The Precision of OFDA2000 and FLEECESCAN for Estimating the Diameter Characteristics of Fleeces: A Case Study

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Summary

The 95% Confidence Limits relevant to the entire fleece were determined for three different measurement systems, as they are used commercially in Australia, as follows:

Measurement System	MFD (μm)	SDD (μm)	CVD (%)
OFDA2000 In-Shed (for one staple Flank Sampling [a])	**± 1.41**	**± 0.6**[#]	**± 2.3**[#]
OFDA2000 In-Shed (for one staple Midside Sampling)	**± 1.28**	**± 0.6**[#]	**± 2.2**[#]
FLEECESCAN In-Store (1,000 fibres measured)	**± 1.02**	**± 0.8**	**± 3.5**
Laboratory LASERSCAN by Midside (1,000 fibres measured)	**± 1.19**	**± 0.7**	**± 3.0**

Notes: [a] The Flank sampling is in very close proximity to the commonly used pinbone site and is provided here for the purposes of comparison.
The Between-Sheep Ranges of SDD and CVD for the OFDA2000 measured fleeces were lower than the Between-Sheep Ranges measured by FLEECESCAN and Laboratory LASERSCAN.

These Confidence Limits are relevant to the sampling procedures and laboratory practices of the participating testers. The Confidence Limit will be widened if the number of measured fibres is less than that used in this study. Some FLEECESCAN operators are known to measure 600 fibres. This will result in a small increase in the reported Confidence Limits (i.e. ± **1.02μm** to ± **1.04μm** for MFD). Unlike the traditional midside sampling and Laboratory testing **no Industry agreed Standards exist for either the OFDA2000 or FLEECESCAN**. Hence, wool producers need to be aware that individual operators can determine their own sampling and testing procedures.

The commercial implications of the results presented above relate to sheep selection and fleece classing. The lower the Confidence Limit the better will be the ability to differentiate between individual fleeces and individual sheep. In past times, many wool producers have used Laboratory testing of midside samples to improve their flock. As the uniformity of the flock increases the further economic gains will be limited by the Confidence Limit. Wool producers will need to take this into account when deciding on what sampling and testing procedures should be used on their flock. For example, it would be commercially beneficial to test the breeding rams at a higher sampling and testing frequency (i.e. measure more specimens with FLEECESCAN or more sites with OFDA2000) than the breeding ewes.

Introduction

A number of authors have reported that the precision of the measurement of a fleece will have an impact on the decisions taken on-farm with respect to sheep selection for on-going breeding or culling and fleece selection for preparing classed lines of wool of different Mean Fibre Diameter (MFD) for sale (Peterson and Gherardi (2001), Baxter (2001), Vizard and Williams (1993) and Marler (2001)). Determination of the precision of MFD for a fleece test has been the subject of many research studies (Cottle et al (1996), Morgan (1990), Baxter (2000)). All of these relate to the precision of a single test conducted at one site on the animal, whereas the precision that is important is the precision of the measured value as it represents the entire fleece. The precision of any value based on a calculation for one site will underestimate the precision relevant to the entire fleece, as it inevitably does not include the variation over the fleece. This paper summarises the first attempt to validate a model, which aims to represent the precision of the entire fleece developed by Marler and Couchman (2001). Any estimate of precision will be dependent on the procedures used to determine the average value. As any change in the procedures is likely to have an impact the precision, quoting a 95% confidence limit without the detailed procedures that accompany it is meaningless.

This report summarises the data from a series of trials conducted on one property (Marler *et al.* 2002). The 95% Confidence Limits relevant to three different measurement systems were determined:

- The OFDA 2000 measuring a single staple taken from one site on-farm;
- The LASERSCAN laboratory testing of a midside sample taken on-farm; and
- The minicore sampling of the skirted fleece and testing on a FLEECESCAN system in a store environment.

Materials and Methods

Sampling Procedures

One hundred, one and a quarter year old, ewes with 11 months of wool growth were selected at random from a commercial flock of approximately 5,000 sheep. Immediately prior to shearing five different sites were marked with different colour raddle. Samples from the five sites (Shoulder, Midside, Flank, MidBack, and Rump) were collected from the fleece after it had been thrown on the skirting table. Each site sample was placed in a plastic bag and labelled with the sheep number and the sampling site. After skirting, the fleece without any belly wool was collected and placed in a plastic bag together with the sheep number.

Subampling and Measurement Procedures

- *Subsampling and Measurement of Individual Fleeces.*

Using the Fleece Minicorer component of the FLEECESCAN system, each individual fleece was minicored six times to produce six separately identified test specimens. Three test specimens were tested using the FLEECESCAN system operated in a wool store. Three test specimens were tested using a LASERSCAN operated in a wool-testing laboratory.

- *Subsampling and Measurement of Site Samples.*

OFDA2000. Three individual staples were selected from each site for each sheep. These were individually labelled and packaged in small plastic bags. The staples were sent to a commercial OFDA2000 operator for measurement. The sampling and measurement procedures differed from those normally used only in that the staples were drawn from shorn wool samples and the OFDA2000 measurements were made in an office environment whereas most routine measurements are conducted on the farm from staples gathered by careful cutting close to the skin at one site (eg the hip bone).

