expected Mean Square
Sheep (S)	159	VR + 2 VSO + 4 VS
Operators (O)	1	VR + 2 VSO + 320 VO
Sheep*Operator (SO)	159	VR + 2 VSO
Reps Sh*Op (R)	320	VR

The variance components VR, VSO, VO and VS were estimated by equating observed and expected mean squares, except that negative variance estimates were set to zero. From these, the total measurement error variance was calculated as VT = VR + VSO + VO, and the repeatability of measurements on different sheep was estimated as VS/(VS + VT). This total measurement error variance applies to the site, not the whole fleece, for the OFDA2000 measurements, as does the repeatability. In addition, a 95% confidence interval was calculated as 1.96 times the square root of VT.

On-Farm Sampling followed by Laboratory Measurement

The data for the five measurements at two sites by both Lab OFDA100 and Lab LSN were subjected to analysis of variance of the following form (see Table 9), which was simpler than for on-farm measurements because of the absence of operator/instrument effects.

Table 9 **Analysis of variance for laboratory measurements**

Source	D.F.	Expected Mean Square
Sheep	159	VR + 2 VS
Replicates	160	VR

The variance components were estimated by equating observed and expected mean squares, and the repeatability was computed as VS/(VS + VR). The 95% confidence interval was calculated as 1.96 times the square root of VR.

RESULTS

Whole-Fleece "True-Value"

The raw data used to assign the "whole-fleece true values" was analysed to ensure that the agreement between the Lab OFDA100 and Lab LSN results was acceptable. These analyses are presented as Appendix 2.

It was concluded that the two technologies give highly correlated measures of MFD, with very similar means, though the Lab OFDA100 value was, on average, greater than the Lab LSN Laserscan value by 0.22 µm. (It should be noted that all the whole fleece measurements were carried out in one laboratory.) The correlation between the MFD results for Lab LSN and the Lab OFDA100 for all properties was high (r =0.98 - 0.99), which is not surprising as the methodology used by both instruments is similar to that of a certified core test. This strong correlation for MFD indicates that a high level of confidence can be placed on the whole fleece measurement; which is used as the "true value" in this trial.

Overall, the agreement between Lab LSN and Lab OFDA100 for SDD, CVD and CFR is good as judged by both the mean and correlation.

Although there was reasonable agreement between the measurement of CFR by Lab LSN and Lab OFDA100, the level of confidence in this measurement is relatively low (see Tables 15 and 16). The measurement of CFR is effectively controlled by a relatively small number of fibres in the coarse tail of the diameter distribution. Such percentage test results have a binomial rather than a normal (Gaussian) distribution. The precision of such proportional count data can only be improved by increasing the total number of individual fibre measurements. CFR is primarily determined by MFD and SDD, such that the coarser the wool and the higher the SDD, the greater the number of fibres measured in this tail, and conversely, fewer fibres are measured in the tail for fine wools.

MFC displayed a clear difference in mean and a lower correlation. The differences in the results for MFC (9 to 10 degrees/mm) confirm that calibration procedures are required to harmonise the different measurement systems. This work is in hand in another forum. Despite the absence of any calibration procedures, the results exhibited a correlation of 0.88 and a geometric mean slope of 1.09.

The impact of the observed differences in MFC on the 'whole-fleece" Confidence Limits was examined and found to be small (see Appendix 3).

The Accuracy of Fleece Measurement Systems

Table 10 presents for the four properties the mean results for MFD measured using the different test instruments along with the difference from the whole fleece average.

Table 10 Mean and difference from whole fleece mean for MFD, measured using seven test instruments/methods

Properties	Whole Flc Avg	Pinbone			Fleece	Midside		
		Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
4 (AM)	**20.89**	21.39	21.61	21.34	21.27	20.38	20.52	20.40
Diff Wh Flc		0.50	0.72	0.45	0.38	-0.51	-0.37	-0.49
5 (WE)	**17.96**	18.14	18.21	18.34	18.11	17.94	17.68	17.56
Diff Wh Flc		0.17	0.25	0.37	0.14	-0.03	-0.28	-0.40
6 (AE)	**17.91**	18.15	18.25	18.43	17.96	17.70	17.58	17.49
Diff Wh Flc		0.24	0.34	0.52	0.05	-0.21	-0.33	-0.42
7 (MP)	**21.35**	22.51	22.86	22.92	21.41	21.31	21.45	21.19
Diff Wh Flc		1.15	1.51	1.57	0.06	-0.04	0.10	-0.16
Average 4-	**19.53**	**20.05cd**	**20.23d**	**20.26d**	**19.69bc**	**19.33ab**	**19.31ab**	**19.16a**
Diff Wh Flc		**0.52 ***	**0.71 *****	**0.73 *****	**0.16NS**	**-0.20NS**	**-0.22NS**	**-0.37 ***

The 5% LSD values for the means were 0.412. The standard errors of the mean differences from the whole fleece were 0.202.

The means and differences from whole-fleece means were subjected to analysis of variance, fitting properties and methods as main effects and using the residual mean square as an estimate of the error variance in each case. For the means, the least significant difference at the 5% level was calculated, and any averages with the same letter do not differ significantly by this criterion. For the differences from the whole-fleece mean, the standard error of a method mean was calculated and the average difference from the whole-fleece mean for each method was tested for difference from zero by a Student's t test (* = P<0.05, ** = P<0.01, *** = P<0.001, NS>0.05).

Conclusions for MFD Relevant to Accuracy

(a) For on-farm MFD measurements, OFDA2000 measured on midsides and Fleecescan measured on fleeces gave equivalent accuracy compared with the whole fleece average.

(b) For MFD, the pinbone samples measured on-farm or in a laboratory provided significantly higher results (average +0.6 µm) than the whole fleece average. The pinbone as a sampling site does not give as accurate a measure for MFD for the whole fleece.

(c) For MFD, the midside samples measured on-farm or in a laboratory tended to produce lower results (average -0.3 µm) than the whole fleece average, but they are not always significantly different.

(d) For MFD, on an individual property basis, it is unlikely that on-farm results from OFDA2000 midside and Fleecescan will exactly match the Certified Test results for a property.

(e) To enable comparisons across years, is recommended that the MFD is measured using the same instrument/method.

Table 11 presents a least significant difference test for five parameters for the last four properties using seven test instruments/methods. The differences from the whole fleece average are presented.

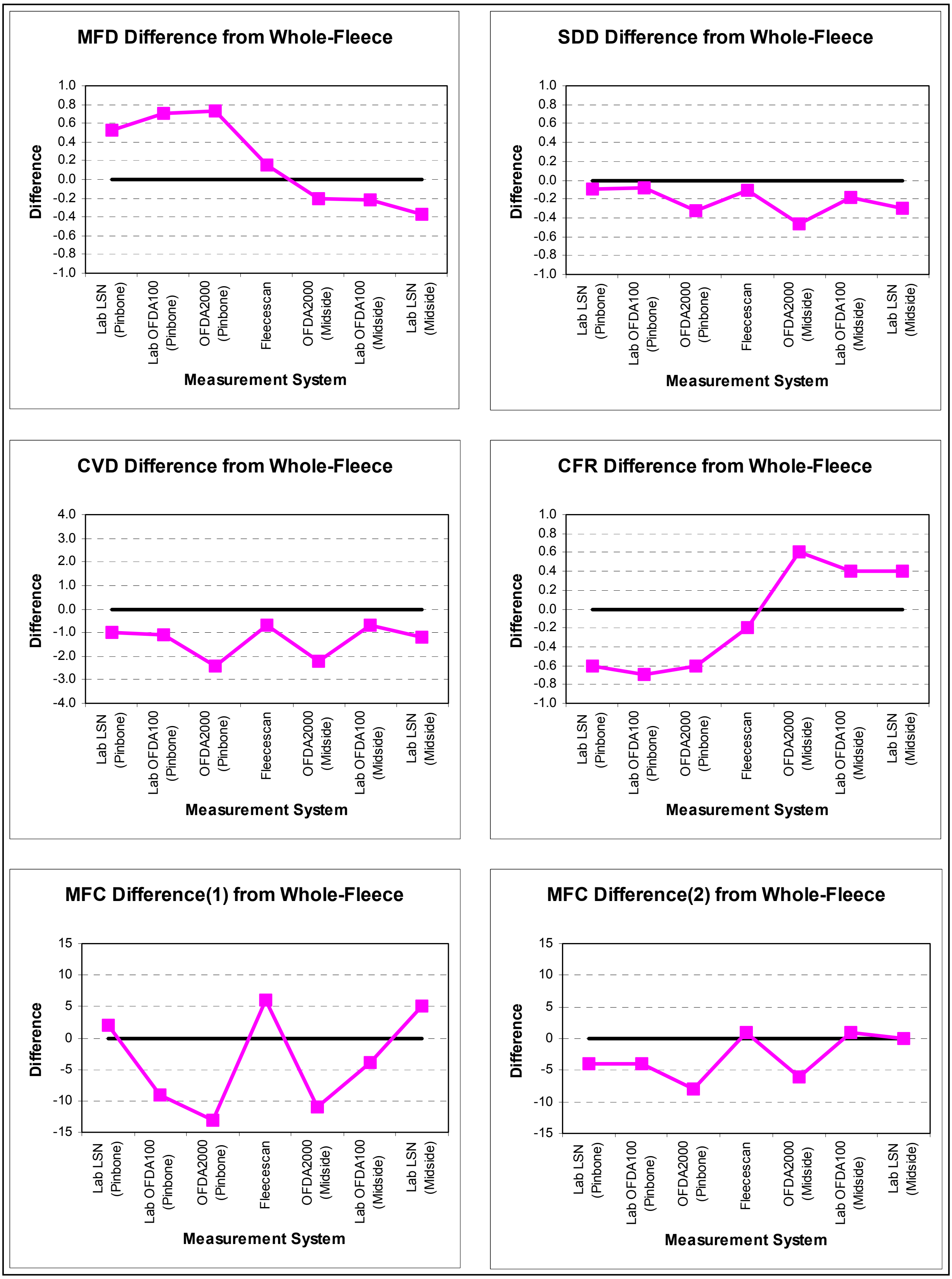
Table 11 Mean and difference from whole fleece mean for MFD, CVD, SDD, CFR and MFC, measured using seven test instruments/methods

Parameter	Whole Flc Avg	Pinbone			Fleece	Midside		
		Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
MFD	**19.53**	20.05**cd**	20.23**d**	20.26d	19.69**bc**	19.33**ab**	19.31**ab**	19.16**a**
Diff Wh Flc		0.52	0.70	0.73	0.16	-0.20	-0.22	-0.37
SDD	**4.05**	3.95**cd**	3.97**d**	3.72**b**	3.95**cd**	3.58**a**	3.87**c**	3.76**b**
Diff Wh Flc		-0.10	-0.08	-0.33	-0.11	-0.47	-0.18	-0.30
CVD	**20.8**	19.7**b**	19.7**b**	18.3**a**	20.1**b**	18.5**a**	20.1**b**	19.6**b**
Diff Wh Flc		-1.0	-1.1	-2.4	-0.7	-2.2	-0.7	-1.2
CFR	**98.1**	97.6**ab**	97.4**a**	97.6**ab**	98.0**abc**	98.8**c**	98.6bc	98.6**bc**
Diff Wh Flc		-0.6	-0.7	-0.6	-0.2	0.6	0.4	0.4
MFC	**93**	94**c**	84**ab**	80**a**	99**c**	82**a**	88**b**	98**c**
Diff Wh Flc		2	-9	-13	6	-11	-4	5
Differences for MFC from Whole Fleece Lab LSN and Lab OFDA100								
LSN	**98**	-4			1			0
OFDA100	**88**		-4	-8		-6	1	

Note: Means within a row with the same letter do not differ significantly at the 5% level using a least significant difference test with the error variance estimated from an analysis of variance fitting terms for properties and methods. The significance of differences from whole-fleece averages is tested using a similar analysis of variance to estimate standard errors of means (* = P<0.05, ** = P<0.01, No asterisk = P>0.05). The 5% LSD values were: MFD = 0.412, SDD = 0.097, CVD = 0.634, CFR = 1.098, MFC = 3.81.

Figure 1 presents the above differences in a graphical form. In the case of MFC two graphs are shown: the first ("MFC Difference(1)") shows the differences relevant to the whole-fleece values derived from the average of the LSN and OFDA100 results whereas the second ("MFC Difference(2)") shows the differences relevant to the value of the similar technology. That is, Lab LSN Fleece Measurement values and Fleecescan values are referenced to the whole-fleece Lab LSN whereas Lab OFDA100 Fleece Measurement values and OFDA2000 values are referenced to the whole-fleece Lab OFDA100 as per the bottom lines of the above table.

Figure 1 Graphical Summary of the Differences from the Whole-Fleece Values.



Conclusions for other Fibre Parameters Relevant to Accuracy

In general, the accuracy of measurement for the four other diameter parameters by the seven instrument/method used was more variable than found for MFD. The following conclusions apply:

(a) SDD and CVD measured using OFDA2000 exhibited the greatest divergence from the whole fleece average (-0.3µm to -0.5µm for SDD and -2.2% to -2.7% for CVD) and were probably influenced by the "distribution trimming" tool used in the OFDA2000 software. It is recommended that the manufacturers further examine this.

(b) Compared to the whole fleece average, the CFR results for pinbone samples were significantly lower (-0.7 %), while the midside results were overall significantly higher (+0.6%).

(c) It is generally acknowledged that the measurement of MFC is greatly influenced by the sample preparation for each instrument. The whole fleece Lab OFDA100 and Lab LSN results differed on average by 10 degrees/mm. When whole fleece Laserscan is used as the basis for comparisons for Fleecescan and Lab LSN and the whole fleece OFDA100 is used as the basis for comparisons for Lab OFDA100 and OFDA2000 the following conclusions can be drawn:

- midside sampling produced MFC results consistent with the whole fleece values;
- pinbone sampling produced MFC results that were lower than the whole fleece values by 4 degrees/mm;
- Fleecescan produced MFC results consistent with the whole fleece values; and
- OFDA2000 produced MFC results that were 7 degrees/mm lower than the corresponding whole fleece OFDA100 values, irrespective if the sample was drawn from the midside or the pinbone. The difference is likely to be related to the different preparation systems used for the OFDA100 compared to the OFDA2000.

(d) It is not recommended that the results for other parameters measured using different instrument/methods be used to compare sheep across years.

Note: calibration issues related to MFC are being examined in another forum.

The Precision of Fleece Measurement Systems

Site and Whole Fleece Confidence Limits

Analyses of variance of site and whole fleece confidence limits were made fitting properties and methods as main effects and taking the residual mean square (with 18 D.F.) as an estimate of the error variance. This was used to calculate a LSD (least significant difference) for comparing the means of the seven methods. Note: The 95% confidence limits were derived for the current commercial operations at the time of the trial.

Tables 12 and 13 report MFD site and whole fleece confidence limits for the individual properties.

Table 12 95% SITE Confidence Limits for MFD

Property	Fleece	Pinbone			Fleece	Midside		
	Whole Flc Avg	Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
4 (AM)	20.9	0.83	0.97	0.89	1.27	1.00	0.96	0.95
5 (WE)	18.0	0.72	0.67	0.81	0.90	0.78	0.66	0.69
6 (AE)	17.9	0.71	0.67	0.86	0.79	1.01	0.58	0.57
7 (MP)	21.4	1.03	0.93	1.23	1.42	1.06	0.99	0.99
Average	**19.5**	**0.82ab**	**0.81ab**	**0.95bcd**	**1.10d**	**0.96cd**	**0.80a**	**0.80a**

Means with the same letter do not differ significantly by the LSD test. 5% LSD = 0.148.

The observed differences in the site confidence limits are more a reflection of the variation in sampling regimes used by each measurement technology, than the measurement system itself. For example, the variation between the diameters of individual fibres in a Fleecescan test is going to be greater than the variation in a midside sample as it includes a random selection of individual fibres from all over the fleece. Hence, comparisons made at this level are akin to comparing apples with oranges. The ranking of lowest to highest (laboratory methods < OFDA2000 methods < Fleecescan) is simply a ranking that largely reflects the variation of diameter from a within single staple to within the entire fleece. A more appropriate comparison relates to Confidence Limits for the whole fleece, as shown in Table 13.

Table 13 95% WHOLE FLEECE Confidence Limits for MFD

Property	Fleece	Pinbone			Fleece	Midside		
	Whole Flc Avg	Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
4 (AM)	20.9	1.14	1.40	1.41	1.35	1.24	1.10	1.14
5 (WE)	18.0	1.02	0.99	1.15	1.00	1.07	0.91	0.90
6 (AE)	17.9	0.92	0.90	1.13	0.84	1.13	0.79	0.78
7 (MP)	21.4	1.68	1.70	1.88	1.50	1.52	1.38	1.34
Average	**19.5**	**1.19c**	**1.25c**	**1.39d**	**1.17bc**	**1.24c**	**1.05ab**	**1.04a**

Means with the same letter do not differ significantly by the LSD test (5% LSD = 0.131).

Table 14 presents the correlations between the whole fleece MFD and that measured using each of the seven test instruments/methods. The measurement of MFD by on-farm measurement methodologies was highly correlated with whole fleece MFD.

Table 14 Correlations between MFD measured using seven test instruments/methods and MFD estimated on the whole fleece for the properties

Property	Fleece	Pinbone			Fleece	Midside		
	Whole Flc Avg	Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
4 (AM)	20.9	0.89	0.84	0.83	0.85	0.94	0.88	0.87
5 (WE)	18.0	0.86	0.86	0.83	0.84	0.84	0.88	0.87
6 (AE)	17.9	0.92	0.92	0.88	0.93	0.87	0.93	0.94
7 (MP)	21.4	0.88	0.87	0.83	0.88	0.87	0.89	0.89
Average	**19.5**	**0.89b**	**0.87ab**	**0.84a**	**0.88b**	**0.88b**	**0.90b**	**0.89b**

Means with the same letter do not differ significantly at the 5% level (5% LSD = 0.034).

<u>Conclusions for MFD Relevant to Precision</u>

(a) To be meaningful, precision comparisons can only be made for estimates relevant to the whole fleece as those relevant to a site do not include all the sources of variation present.

(b) Midside sampling and laboratory testing gave the best and equivalent confidence limits of ±1.04μm for Laserscan and ±1.05μm OFDA100.

(c) The Fleecescan (±1.17μm) and OFDA2000 midside sampling (±1.24μm) were considered to be equivalent in precision.

(d) The pinbone sampling produced results which had poorer confidence limits than midside sampling.

(e) Of all the methods evaluated in this trial, the pinbone sampling and OFDA2000 measurement produced the least precise confidence limit (±1.39μm).

Tables 15 and 16 present the site and whole fleece confidence limits for MFD, SDD, CVD, CFR and MFC.

Table 15 95% SITE Confidence Limits for MFD, CVD, SDD, CFR and MFC for four properties, measured using seven test instruments/methods

Parameter	Fleece	Pinbone			Fleece	Midside		
	Whole Flc Avg	Lab LSN	Lab OFDA100	OFDA-2000	Fleece -scan	OFDA-2000	Lab OFDA100	Lab LSN
MFD	**19.53**	0.82**ab**	0.81**ab**	0.95**bc**	1.10**d**	0.96**cd**	0.80**a**	0.80**a**
SDD	**4.05**	0.59**d**	0.39**b**	0.35**ab**	0.66**e**	0.36**b**	0.29**a**	0.49**c**
CVD	**20.8**	2.91**d**	1.97**b**	1.43**a**	3.26**d**	1.57**a**	1.71**ab**	2.44**c**
CFR	**98.1**	1.45**bc**	1.34**bcd**	1.62**cd**	1.78**d**	1.18**abc**	0.91**a**	1.15**ab**
MFC	**93**	11.80**c**	8.74**ab**	10.48**b**	12.36**c**	10.64**bc**	7.38**a**	11.32**c**

Means with the same letter do not differ significantly at the 5% level. The 5% LSD values are: MFD = 0.148, SDD = 0.057, CVD = 0.353, CFR = 0.462, MFC = 2.776.

The same principle as applies to the 95% Site and Whole Fleece Confidence limits for MFD also applies to the four other measured parameters. That is: observed differences in the site confidence limits are more a reflection of the variation in sampling regimes used by each measurement technology than of the measurement system itself. The ranking of lowest to highest (laboratory methods < OFDA2000 methods < Fleecescan) is simply a ranking that largely reflects the variation of diameter from a single staple to the entire fleece.

However, there are significant differences in the precision estimates of midside and pinbone MFC between Lab OFDA100 and Lab LSN, that do not reflect differences in sampling regime, but rather differences in laboratory methodologies. This may in part be due to the lower number of fibre snippets measured by Lab LSN compared to Lab OFDA100 (800 vs. 1900).

Table 16 95% WHOLE FLEECE Confidence Limits for MFD, CVD, SDD, CFR and MFC for the properties, measured using seven test instruments/methods

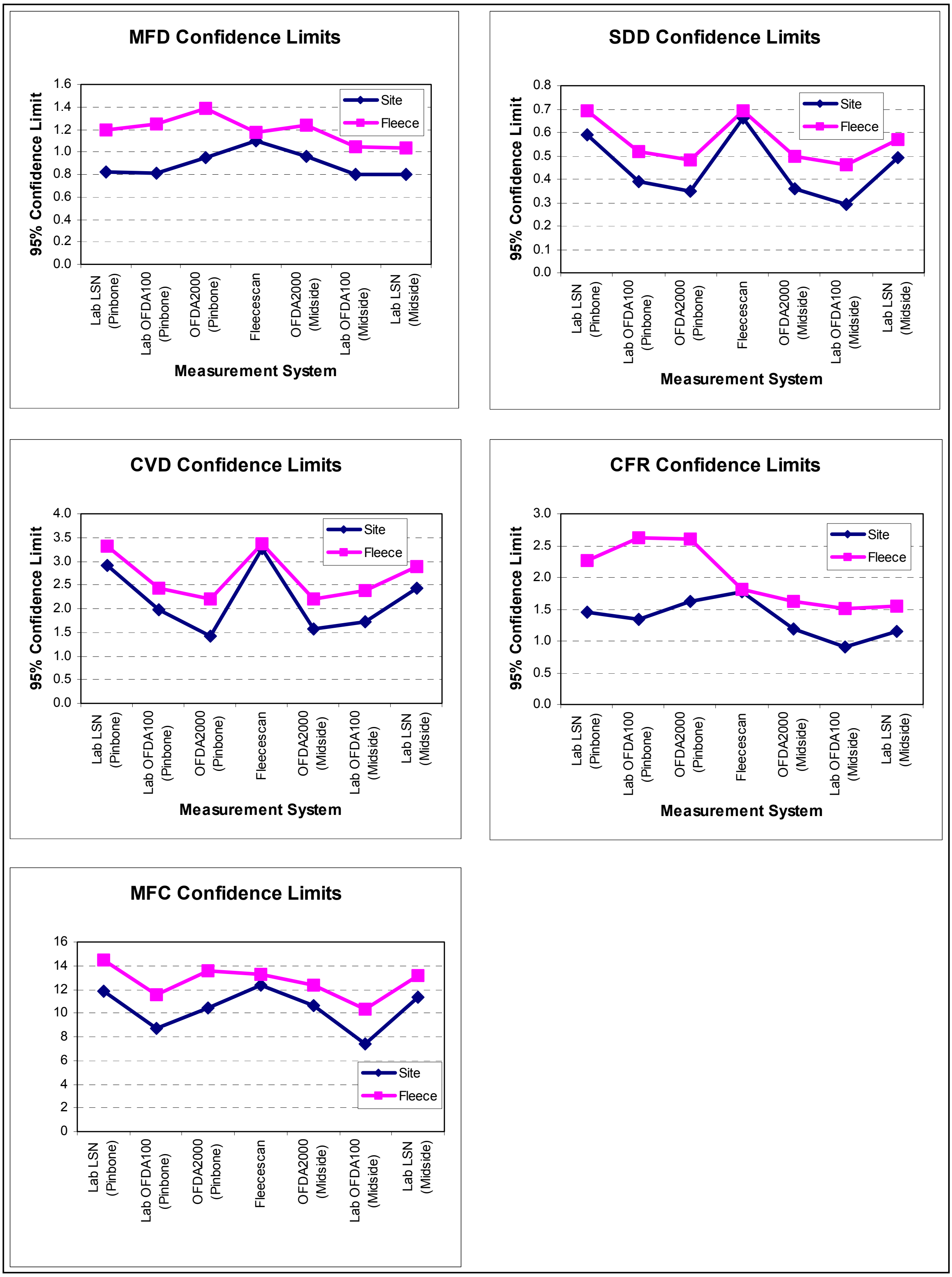
Parameter	Fleece	Pinbone			Fleece	Midside		
	Whole Flc Avg	Lab LSN	Lab OFDA1	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA10	Lab LSN
MFD	**19.53**	1.19**c**	1.25**c**	1.39**d**	1.17**bc**	1.24**c**	1.05**ab**	1.04**a**
SDD	**4.05**	0.69**a**	0.52**a**	0.48**a**	0.69**a**	0.50**a**	0.46**a**	0.57**a**
CVD	**20.8**	3.31**c**	2.43**a**	2.21**a**	3.36**c**	2.19**a**	2.39**a**	2.89**b**
CFR	**98.1**	2.27**a**	2.62**a**	2.61**a**	1.82**a**	1.62**a**	1.51**a**	1.55**a**
MFC	**93**	14.48**b**	11.54**a**	13.58**b**	13.25**a**	12.37**ab**	10.32**a**	13.21**a**

Means with the same letter do not differ significantly by the LSD test. The 5% LSD values are: MFD = 0.131, SDD = 0.064, CVD = 0.316, CFR = 1.199, MFC = 3.066.

The impact of the already reported differences between Lab OFDA100 and Lab LSN as the "true whole-fleece value" was examined (see Appendix 4) and found to have only a small impact on the MFC results presented in Table 16 above. The results confirm that aside from Lab OFDA100, which tends to have the lowest confidence limit, all other methodologies have very similar whole fleece precision.

Figure 2 presents the overall Confidence Limits for both the "Site" and the "Whole-Fleece in a graphical form. The difference between the "Fleece" and "Site" lines represents the additional variation that has been added relevant to the ability of the particular site to represent the "true" value for the whole fleece for each individual fleece. As the Fleecescan System randomly samples fibres from the entire skirted fleece it is not surprising that it has the least additional variation added.

Figure 2 Graphical Summary of the 95% Confidence Limits for the Seven Different Measurement Systems.



Conclusions for other Fibre Parameters Relevant to Precision

(a) To be meaningful, precision comparisons can only be made for estimates relevant to the whole fleece as those relevant to a site do not include all the sources of variation present.

(b) The precision estimates for SDD measurements varied from ±0.5 µm to ±0.7 µm and with all methods of measurement being considered equivalent.

(c) The precision estimates for CVD measurements varied from ±2.2% to ±3.4%. The OFDA2000 produced the best results (±.2.2%) but this needs to be considered with the earlier results that they also produce lower CVD values by 2% to 3%. Fleecescan and pinbone sampling with Lab LSN measurement gave the worst precision of ±3.4% and ±3.3% respectively.

(d) The precision estimates for CFR measurements varied from ±1.5% to ±2.6% and with all methods of measurement being considered equivalent. There was a tendency for the pinbone samples to produce poorer precision than the midside samples.

(e) The precision estimates for MFC measurements varied from ±10 degrees/mm to ±14 degrees/mm.

Improving the Precision of Measurement

In practice, it is useful to improve the precision when testing animals of high value (eg. rams or stud ewes). A higher precision would give the producer greater confidence that the sheep selected (i.e. those that exert a greater genetic influence over all flocks) are the best. Whilst the cost of a test is always of primary importance, it is important that the producer weighs up the benefit:cost of improved precision when testing high value animals.

For example, for MFD the 95% CL for the Fleecescan are based on the measurement of one test specimen of 600 snippets whereas the 95% CL for Lab LSN are based on one test specimen of 1000 snippets. The smaller number of snippets measured with the Fleecescan marginally increases the Confidence Limits. In the case of MFD the increase can be calculated by separating the "true" between-replicate variance from the "measured" between-replicate variance and the between-fibres variance calculated from the average between-fibres SDD of the whole fleece measurement (i.e. the SDD of 4.05 in Table 26). The estimated between replicate variance for 1000 fibre measurements can be calculated from the "measured" between-replicate variance (for 600 fibres) minus between-fibres variance divided by 600 plus the between-fibres variance divided by 1000. The use of 1000 rather than 600 snippets would therefore lead to a small decrease in the 95% Confidence Limit for MFD from the ± 1.17µm reported above, to ± 1.15µm (adapted from Marler *et al.* 2002a). It is therefore considered unlikely that improving precision marginally by using 1000 rather than 600 snippets would out-weigh the benefits of a quicker measurement.

As another example, the precision of OFDA2000 or laboratory measurements could be improved by testing more sample sites. This trial does not allow the calculation of the confidence limits if more than one site is used as the multiple regression of, for example three different sampling sites, is required. However, extensive work by Turner in 1956 demonstrated that sampling in three sites across a fleece provides a good estimate of the variation over the fleece. This might be important for ram testing.

Selection Differentials for Mean Fibre Diameter

The values for whole fleece in Tables 17 and 18 were calculated by ranking the whole fleece averages for each sheep and choosing the 128 (80%) or 32 (20%) of the 160 which had the lowest MFD. The mean of these sheep was calculated and from it the mean of all 160 sheep was subtracted to give the selection differential. For each of the other measurements, there were either two (for laboratory measurements) or four (for on-farm measurements) measurements per sheep. The sheep were ranked on each of these two or four measurements, and the best 128 or 32 on that measurement had their whole fleece values averaged to give 2 or 4 selection differentials, which were then averaged to provide the values in the tables.

Table 17 Selection differentials for MFD measured using seven test instruments/methods with 80% selected. Differentials are negative

Property	Fleece	Pinbone			Fleece	Midside		
	Whole Flc Avg	Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
4 (AM)	**0.3726**	0.2999	0.3003	0.2619	0.2869	0.2773	0.3111	0.2932
5 (WE)	**0.2809**	0.2421	0.2281	0.2249	0.2208	0.2224	0.2366	0.2272
6 (AE)	**0.3975**	0.3518	0.3628	0.3397	0.3447	0.3168	0.3597	0.3599
7 (MP)	**0.5011**	0.4089	0.4222	0.3821	0.4257	0.4137	0.4296	0.4165
Average	**0.3880**	**0.3257c**	**0.3284c**	**0.3022a**	**0.3195bc**	**0.3076ab**	**0.3342c**	**0.3242c**

Means with the same letter do not differ significantly by the LSD test. 5% LSD = 0.015.

Table 18 Selection differentials for MFD measured using seven test instruments/methods with 20% selected. Differentials are negative

Property	Fleece	Pinbone			Fleece	Midside		
	Whole Flc Avg	Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
4 (AM)	**1.6423**	1.4990	1.3763	1.4388	1.4173	1.4156	1.4330	1.4377
5 (WE)	**1.2005**	0.9876	1.0345	0.9569	1.0366	1.0067	1.0665	1.0559
6 (AE)	**1.4848**	1.3380	1.3774	1.2866	1.3815	1.3391	1.4079	1.3758
7 (MP)	**1.9112**	1.7713	1.7631	1.7288	1.5889	1.5696	1.6577	1.6498
Average	**1.5597**	**1.3990a**	**1.3878a**	**1.3528a**	**1.3561a**	**1.3328a**	**1.3913a**	**1.3798a**

Means with the same letter do not differ significantly by the LSD test. 5% LSD = 0.080.

It appears that the laboratory measurements give similar selection differentials, which are a little higher than those given by on-farm measurements, which are quite similar among themselves. For the 20% selection the laboratory selection differentials average 89% of the Whole Fleece values, while the on-farm differentials average 86%. For the 80% selection the corresponding percentages are 85% and 80%.

The selection differentials shown in Tables 17 and 18 were subjected to analyses of variance (see Table 19), fitting four properties and seven test methods as main effects, with the residual mean square being used as the error term.

Table 19 Analysis of variance of selection differentials for MFD using seven test instruments/methods on four properties

Source	D.F.	80% M.S.	Probability	20% M.S.	Probability
Properties	3	0.043944	<0.0001	0.511850	<0.0001
Methods	6	0.005310	0.003	0.002342	0.57
Lab vs. On-farm	1	0.002316	0.0002	0.011608	0.06
Within Locations	5	0.000173	0.19	0.000489	0.97
Residual	18	0.000103		0.002881	

There were large and very highly significant differences between properties. For 80% selection there were highly significant differences between methods (p = 0.003). When the between methods sum of squares was partitioned into components between Locations (Laboratory and On-Farm) and within Locations, the difference between Laboratory and On-Farm was highly significant, while the differences between methods within locations were not significant. For 20% selection, the differences between methods were not significant, but the difference between Laboratory and On-Farm methods approached significance (p = 0.06).

This analysis of selection differentials suggest that laboratory measurements offer slightly better precision and strong correlations with whole fleece measurements, ultimately resulting in better selection differentials than both OFDA2000 and Fleecescan on-farm methods. Ideally, measurements on high value animals (such as rams) should be performed using the best possible precision as there is greater selection emphasis placed on these animals and more reliance placed on the test result. The best precision is available under testing within Australian standards in a laboratory with either OFDA100 or Laserscan

However, there is less than 0.05µm at 80% selection and 0.07µm at 20% selection in the selection differential achieved between measurement methods. These differences are unlikely to have a large impact on the genetic and economic gain that can be derived from animal selections using MFD. Thus, wool producers need to weigh up the convenience benefits of on farm testing against any loss of precision when considering which test procedure to use for their flock and circumstances. Other service factors such testing costs, labour efficiency and yard or shed design may be more important.

Selection Differentials for Mean Fibre Curvature

The values for whole fleece in Tables 20 and 21 (using whole-fleece Lab LSN (Tables 20 & 21) as the "true" MFC and using whole-fleece Lab OFDA100 (Tables 20a & 21a) as the "true" MFC) were calculated by ranking the whole fleece averages for each sheep and choosing the 128 (80%) or 32 (20%) of the 160 , which had the lowest MFC. The mean of these sheep was calculated and from it the mean of all 160 sheep was subtracted to give the selection differential. For each of the other measurements, there were either two (for laboratory measurements) or four (for on-farm measurements) measurements per sheep. The sheep were ranked on each of these two or four measurements, and the best 128 or 32 on that measurement had their whole fleece values averaged to give 2 or 4 selection differentials, which were then averaged to provide the values in the tables.

Table 20 Properties 4, 5, 6 and 7 – Selection differentials for MFC measured using seven test instruments/methods with 80% selected. Differentials are negative. Lab Laserscan used as the "true" whole fleece measure.

Property	Fleece	Pinbone			Fleece	Midside		
	Whole Flc Avg	Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
4 (AM)	1.87	1.44	1.35	1.23	1.36	1.22	1.36	1.22
5 (WE)	2.69	1.74	1.81	1.57	1.64	1.83	2.04	1.72
6 (AE)	1.72	0.79	0.93	0.83	0.95	1.03	1.12	1.00
7 (MP)	2.71	1.68	1.92	1.69	1.68	1.84	1.87	1.70
Average	2.25	1.41ab	1.50bc	1.33a	1.39ab	1.48bc	1.60c	1.39ab

Means with the same letter do not differ significantly by the LSD test. 5% LSD = 0.127.

Table 21 Properties 4, 5, 6 and 7 – Selection differentials for MFC measured using seven test instruments/methods with 20% selected. Differentials are negative. Lab Laserscan used as the "true" whole fleece measure.

Property	Fleece	Pinbone			Fleece	Midside		
	Whole Flc Avg	Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
4 (AM)	7.72	5.79	6.16	5.84	5.21	5.12	6.07	5.43
5 (WE)	9.92	7.25	7.38	6.94	7.00	6.95	7.29	7.30
6 (AE)	6.78	3.16	3.22	2.97	3.98	2.88	4.36	4.18
7 (MP)	11.26	7.50	9.26	8.36	8.69	9.46	10.06	8.16
Average	8.92	5.92a	6.50ab	6.03a	6.22ab	6.10a	6.94b	6.27ab

Means with the same letter do not differ significantly by the LSD test. 5% LSD = 0.795.

Table 20a Properties 4, 5, 6 and 7 – Selection differentials for MFC measured using seven test instruments/methods with 80% selected. Differentials are negative. Lab OFDA100 used as the "true" whole fleece measure..

Property	Fleece	Pinbone			Fleece	Midside		
	Whole Flc Avg	Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
4 (AM)	2.06	1.56	1.46	1.39	1.39	1.43	1.61	1.44
5 (WE)	3.01	2.04	2.12	1.75	1.79	1.90	2.32	1.78
6 (AE)	2.34	1.15	1.45	1.14	1.14	1.33	1.43	1.12
7 (MP)	2.63	1.62	1.87	1.77	1.77	1.92	1.91	1.69
Average	2.51	1.59ab	1.72bc	1.51a	1.52a	1.65ab	1.82c	1.51a

Means with the same letter do not differ significantly by the LSD test. 5% LSD = 0.147.

Table 21a Properties 4, 5, 6 and 7 – Selection differentials for MFC measured using seven test instruments/methods with 20% selected. Differentials are negative. Lab OFDA100 used as the "true" whole fleece measure.

Property	Fleece	Pinbone			Fleece	Midside		
	Whole Flc Avg	Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
4 (AM)	8.46	5.98	6.53	6.39	5.46	5.92	6.70	6.04
5 (WE)	10.49	7.72	7.76	7.53	7.70	7.86	8.79	7.92
6 (AE)	9.11	4.04	5.36	4.17	4.56	4.05	6.31	5.03
7 (MP)	10.82	7.68	9.41	8.73	8.73	9.35	9.75	8.10
Average	9.72	6.36a	7.27bc	6.71ab	6.61a	6.80ab	7.89c	6.77ab

Means with the same letter do not differ significantly by the LSD test. 5% LSD = 0.652.

In all four cases the highest selection differential was obtained by the Lab OFDA100 midside, with OFDA100 pinbone next, with no significant difference between the two in any of the four cases.

Thus regardless of whether Lab Laserscan or Lab OFDA100 was used for the whole fleece value, the Lab OFDA100 sample provided the greatest selection differential. This is probably due to the greater number of measurements made per test on this system compared to the others (Lab OFDA100 – 1900: Lab LSN – 800: OFDA2000 – 700; Fleecescan – 500). Since the pattern of response is different from that with MFD, the analysis of variance conducted for MFD was not performed for MFC. For MFC the laboratory Laserscan measurements are not particularly good predictors of whole fleece values.

This analysis of selection differentials suggests that Lab OFDA100 measurements offer better precision and strong correlations with whole fleece measurements, ultimately resulting in better selection differentials than both the OFDA2000 and Fleecescan on-farm methods. Ideally, measurements on high value animals (such as rams) should be performed using the best possible precision as there is greater selection emphasis placed on these animals and more reliance placed on the test result. The best precision is available under testing within Australian standards in a laboratory with OFDA100.

However, there is less than 0.3 degrees/mm at 80% selection (excluding the Lab OFDA100 the value drops to less than 0.1 degree/mm) and 1.0 degrees/mm at 20% selection (excluding the Lab OFDA100 the value drops to less than 0.3 degree/mm) in the selection differential achieved between measurement methods. These differences are unlikely to have a large impact on the genetic and economic gain that can be derived from animal selections using MFC. Thus, wool producers need to weigh up the convenience benefits of on farm testing against any loss of precision when considering which test procedure to use for their flock and circumstances. Other service factors such testing costs, labour efficiency and yard or shed design may be more important.

CONCLUSIONS

Accuracy

(a) For on-farm MFD measurements, OFDA2000 measured on midsides and Fleecescan measured on fleeces gave equivalent accuracy compared with the whole fleece average.

(b) For MFD, the pinbone samples measured on-farm or in a laboratory provided significantly higher results (average +0.6 µm) than the whole fleece average. The pinbone as a sampling site does not give an accurate measure of MFD for the whole fleece.

(c) For MFD, the midside samples measured on-farm or in a laboratory tended to produce lower results (average -0.3 µm) than the whole fleece average, but they are not always significantly different.

(d) For MFD, on an individual property basis, it is unlikely that on-farm results from OFDA2000 midside and Fleecescan will exactly match the Certified Test results for a property.

(f) To enable comparisons across years, it is recommended that the MFD is measured using the same instrument/method.

(g) In general, the accuracy of measurement for the four other diameter parameters by the seven instrument/method used was more variable than found for MFD.

(f) SDD and CVD measured using OFDA2000 exhibited the greatest divergence from the whole fleece average (-0.3 µm to –0.5 µm for SDD and –2.2% to –2.7% for CVD) and were probably influenced by the “distribution trimming” tool used in the OFDA2000 software. It is recommended that the manufacturers further examine this.

(g) Compared to the whole fleece average, the CFR results for pinbone samples were significantly lower (-0.7%), while the midside results were overall significantly higher (+0.6%).

(h) It is generally acknowledged that the measurement of MFC is greatly influenced by the sample preparation for each instrument. The whole fleece Lab OFDA100 and Lab LSN results differed on average by 10 degrees/mm. When whole fleece Laserscan is used as the basis for comparisons for Fleecescan and Lab LSN and the whole fleece OFDA100 is used as the basis for comparisons for Lab OFDA100 and OFDA2000 the following conclusions can be drawn:

- midside sampling produced MFC results consistent with the whole fleece values;
- pinbone sampling produced MFC results that were lower than the whole fleece values by 4 degrees/mm;
- Fleecescan produced MFC results consistent with the whole fleece values; and
- OFDA2000 produced MFC results that were 7 degrees/mm lower than the corresponding whole fleece OFDA100 values, irrespective if the sample was drawn from the midside or the pinbone. The difference is likely to be related to the totally different preparation systems used for the OFDA100 compared to the OFDA2000.

(i) To enable comparisons across years, is recommended that all parameters are measured using the same instrument/method.

(j) Ideally, measurements on high value animals (such as rams) should be performed using the best possible precision as there is greater selection emphasis placed on these animals and more reliance placed on the test result.

(k) Laboratory measurements offer slightly better precision and correlations with whole fleece measurements, ultimately resulting in better selection differentials than both OFDA2000 and Fleecescan on-farm methods. However, there is less than 0.05 µm at 80% and 0.07 µm at 20% in selection differential between on-farm and laboratory measurement methods.

(l) These differences are unlikely to have a large impact on the genetic and economic gain that can be derived from animal selections using MFD. Thus, wool producers need to weigh up the convenience benefits of on farm testing against any loss of precision when considering which test procedure to use for their flock and circumstances. Other service factors such testing costs, labour efficiency and yard or shed design may be more important.

Precision

(a) To be meaningful, precision comparisons can only be made for estimates relevant to the whole fleece as those relevant to a site do not include all the sources of variation present over an animal.

(b) The precision estimates for MFD measurements varied from ±1.04 µm to ±1.39 µm across the different systems evaluated in the trial. The following comments are relevant to MFD:

- midside sampling and laboratory testing gave the lowest and equivalent confidence limits of ±1.04 µm for Laserscan and ±1.05 µm OFDA100;
- the Fleecescan (±1.17 µm) and OFDA2000 midside sampling (±1.24 µm) were considered to be equivalent in precision;
- the pinbone sampling produced results which had poorer confidence limits than midside sampling; and
- the pinbone sampling and OFDA2000 measurement produced the highest confidence limit (±1.39 µm) of all the methods evaluated in this trial.

(c) The precision estimates for SDD measurements varied from ±0.5µm to ±0.7µm and with all methods of measurement being considered equivalent.

(d) The precision estimates for CVD measurements varied from ±.2.2% to ±3.4%. The OFDA2000 produced the best results (±0.2.2%) but this needs to be considered with the earlier results that they also produce lower CVD values by 2% to 3%. Fleecescan and pinbone sampling with Lab LSN measurement gave the worst precision of ±3.4% and ±3.3%, respectively.

(e) The precision estimates for CFR measurements varied from ±1.5% to ±2.6% and with all methods of measurement being considered equivalent. There was a clear tendency for the pinbone samples to produce poorer precision than the midside samples;

(f) The precision estimates for MFC measurements varied from ±10 degrees/mm to ±14 degrees/mm.

RECOMMENDATIONS

(a) Any benefits to wool producers using fleece measurement of any wool trait to aid their "on-farm" decision-making will be dependent on both the range of the wool trait in the mob of sheep and the Whole-Fleece Confidence Limit of the technology chosen to undertake the measurements. It should be noted that the latter can be improved over what has been determined in this report by extra sampling and testing at additional cost.

(b) The use of CFR in sheep selection, as it is relatively imprecise, is not recommended. CFR is closely correlated with MFD and consequently it is better to use MFD.

(c) That measurements on high value animals (such as rams) should be performed using the highest precision available.

(d) For commercial selection procedures where the animals are of less value, the benefits and convenience of on-farm testing may outweigh any small loss in precision.

(e) The OFDA2000 manufacturer re-examine the application of the "distribution trimming tool" in light of the measured differences in SDD and CVD.

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Expert Advisory Group Members

Mr Peter Baxter	SGS Wool Testing Services	Wellington, New Zealand
Dr Ralph Behrendt	Dept Primary Industries	Hamilton, VIC
Dr Kerry Hansford	Teckel Consulting Pty Ltd	Melbourne, VIC
Dr Bill Humphries	CSIRO Textile and Fibre Technology	Geelong, VIC
Dr John James	Consultant	Sydney, NSW
Mr Jim Marler	AWTA Ltd	Sydney, NSW
Dr Paul Swan	AWI Ltd	Sydney, NSW
Mr George Waldthausen (Chair)	AWI Ltd	Sydney, NSW

Woolgrowers

Jack Donaldson
"Chatsworth House", Lake Bolac, VIC

Bill Blackwell
"Corea", Dunkeld, VIC

Alan MacInnes
"Bernifay", Natimuk, VIC

Bill & Vicki Webb
"Marbarrup", Kojunup, WA

Bevan McKnight
"Mt Sturgeon", Dunkeld, VIC

Angus Jackson
"Corea Lane", Glenthompson, VIC

Austin Eagle
"Glenara North", Horsham, VIC

Ken Baldry
"Wallendbeen East", Cootamundra, NSW

David Oddie
"Challicum Park", Beaufort, VIC

Jim Mitchell
"Carlyle", Angaston, SA

Instrument Owner/Operators

Janelle Pearson
Landmark, Bendigo, VIC

Bill Crawford and Megan Jackson
"Sierra Park", Victoria Valley, VIC

Russell Pitcher
RD Pitcher, Skipton, VIC

Paul Cocking
Riverina Wool Testers Pty Ltd
Wagga Wagga, NSW

Paul Cousins
Cousins Merino Services Pty Ltd, Burra, SA

Anita Eyres
Doreenup Wool Testing, Kojonup, WA

Ian Bradtke
CH Bradtke & Son, Peterborough, SA

Joyce and Leigh Gordon
Bullawyn Pastoral Co, Dunkeld, VIC

Colin Parker
Dunkeld, VIC

Sarah Lannan
Landmark, Goulburn, NSW

Paul Vallely
Southern Tablelands Fibre Testing
Crookwell, NSW

Sydney East
Multiplex Constructions Pty Ltd, Dongra, WA

Andy Paton
Mobile Microns, Deniliquin, NSW

Service Providers

Jock Simmons
Aust. Cashmere Growers Assoc. Kellyville, NSW

Rod Agar and John Billing
AWTA Ltd., Melbourne, VIC

Bill Johnstone
IWG, Fremantle, WA

Richard Manning
IWG, Tamworth, NSW

John Cheshire and Andrew Lindsay
AWTA Ltd, Sydney, NSW

Eric Reiher
AWTA Ltd, Newcastle, NSW

David Cother
AWEX, Melbourne, VIC

Ross Bawden and Cam Cuthbertson
Landmark, Brooklyn, VIC

Rob Mahoney
Skipton, VIC

Bruno DeMattia
Melbourne, VIC

Additional Trial Staff

Steve Harvey
Malvern, VIC

Linda Venables
Rippolea, VIC

Jeff Wilson
Wallan, VIC

Peter Conrick
Turretfield, SA

Don Wight
Adelaide, SA

Cheryl Pope
Orange, NSW

Project Management

Program Manager: Mr George Waldthausen, AWI Ltd

Project Manager: Mr Gary Macfarlane, GMAC Consulting Pty Ltd.

Trial Manager: Mr Russell Pattinson, Miracle Dog Pty Ltd.

Project Consultants

Statistical Analysis: Dr John James, Consultant

Final Milestone Report Preparation: Dr Kerry Hansford, Teckel Consulting Pty Ltd

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APPENDIX 1

SUMMARY DATA FOR EACH INDIVIDUAL PROPERTY.

Table A1.1 Property 4 (AM) - Mean and regression parameters for MFD, CVD, SDD, CFR and MFC for Lab LSN and Lab OFDA100 (Method E)

Parameter	Whole Fleece	Lab LSN	Lab OFDA100	Regression Parameters		
				Correlation	Std Dev	Geometric Mean
MFD	20.89	20.85	20.93	0.99	0.17	1.00
SDD	4.18	4.18	4.18	0.94	0.14	1.10
CVD	20.03	20.05	20	0.95	0.60	1.17
CFR	97.6	97.59	97.62	0.97	0.31	1.13
MFC	84.78	90.94	78.63	0.93	2.02	1.10

Table A1.2 Property 4 (AM) - Trait means (MFD, CVD, SDD, CFR and MFC) measured using seven test instruments/methods

Parameter	Whole Fleece	Pinbone			Fleece	Midside		
		Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
MFD	20.89	21.39	21.61	21.34	21.27	20.38	20.52	20.40
SDD	4.18	4.11	4.07	3.91	4.05	3.69	4.03	3.93
CVD	20.0	19.2	18.9	18.3	19.1	18.1	19.7	19.3
CFR	97.6	97.2	97.1	97.4	97.4	98.6	98.2	98.2
MFC	85	88	73	72	91	74	76	88

Table A1.3 **For Property 4 (AM) - For each instrument, 95% site and fleece confidence limits and correlation with and difference from whole fleece mean values for MFD, CVD, SDD, CFR and MFC**

Statistic	Pinbone			Fleece	Midside		
	Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
MFD (Whole Flc = 20.89)							
95% CL Site	0.83	0.97	0.89	1.27	1.00	0.96	0.95
95% CL Flc	1.14	1.40	1.41	1.35	1.24	1.10	1.14
Cor Wh Flc	0.89	0.84	0.83	0.85	0.94	0.88	0.87
Mean	21.39	21.61	21.34	21.27	20.38	20.52	20.40
Diff Wh Flc	0.50	0.72	0.45	0.38	-0.51	-0.37	-0.49
SDD (Whole Flc = 4.18)							
95% CL Site	0.51	0.43	0.32	0.65	0.37	0.30	0.48
95% CL Flc	0.60	0.53	0.43	0.68	0.49	0.49	0.57
Cor Wh Flc	0.80	0.83	0.87	0.76	0.82	0.85	0.79
Mean	4.11	4.07	3.91	4.05	3.69	4.03	3.93
Diff Wh Flc	-0.07	-0.10	-0.27	-0.13	-0.49	-0.14	-0.24
CVD (Whole Flc = 20.03)							
95% CL Site	2.44	2.05	1.39	3.05	1.53	1.77	2.29
95% CL Flc	2.72	2.21	1.94	3.17	1.99	2.54	2.61
Cor Wh Flc	0.78	0.85	0.87	0.75	0.86	0.83	0.81
Mean	19.22	18.89	18.34	19.08	18.12	19.70	19.33
Diff Wh Flc	-0.81	-1.14	-1.68	-0.95	-1.91	-0.33	-0.69
CFR (Whole Flc = 97.60)							
95% CL Site	1.63	1.58	1.59	2.18	1.39	1.04	1.56
95% CL Flc	1.97	2.73	2.39	2.26	1.88	1.66	1.84
Cor Wh Flc	0.85	0.79	0.80	0.76	0.73	0.83	0.77
Mean	97.19	97.07	97.37	97.42	98.63	98.21	98.15
Diff Wh Flc	-0.41	-0.53	-0.23	-0.19	1.03	0.61	0.55
MFC (Whole Flc = 84.78)							
95% CL Site	8.05	6.13	8.06	10.38	9.17	5.30	7.89
95% CL Flc	9.74	8.49	10.69	11.06	10.64	7.56	9.62
Cor Wh Flc	0.76	0.80	0.71	0.67	0.71	0.83	0.74
Mean	87.82	73.20	72.39	90.79	74.39	75.62	88.47
Diff Wh Flc	3.03	-11.59	-12.40	6.00	-10.39	-9.16	3.68

Table A1.4 **Property 5 (WE) - Mean and regression parameters for MFD, CVD, SDD, CFR and MFC for Lab LSN and Lab OFDA100 (Method E)**

Parameter	Whole Fleece	Lab LSN	Lab OFDA100	Regression Parameters		
				Correlation	Std Dev	Geometric Mean
MFD	17.96	17.82	18.11	0.98	0.18	1.06
SDD	3.5	3.41	3.59	0.91	0.11	1.02
CVD	19.5	19.13	19.87	0.9	0.59	1.02
CFR	99.57	99.44	99.71	0.74	0.11	1.24
MFC	92.3	96.48	88.13	0.87	3.61	1.08

Table A1.5 **Property 5 (WE) - Trait means (MFD, CVD, SDD, CFR and MFC) measured using seven test instruments/methods**

Parameter	Whole Fleece	Pinbone			Fleece	Midside		
		Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
MFD	17.96	18.14	18.21	18.34	18.11	17.94	17.68	17.56
SDD	3.50	3.41	3.50	3.15	3.50	3.13	3.45	3.33
CVD	19.5	18.8	19.2	17.2	19.4	17.5	19.5	19.0
CFR	99.6	99.5	99.8	99.8	99.2	99.8	99.8	99.6
MFC	92	98	88	82	100	80	91	98

Table A1.6 For Property 5 (WE) - For each instrument, 95% site and fleece confidence limits and correlation with and difference from whole fleece mean values for MFD, CVD, SDD, CFR and MFC

Statistic	Pinbone			Fleece	Midside		
	Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
MFD (Whole Flc = 17.96)							
95% CL Site	0.72	0.67	0.81	0.90	0.78	0.66	0.69
95% CL Flc	1.02	0.99	1.15	1.00	1.07	0.91	0.90
Cor Wh Flc	0.86	0.86	0.83	0.84	0.84	0.88	0.87
Mean	18.14	18.21	18.34	18.11	17.94	17.68	17.56
Diff Wh Flc	0.17	0.25	0.37	0.14	-0.03	-0.28	-0.40
SDD (Whole Flc = 3.50)							
95% CL Site	0.59	0.32	0.32	0.66	0.30	0.29	0.46
95% CL Flc	0.62	0.42	0.42	0.68	0.38	0.36	0.50
Cor Wh Flc	0.64	0.74	0.73	0.60	0.78	0.84	0.73
Mean	3.41	3.50	3.15	3.50	3.13	3.45	3.33
Diff Wh Flc	-0.09	0.00	-0.35	0.00	-0.36	-0.05	-0.17
CVD (Whole Flc 19.50)							
95% CL Site	3.11	1.82	1.45	3.50	1.52	1.72	2.52
95% CL Flc	3.26	2.12	1.96	3.56	1.86	2.15	2.84
Cor Wh Flc	0.53	0.71	0.70	0.56	0.75	0.79	0.67
Mean	18.82	19.22	17.21	19.35	17.50	19.50	19.00
Diff Wh Flc	-0.68	-0.28	-2.29	-0.15	-2.00	0.00	-0.50
CFR (Whole Flc = 99.57)							
95% CL Site	0.56	0.21	0.31	0.79	0.30	0.20	0.47
95% CL Flc	0.51	0.31	0.46	0.79	0.46	0.35	0.41
Cor Wh Flc	0.56	0.68	0.42	0.35	0.30	0.41	0.58
Mean	99.48	99.76	99.79	99.24	99.85	99.82	99.58
Diff Wh Flc	-0.10	0.19	0.22	-0.33	0.27	0.25	0.00
MFC (Whole Flc = 92.30)							
95% CL Site	10.87	8.22	11.07	10.58	10.81	7.13	11.03
95% CL Flc	15.01	11.93	13.83	11.83	12.39	11.21	13.70
Cor Wh Flc	0.79	0.83	0.76	0.76	0.79	0.85	0.77
Mean	98.06	87.86	82.24	100.49	80.43	90.89	98.45
Diff Wh Flc	5.75	-4.44	-10.07	8.19	-11.88	-1.42	6.15

Table A1.7 **Property 6 (AE) - Mean and regression parameters for MFD, CVD, SDD, CFR and MFC for Lab LSN and Lab OFDA100 (Method E)**

Parameter	Whole Fleece	Lab LSN	Lab OFDA100	Regression Parameters		
				Correlation	Std Dev	Geometric Mean
MFD	17.91	17.89	17.93	0.99	0.17	1.01
SDD	3.93	3.86	4.00	0.95	0.15	1.07
CVD	21.94	21.56	22.31	0.94	0.72	1.13
CFR	99.07	98.94	99.21	0.96	0.19	1.21
MFC	111.03	114.38	107.67	0.72	3.40	1.34

Table A1.8 **Property 6 (AE) - Trait means (MFD, CVD, SDD, CFR and MFC) measured using seven test instruments/methods**

Parameter	Whole Fleece	Pinbone			Fleece	Midside		
		Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
MFD	17.91	18.15	18.25	18.43	17.96	17.70	17.58	17.49
SDD	3.93	3.79	3.81	3.42	3.68	3.36	3.67	3.45
CVD	21.9	20.9	20.9	18.6	20.5	19.0	20.9	19.8
CFR	99.1	99.0	99.3	99.5	99.1	99.8	99.6	99.4
MFC	111	110	100	99	120	104	108	117

Table A1.9 For Property 6 (AE) - For each instrument, 95% site and fleece confidence limits and correlation with and difference from whole fleece mean values for MFD, CVD, SDD, CFR and MFC

Statistic	Pinbone			Fleece	Midside		
	Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
MFD (Whole Flc =17.91)							
95% CL Site	0.71	0.67	0.86	0.79	1.01	0.58	0.57
95% CL Flc	0.92	0.90	1.13	0.84	1.13	0.79	0.78
Cor Wh Flc	0.92	0.92	0.88	0.93	0.87	0.93	0.94
Mean	18.15	18.25	18.43	17.96	17.70	17.58	17.49
Diff Wh Flc	0.24	0.34	0.52	0.05	-0.21	-0.33	-0.42
SDD (Whole Flc = 3.93)							
95% CL Site	0.69	0.42	0.34	0.67	0.43	0.29	0.54
95% CL Flc	0.81	0.60	0.54	0.70	0.62	0.48	0.60
Cor Wh Flc	0.73	0.80	0.81	0.76	0.74	0.86	0.80
Mean	3.79	3.81	3.42	3.68	3.36	3.67	3.45
Diff Wh Flc	-0.14	-0.12	-0.51	-0.25	-0.57	-0.25	-0.48
CVD ((Whole Flc = 21.94)							
95% CL Site	3.60	2.06	1.37	3.44	1.72	1.60	3.00
95% CL Flc	4.15	2.97	2.74	3.57	2.74	2.53	3.25
Cor Wh Flc	0.69	0.79	0.77	0.74	0.77	0.85	0.78
Mean	20.86	20.93	18.59	20.50	19.00	20.95	19.75
Diff Wh Flc	-1.08	-1.01	-3.35	-1.43	-2.94	-0.99	-2.18
CFR (99.07)							
95% CL Site	0.76	0.84	0.76	1.04	0.78	0.39	0.58
95% CL Flc	1.19	1.25	1.07	1.13	1.25	0.97	1.00
Cor Wh Flc	0.73	0.72	0.70	0.70	0.49	0.72	0.70
Mean	99.01	99.27	99.54	99.08	99.78	99.59	99.42
Diff Wh Flc	-0.07	0.20	0.46	0.00	0.71	0.51	0.35
MFC(Whole Flc = 111.03)							
95% CL Site	12.97	11.15	13.15	17.87	14.02	9.22	10.95
95% CL Flc	13.25	11.84	15.31	18.58	14.85	10.21	12.55
Cor Wh Flc	0.58	0.69	0.57	0.48	0.62	0.80	0.69
Mean	110.15	99.86	98.86	120.23	103.80	107.80	116.79
Diff Wh Flc	-0.87	-11.17	-12.16	9.21	-7.22	-3.22	5.76

Table A1.10 Property 7 (MP) - Mean and regression parameters for MFD, CVD, SDD, CFR and MFC for Lab LSN and Lab OFDA100 (Method E)

Parameter	Whole Fleece	Lab LSN	Lab OFDA100	Regression Parameters		
				Correlation	Std Dev	Geometric Mean
MFD	21.35	21.12	21.59	0.99	0.22	1.10
SDD	4.6	4.58	4.63	0.94	0.18	1.05
CVD	21.58	21.71	21.44	0.91	0.85	1.06
CFR	96.3	96.68	95.93	0.99	0.38	1.29
MFC	83.08	88.9	77.25	0.93	2.91	0.97

Table A1.11 Property 7 (MP) -Trait means (for MFD, CVD, SDD, CFR and MFC) measured using seven test instruments/methods

Parameter	Whole Fleece	Pinbone			Fleece	Midside		
		Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
MFD	21.35	22.51	22.86	22.92	21.41	21.31	21.45	21.19
SDD	4.60	4.50	4.51	4.41	4.55	4.16	4.35	4.30
CVD	21.6	20.0	19.7	19.3	21.3	19.5	20.3	20.3
CFR	96.3	94.6	93.6	93.5	96.2	96.8	96.6	97.1
MFC	83	82	74	67	83	69	79	88

Table A1.12 For Property 7 (MP) - For each instrument, 95% site and fleece confidence limits and correlation with and difference from whole fleece mean values for MFD, CVD, SDD, CFR and MFC

Variance	Pinbone			Fleece	Midside		
	Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
				MFD (Whole Flc = 21.35)			
95% CL Site	1.03	0.93	1.23	1.42	1.06	0.99	0.99
95% CL Flc	1.68	1.70	1.88	1.50	1.52	1.38	1.34
Cor Wh Flc	0.88	0.87	0.83	0.88	0.87	0.89	0.89
Mean	22.51	22.86	22.92	21.41	21.31	21.45	21.19
Diff Wh Flc	1.15	1.51	1.57	0.06	-0.04	0.10	-0.16
				SDD(Whole Flc = 4.60)			
95% CL Site	0.57	0.39	0.40	0.67	0.35	0.29	0.49
95% CL Flc	0.73	0.53	0.53	0.70	0.50	0.52	0.61
Cor Wh Flc	0.85	0.91	0.89	0.82	0.89	0.89	0.85
Mean	4.50	4.51	4.41	4.55	4.16	4.35	4.30
Diff Wh Flc	-0.11	-0.10	-0.19	-0.05	-0.45	-0.26	-0.30
				CVD (Whole Flc = 21.58)			
95% CL Site	2.50	1.96	1.52	3.03	1.51	1.75	2.39
95% CL Flc	3.12	2.41	2.19	3.15	2.17	2.53	2.87
Cor Wh Flc	0.76	0.83	0.85	0.78	0.86	0.84	0.80
Mean	19.98	19.70	19.25	21.29	19.53	20.28	20.32
Diff Wh Flc	-1.60	-1.88	-2.32	-0.28	-2.05	-1.30	-1.25
				CFR (Whole Flc = 96.3)			
95% CL Site	2.85	2.71	3.82	3.12	2.24	2.01	1.97
95% CL Flc	5.40	6.19	6.51	3.11	2.89	3.05	2.95
Cor Wh Flc	0.88	0.90	0.85	0.87	0.89	0.88	0.86
Mean	94.56	93.62	93.53	96.20	96.84	96.62	97.08
Diff Wh Flc	-1.75	-2.69	-2.77	-0.10	0.53	0.32	0.77
				MFC (Whole Flc =83.08)			
95% CL Site	15.30	9.44	9.63	10.62	8.57	7.85	15.39
95% CL Flc	19.90	13.89	14.50	11.54	11.60	12.29	16.95
Cor Wh Flc	0.75	0.85	0.80	0.78	0.84	0.87	0.72
Mean	81.53	74.22	66.92	82.57	69.36	79.08	88.23
Diff Wh Flc	-1.55	-8.85	-16.15	-0.51	-13.72	-3.99	5.15

APPENDIX 2

VALIDATION OF WHOLE-FLEECE VALUES AS THE "TRUE" FLEECE MEAN

Table A2.1 Mean and regression parameters for MFD for Lab LSN and Lab OFDA100 (Method E)

Property	Whole Flc Avg	Lab LSN	Lab OFDA100	Regression Parameters		
				Correlation	Std Dev	Geometric Mean
4 (AM)	20.89	20.85	20.93***	0.99	0.17	1.00 **NS**
5 (WE)	17.96	17.82	18.11***	0.98	0.18	1.06 **
6 (AE)	17.91	17.89	17.93**	0.99	0.17	1.01 **NS**
7 (MP)	21.35	21.12	21.59***	0.99	0.22	1.01 **NS**
Avg 4 - 7	**19.53**	**19.42**	**19.64**	**0.99**	**0.19**	**1.02**

Table A2.2 Mean and regression parameters for SDD for Lab LSN and Lab OFDA100 (Method E)

Property	Whole Flc Avg	Lab LSN	Lab OFDA100	Regression Parameters		
				Correlation	Std Dev	Geometric Mean
4 (AM)	4.18	4.18	4.18 NS	0.94	0.14	1.10***
5 (WE)	3.50	3.41	3.59***	0.91	0.11	1.02 NS
6 (AE)	3.93	3.86	4.00***	0.95	0.15	1.07*
7 (MP)	4.60	4.58	4.63**	0.94	0.18	1.05 NS
Avg 4 - 7	**4.05**	**4.01**	**4.10**	**0.94**	**0.15**	**1.06**

Table A2.3 Mean and regression parameters for CVD for Lab LSN and Lab OFDA100 (Method E)

Property	Whole Flc Avg	Lab LSN	Lab OFDA100	Regression Parameters		
				Correlation	Std Dev	Geometric Mean
4 (AM)	20.03	20.05	20.00 NS	0.95	0.60	1.17***
5 (WE)	19.50	19.13	19.87***	0.90	0.59	1.02 NS
6 (AE)	21.94	21.56	22.31***	0.94	0.72	1.13***
7 (MP)	21.58	21.71	21.44***	0.91	0.85	1.06 NS
Avg 4 - 7	**20.76**	**20.61**	**20.91**	**0.93**	**0.69**	**1.10**

Table A2.4 Mean and regression parameters for CFR for Lab LSN and Lab OFDA100 (Method E)

Property	Whole Flc Avg	Lab LSN	Lab OFDA100	Regression Parameters		
				Correlation	Std Dev	Geometric Mean
4 (AM)	97.60	97.59	97.62 NS	0.97	0.31	1.13***
5 (WE)	99.57	99.44	99.71***	0.74	0.11	1.24***
6 (AE)	99.07	98.94	99.21***	0.96	0.19	1.21***
7 (MP)	96.30	96.68	95.93***	0.99	0.38	1.29***
Avg 4 - 7	**98.16**	**98.12**	**0.92**	**0.25**	**1.22**	**98.16**

Table A2.5 Mean and regression parameters for MFC for Lab LSN and Lab OFDA100 (Method E)

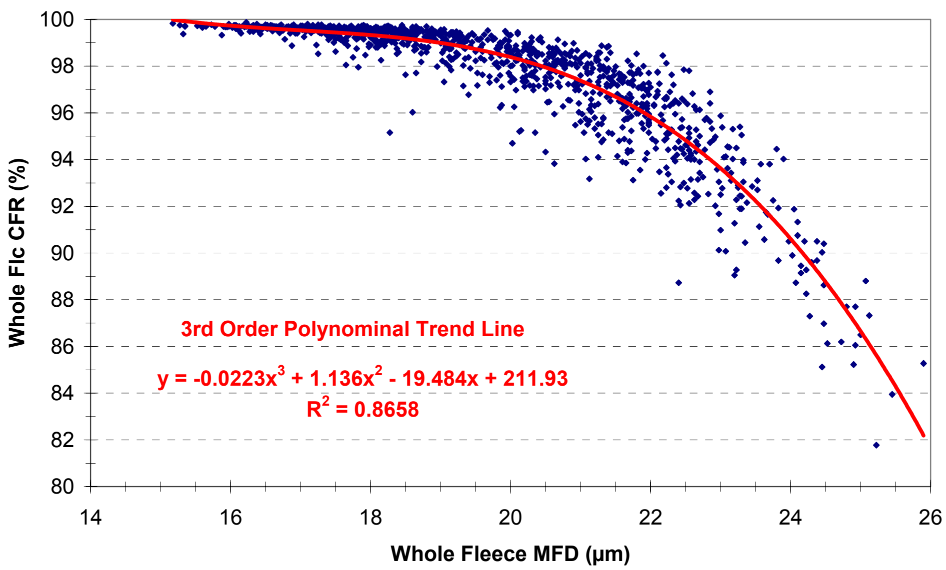
Property	Whole Flc Avg	Lab LSN	Lab OFDA100	Regression Parameters		
				Correlation	Std Dev	Geometric Mean
4 (AM)	84.78	90.94	78.63***	0.93	2.02	1.10**
5 (WE)	92.30	96.48	88.13***	0.87	3.61	1.08 NS
6 (AE)	111.03	114.38	107.67***	0.72	3.40	1.34***
7 (MP)	83.08	88.90	77.25***	0.93	2.91	0.97 NS
Avg 4 - 7	**92.80**	**97.68**	**87.92**	**0.86**	**2.99**	**1.12**

Overall, the agreement between Lab LSN and Lab OFDA100 for MFD, SDD, CVD and CFR is good as judged by both the mean and correlation. MFC displays a clear difference in mean and a lower correlation. The differences in the results for MFC (9 to 10 degrees/mm) confirm that calibration procedures are required.

Table A2.6 Correlations between MFD and CFR

Property	Whole Flc Avg MFD	Whole Flc Avg CFR	Correlation
4 (AM)	20.89	97.6	-0.71
5 (WE)	17.96	99.6	-0.60
6 (AE)	17.91	99.1	-0.62
7 (MP)	21.35	96.3	-0.84
Average 4 – 7	**19.53**	**98.14**	**-0.69**

Figure A2.1 Relationship between whole fleece MFD and CFR



APPENDIX 3

CALCULATIONS TO CONVERT THE SITE CONFIDENCE LIMIT TO A WHOLE-FLEECE CONFIDENCE LIMIT

The calculation of the precision of a test result as it relates to the whole fleece rather than a single site has been a major issue for the EAG.

The original protocol document used an approach that was aimed at providing an estimate of the additional variance to be added to the site variance through a simple regression analysis. The error variance around the linear regression was the variance to be added to the site variance. This would allow the site mean value to have a linear bias to the whole fleece mean value without it impacting on the whole fleece precision estimate. This became known as Method B2.

This approach was modified slightly to an analysis based around covariance calculations. This became known as B1.

A third option was to simply determine the additional variance from the variance of the differences between the site mean value and the whole fleece mean value for the sheep within the one mob. This became known as Method C.

An example comparison of the three methods for one property is provided in Tables A3.1, A3.2 and A3.3. The results are also presented graphically in Figure A3.1.

Table A3.1 Calculations for Method B1

MODEL

Whole Fleece Error Variance = Within Site Error Variance + "True" Residual Regression Variance

Whole Fleece Error Variance = VT(Method) + Observed Residual Regression Variance - Error Variance in Y - Error Variance in X

Whole Fleece Error Variance = VT(Method) + Observed Residual Regression Variance - VAR(CERT) - VT(Method)/NREPS

When NREPS=1 Whole Fleece Error Variance = Observed Residual Regression Variance -

Regression METHOD B Calculation 1

	Pinbone			Fleece	Midside			
	LAB LSN	LAB OFDA	OFDA2000	Fleecescan	OFDA2000	LAB OFDA	LAB LSN	
VT(Method)	0.1334	0.1170	0.1721	0.2122	0.1586	0.1146	0.1239	VT(Method) = Within Site Variance
Vtotal	1.0399	0.9676	1.0865	0.8720	1.0198	0.9423	0.9017	Vtotal = VT+VS
Covariance	0.7269	0.6995	0.7157	0.6494	0.7046	0.7071	0.6878	Covariance = Covar(x,FICAVE)
Reg.Coeff.	0.6990	0.7230	0.6587	0.7448	0.6910	0.7504	0.7628	b=Covariance/VT(Method)
TRFLCVAR	0.6956	0.6956	0.6956	0.6956	0.6956	0.6956	0.6956	Variance in Y = VSheep from Cert Data
VAR(CERT)	0.0093	0.0093	0.0093	0.0093	0.0093	0.0093	0.0093	Error Variance in Y = VAR(CERT) = Error Variance in Whole Fleece Average
AFLVAR	0.6864	0.6864	0.6864	0.6864	0.6864	0.6864	0.6864	Adjusted Fleece Variance = AFLVAR = Measured Fleece Variance - VAR(CERT)
VAR(reg)	0.5080	0.5057	0.4714	0.4837	0.4869	0.5306	0.5247	Variance Accounted for by Regression = Reg Coeff*Covariance
VAR(REGRES)	0.1783	0.1807	0.2150	0.2027	0.1995	0.1558	0.1617	Variance NOT Accounted for by Regression = VAR(REGRES) = AFLVAR -
WFLVAR	0.1783	0.1807	0.2150	0.2027	0.1995	0.1558	0.1617	Whole Fleece Variance = AFLVAR - RegCoeff*Covariance
95% CL Fleece	0.83	0.83	0.91	0.88	0.88	0.77	0.79	95%Clt Fleece = 1.96*Sqrt(WFLVAR)
95% CL Site	0.72	0.67	0.81	0.90	0.78	0.66	0.69	95%Clt Site = 1.96*Sqrt(VT(Method))
R	0.8603	0.8584	0.8287	0.8395	0.8422	0.8792	0.8743	R = Covariance/(sqrt(Vtotal)*sqrt(AFLVAR))

Note: The Experimental Design does not define the weightings of the individual components of

Table A3.2 Calculations for Method C

MODEL

Whole Fleece Error Variance = Within Site Error Variance + Variance due to the Differences from the "True" Values

Whole Fleece Error Variance = Within Site Error Variance + "True" Variance of the Differences

Non-Regression

	Pinbone			Fleece	Midside			
	LAB LSN	LAB OFDA	OFDA2000	Fleecescan	OFDA2000	LAB OFDA	LAB LSN	
VT(Method)	0.1334	0.1170	0.1721	0.2122	0.1586	0.1146	0.1239	VT(Method) = within site measurement error variance
VH	0.9065	0.8505	0.9144	0.6598	0.8612	0.8277	0.7779	VH = between sheep variance component
Vtotal	1.0399	0.9676	1.0865	0.8720	1.0198	0.9423	0.9017	Vtotal = VT(Method) + VH
r	0.8718	0.8791	0.8416	0.7566	0.8445	0.8784	0.8626	r = repeatability = VH / Vtotal
AFLVAR	0.6864	0.6864	0.6864	0.6864	0.6864	0.6864	0.6864	AFLVAR = whole fleece variance adjusted for sampling error
Cov	0.7269	0.6995	0.7157	0.6494	0.7046	0.7071	0.6878	Cov = covariance between site measurement and whole fleece average
WFLVAR	0.2726	0.2549	0.3416	0.2595	0.2969	0.2145	0.2125	WFLVAR = AFLVAR + Vtotal - 2*Cov
95% CL Fleece	1.02	0.99	1.15	1.00	1.07	0.91	0.90	
95% CL Site	0.72	0.67	0.81	0.90	0.78	0.66	0.69	

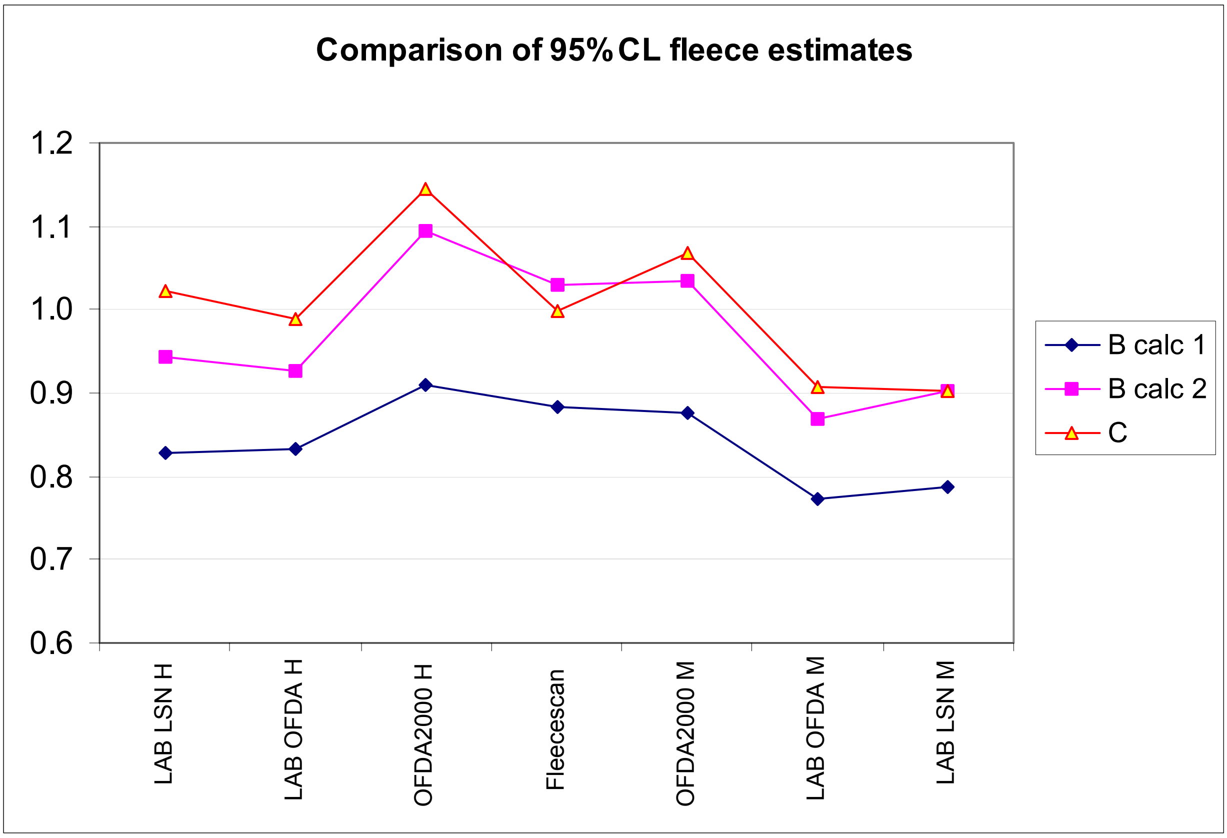
Table A3.3 Calculations for Method B2

Regression METHOD B2 Calculation 2

	Pinbone			Fleece	Midside			
	LAB LSN	LAB OFDA	OFDA2000	Fleecescan	OFDA2000	LAB OFDA	LAB LSN	
VT(Method)	0.1334	0.1170	0.1721	0.2122	0.1586	0.1146	0.1239	VT(Method) = Within Site Variance
SLOPE	0.7655	0.7931	0.7550	0.9330	0.7952	0.8207	0.8348	SLOPE = EXCEL SLOPE(Y,X) Worksheet Function
STEYX	0.4176	0.4170	0.4377	0.3557	0.4113	0.3860	0.3988	Standard Error of Prediction = EXCEL STEYX(Y,X) Worksheet Function
VARYX	0.1744	0.1739	0.1916	0.1265	0.1692	0.1490	0.1591	Residual Regression Variance = VARYX = STEYX squared
NREPS	2	2	4	4	4	2	2	NREPS = Number of values used to calculate Average
VAR(CERT)	0.0093	0.0093	0.0093	0.0093	0.0093	0.0093	0.0093	VAR(CERT) = Error Variance in Whole Fleece Average
ADJERRVAR	0.0985	0.1062	0.1393	0.0642	0.1203	0.0824	0.0879	ADJVAR = VARYX - VAR(CERT) - VT(Method)/Nreps
WFLVAR	0.2319	0.2232	0.3114	0.2764	0.2789	0.1970	0.2117	Whole Fleece Variance = ADJERRVAR + VT(Method)
95% CL Fleece	0.94	0.93	1.09	1.03	1.04	0.87	0.90	95%Clt Fleece = 1.96*Sqrt(WFLVAR)
95% CL Site	0.72	0.67	0.81	0.90	0.78	0.66	0.69	95%Clt Site = 1.96*Sqrt(VT(Method))
R	0.8758	0.8762	0.8626	0.9116	0.8798	0.8950	0.8874	R = Square Root of the EXCEL RSQ(Y,X) Worksheet Function

Note: The Experimental Design defines the weightings of the individual components of variance.

Figure A3.1 Comparison of Confidence Limits by three calculation methods (B1, B2 and C)



Calculation method B1, whilst conceptually giving the better predictor of the prediction error variance, relies on knowledge which is normally unavailable to most on-farm operators (the regression between the site results and the unskirted whole fleece mean). However, comparing the algebra for calculations B and C, the major contribution to the difference in the outcomes would appear to be the effect of the square of the regression gradient b in reducing VT, bearing in mind that b is less than 1 in the least squares model (and $(b-1)^2VH$ should be a relatively small value). One concern with Calculation B1 was that in a number of the analyses conducted the site confidence limit was greater than the whole fleece confidence limit. This can arise because method B1 regresses the prediction towards the mean, while the site confidence limit is calculated for an unregressed prediction. Method C is analogous to the site confidence limit in this respect.

Intuitively, however, the model used in calculation C appears to better represent reality to date, where users and operators assume that the on-farm test result (or laboratory result on a sample) is an adequate predictor of the whole-fleece value. Calculation C also has the advantage of being based on a relatively non-contentious "text-book" calculation for the variance of the differences of two correlated variables.

Calculation B2 appears logical on first sight, it shows the greatest divergence from Calculation C for the pinbone samples and least for the midside samples, which would indicate that the midside sample better represents the whole fleece. It is much closer to Calculation C than Calculation B1.

It was agreed by EAG members that Calculation C was to be used for comparative purposes.

APPENDIX 4

THE IMPACT OF OBSERVED BIASES IN MFC MEASUREMENTS ON THE WHOLE-FLEECE CONFIDENCE LIMITS

Because the correlations between the OFDA100 and Lab LSN measurements of MFC were lower than for the other traits, and there was an appreciable difference in mean between the two measurement procedures, it was considered worthwhile to treat the two measurements separately and calculate confidence limits for the whole fleece MFC as measured by both procedures, as well as the average. The confidence limits were computed by the same method as shown previously for the average. Table A4.1 presents the confidence limits for whole fleece MFC measured by both procedures using each of the seven instruments/methods for the four. For comparison, the confidence limits for the average of four properties are included.

Table A4.1 95% WHOLE FLEECE Confidence Limits for MFC as measured by Lab LSN, Lab OFDA100 and their average for four properties using seven test instruments/methods

Property	Fleece	Pinbone			Fleece	Midside		
	Instrument	Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
4 (AM)	Lab LSN	9.73	8.47	10.69	10.97	10.93	7.85	9.81
	OFDA100	10.01	8.80	10.92	11.36	10.58	7.59	9.69
	Avg	**9.74**	**8.49**	**10.69**	**11.06**	**10.64**	**7.56**	**9.62**
5 (WE)	Lab LSN	15.71	12.64	14.44	12.24	12.94	12.24	14.25
	OFDA100	15.31	12.46	14.31	12.67	13.04	11.49	14.23
	Avg	**15.01**	**11.93**	**13.83**	**11.83**	**12.39**	**11.21**	**13.70**
6 (AE)	Lab LSN	13.74	13.18	15.96	18.64	15.26	11.50	12.68
	OFDA100	14.72	12.69	16.39	19.94	16.19	11.42	14.45
	Avg	**13.25**	**11.84**	**15.31**	**18.58**	**14.85**	**10.21**	**12.55**
7 (MP)	Lab LSN	19.95	14.00	14.71	11.63	11.82	12.19	16.88
	OFDA100	19.87	13.83	14.33	11.50	11.43	12.45	17.04
	Avg	**19.90**	**13.89**	**14.50**	**11.54**	**11.60**	**12.29**	**16.95**
All 4 Properties	Lab LSN	14.78b	12.07ab	13.95b	13.37ab	12.74ab	10.95a	13.41ab
	OFDA100	14.98b	11.95ab	13.99b	13.87b	12.81ab	10.74a	13.85b
	Avg	**14.48b**	**11.54ab**	**13.58b**	**13.25ab**	**12.37ab**	**10.32a**	**13.21ab**

Means with the same letter do not differ significantly by the LSD test. 5% LSD = 3.066 for the average.

The 5% LSD values for the Lab LSN and Lab OFDA100 for the data for all four properties were 2.978 and 3.038 respectively.

Table A4.1 shows there are no important differences in the size of the confidence limits for whole fleece MFC as measured by Lab LSN, Lab OFDA100 or their average. Thus, although there are real differences between the two procedures, the high correlation between them means that either measurement can be predicted with similar accuracy by any of the seven methods. The OFDA100 midside gives the lowest confidence limits for all three whole fleece measurements, but is not significantly better than all other methods.

To further confirm these findings, correlations of the seven MFC measurements with the three whole fleece measurements were computed. These correlations were calculated using the means of the two or four measurements of each type on each sheep, and are therefore not directly comparable with the correlations with whole fleece values given in earlier tables, but the correlation with average whole fleece value was included in the computations. The results are shown in Table A4.2.

Table A4.2 Average correlations for MFC across properties for the seven measurement procedures with the three different estimates of whole fleece measurements

Instrument	Pinbone			Fleece	Midside		
	Lab LSN	Lab OFDA100	OFDA-2000	Fleece-scan	OFDA-2000	Lab OFDA100	Lab LSN
Lab LSN	0.73	0.76	0.73	0.81	0.76	0.79	0.75
OFDA100	0.75	0.80	0.75	0.79	0.78	0.83	0.74
Avg	**0.76**	**0.81**	**0.76**	**0.83**	**0.80**	**0.84**	**0.77**

APPENDIX 5

IMPLICATIONS TO ON FARM DECISIONS

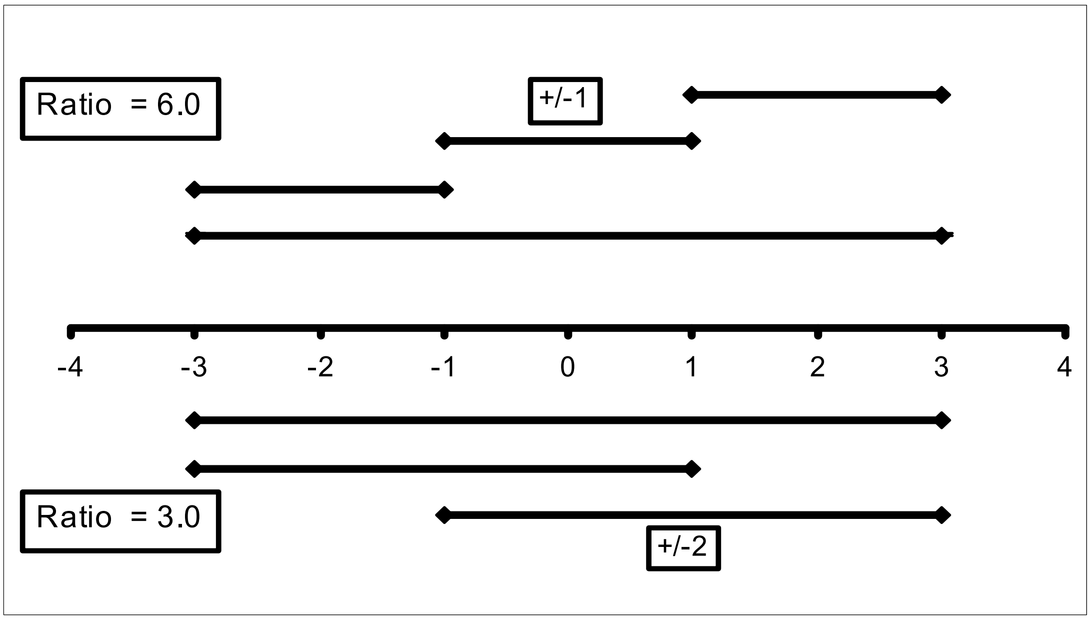
Among the factors that need to be balanced when embarking on a program to use fleece measurement to provide a return on investment:

- The range of the wool trait (e.g. diameter) within the mob;
- The whole fleece confidence limit to be provided by some system of measurement; and
- The cost of the testing.

Some simple examples can help to put this in context by considering the ratio of the Range and Confidence Limit (see Table A5.1).

As an example, consider a mob of sheep that exhibits a range of six units between individual animals, and there are two different test options available: one has a confidence limit of ±1 unit while the other has a confidence limit of ±2 units.

Figure A5.1 Examples of the impact of Confidence Limits of on the possible overlap when applied to a mob with a range of 6 units.



From the Figure A5.1, the examples above the centre line indicate a ratio of 6.0 (derived from a range of 6 and a confidence limit of ±1) demonstrating that it may be possible to divide the mob into three groups without too much overlap. The examples below the line indicate the comparison for a ratio of 3 (derived from the same range of 6 but a confidence limit of ±2) demonstrating the difficulty in dividing the mob into two groups because of the overlap.

Hence, the higher ratio provides a better chance to discriminate between the individuals in the mob during any selection process. When the ratios were calculated for the properties and the different measurement technologies used in this trial, some points can be noted. From Table A5.2 it is clear that the highest ratios observed were related to MFD. The table has used a limiting ratio value of 5.5 as an example simply to highlight those ratios that are greater than 5.5 and those that were less than 5.5. It is clear that it would be more difficult to make selections based on SDD, CVD, CFR and MFC and guarantee a reasonable separation within the group. To be successful one would need to improve the Confidence Limit of these wool traits (see the Section "Improving the Precision of Measurement").

Table A5.2: Ratios of Mob Range to Confidence Limit for Different Technologies and Different Properties.

WHOLE FLEECE CONFIDENCE LIMITS

	PROPERTY	LABLSN	LABOFDA	OFDA2000	FLSN	OFDA2000	LABOFDA	LABLSN	Ranges
MFD	4	1.14	1.40	1.41	1.35	1.24	1.10	1.14	6.77
	5	0.92	0.90	1.13	0.84	1.13	0.79	0.78	6.52
	6	1.02	0.99	1.15	1.00	1.07	0.91	0.90	4.97
	7	1.68	1.70	1.88	1.50	1.52	1.38	1.34	8.45
	AVE	1.19	1.25	1.39	1.17	1.24	1.04	1.04	6.68
SDD	4	0.60	0.53	0.43	0.68	0.49	0.49	0.57	2.54
	5	0.81	0.60	0.54	0.70	0.62	0.48	0.60	2.80
	6	0.62	0.42	0.42	0.68	0.38	0.36	0.50	1.58
	7	0.73	0.53	0.53	0.70	0.50	0.52	0.61	3.16
	AVE	0.69	0.52	0.48	0.69	0.50	0.46	0.57	2.52
CVD	4	2.72	2.21	1.94	3.17	1.99	2.52	2.61	11.77
	5	4.15	2.97	2.74	3.57	2.74	2.53	3.25	13.19
	6	3.26	2.12	1.96	3.56	1.86	2.15	2.84	7.64
	7	3.12	2.70	2.19	3.15	2.17	2.53	2.87	11.71
	AVE	3.31	2.50	2.21	3.36	2.19	2.43	2.89	11.08
CFR	4	1.97	2.73	2.39	2.26	1.88	1.66	1.84	8.42
	5	1.19	1.25	1.07	1.13	1.25	0.97	1.00	4.27
	6	0.51	0.31	0.46	0.79	0.46	0.35	0.41	0.94
	7	5.40	6.19	6.51	3.11	2.89	3.05	2.95	17.63
	AVE	2.27	2.62	2.61	1.82	1.62	1.51	1.55	7.81
MFC	4	9.74	8.49	10.69	11.06	10.64	7.56	9.62	33.35
	5	13.25	11.84	15.31	18.58	14.85	10.21	12.55	29.05
	6	15.01	11.93	13.83	11.83	12.39	11.21	13.70	42.88
	7	19.90	13.89	14.50	11.54	11.60	12.29	16.95	43.75
	AVE	14.48	11.54	13.58	13.25	12.37	10.32	13.20	37.26

RATIOS OF RANGE / CONFIDENCE LIMIT

Ratio Limit

		LABLSN	LABOFDA	OFDA2000	FLSN	OFDA2000	LABOFDA
MFD	4	***5.9***	4.8	4.8	5.0	5.5	***6.1***
	5	***7.1***	***7.2***	***5.8***	***7.8***	***5.8***	***8.3***
	6	4.9	5.0	4.3	5.0	4.7	5.5
	7	5.0	5.0	4.5	***5.6***	***5.6***	***6.1***
	AVE	***5.6***	5.4	4.8	***5.7***	5.4	***6.4***
SDD	4	4.3	4.8	***5.9***	3.7	5.2	5.2
	5	3.5	4.7	5.2	4.0	4.5	***5.8***
	6	2.5	3.8	3.8	2.3	4.2	4.4
	7	4.3	***6.0***	***6.0***	4.5	***6.3***	***6.1***
	AVE	3.7	4.9	5.3	3.7	5.1	5.4
CVD	4	4.3	5.3	***6.1***	3.7	***5.9***	4.7
	5	3.2	4.4	4.8	3.7	4.8	5.2
	6	2.3	3.6	3.9	2.1	4.1	3.6
	7	3.7	4.3	5.3	3.7	5.4	4.6
	AVE	3.3	4.4	5.0	3.3	5.1	4.6
CFR	4	4.3	3.1	3.5	3.7	4.5	5.1
	5	3.6	3.4	4.0	3.8	3.4	4.4
	6	1.8	3.1	2.0	1.2	2.1	2.7
	7	3.3	2.8	2.7	***5.7***	***6.1***	***5.8***
	AVE	3.4	3.0	3.0	4.3	4.8	5.2
MFC	4	3.4	3.9	3.1	3.0	3.1	4.4
	5	2.2	2.5	1.9	1.6	2.0	2.8
	6	2.9	3.6	3.1	3.6	3.5	3.8
	7	2.2	3.2	3.0	3.8	3.8	3.6
	AVE	2.6	3.2	2.7	2.8	3.0	3.6