"Laboratory" LASERSCAN (LLSN) and "In-Store" FLEECESCAN (FLSN). After the staples had been sampled for the OFDA2000 measurements, each site sample was minicored using a LABORATORY MINICORER, designed to handle midside samples, six times to produce six separately identified test specimens. The three test specimens from each site sample were sent to the "In-Store" FLEECESCAN for cleaning and measurement. One thousand fibres were measured from each test specimen. A further three test specimens from each site sample were sent to the laboratory for cleaning and measurement using the same procedures applied to commercial midside testing. One thousand fibres were measured from each test specimen.

Methods Used to Estimate of the Precision of the Measured Result.

The most important issue for wool producers is the precision (i.e. the 95% confidence limit) of the measured result as it relates to the entire fleece. At the time of writing this report, all scientific studies read by the authors report the precision of the test result as it relates to the sample being tested. This ignores any variability that arises from differences over the fleece. This report will provide estimates of both.

Fleece Sampling. In this case all parts of a fleece have equal probability of being sampled. The precision was estimated by calculating the pooled between-test-specimens variance and converting this to a 95% Confidence Limit as indicated in equation 1.

$$\text{95\% Confidence Limit} = 1.96 \times \sqrt{(\text{Between Test Specimen Variance})} \quad \text{……………………..Equation 1}$$

The above estimate represents the precision of the measured result as it relates to the entire fleece.

Site Sampling. As the common benchmarks for site sampling in the industry today relate to midside laboratory testing (by LASERSCAN or OFDA100) or testing samples from the hipbone (by OFDA2000), the precision estimates for these two procedures that most reflect these sites have been calculated. It must be remembered that this precision estimate only relates to the confidence for the site being sampled.

An approach recommended by Marler and Couchman (2001), which used the Between-Reps-Within-Site Variance together with an estimate of the uncertainty of the site being truly representative of the mean for the fleece, was also investigated. The uncertainty was estimated by regressing the site average against the overall fleece average to determine the residual variance around the regression line. The precision calculation used was as described in equation 2.

$$\text{95\% Confidence Limit} = 1.96 \times \sqrt{((\text{Between Test Specimen Variance}) + (\text{Regression Variance}))} \quad \text{……..Equation 2}$$

No statistical significance test exists for comparing Confidence Limits directly. It is possible, in Tables 1 to 4, to compare one Confidence Limit estimate to another by calculating an equivalent F_{Ratio} by dividing the larger Confidence Limit by the smaller and then squaring the value obtained. The critical F_{Ratio} , for a 95% probability level, appropriate to the data presented is $F_{(0.05,200,200)} = 1.263$. For the common commercial procedures, statistical equivalence at the 95% probability level is indicated by an alphabetical code where values with the same superscript can be considered to be equivalent.

Results and Discussion

Repeat Fleece Sampling.

Table 1 summarises the 95% confidence limits derived for the entire fleece, cleaning in either solvent (FLSN) or hot water and detergent (LLSN) followed by the measurement of 1000 fibres for MFD, SDD and CVD.

Table 1: Fleece Sampling 95% Confidence Limits

	FLSN	LLSN
Mean Fibre Diameter (µm)	± 1.02[a]	± 1.09[a]
Standard Deviation of Diameter (µm)	± 0.76[b]	± 0.73[b]
Coefficient of Variation of Fibre Diameter (%)	± 3.52[c]	± 3.23[c]

Some FLEECESCAN operators measure 600 fibres to speed up the measurement process in the shed. This will increase the Confidence Limits reported here slightly. In the case of MFD the increase can be calculated by separating the "true" Between-Test-Specimens variance from the "measured" Between-Test-Specimens variance and the Between-Fibres variance calculated from the average Between-Fibres SD (i.e. the SDD from Table 4 below). The Estimated Between-Test-Specimens Variance for 600 fibre measurements can be calculated from the "Measured" Between-Test-Specimens Variance (for 1000 fibres) minus Between-Fibres Variance divided by 1000 plus the Between-Fibres Variance divided by 600. This leads to an increase in the 95% Confidence Limit for MFD from the ± 1.02µm, reported above, to ± 1.04µm.

Site Sampling.
In Australia, the two most common sites that are being used by commercial operators are the midside and the pinbone, the pinbone being *"the preferred site by OFDA2000 operators"* (Australian Wool Innovation Pty Ltd (2002)). The nearest site to the pinbone in this trial was the right flank. To enable precision comparisons between the most commonly used commercial practices in Australia, the relevant sites have been highlighted in Tables 2, 3 and 4 by the use of a "com" subscript. The 95% Confidence Limit estimates for these two sites was compared in Table 2 to the 95% Confidence Limit for the full FLEECESCAN system which included the minicore sampling of the entire fleece.

Table 2: Summary of 95% Confidence Limits for MFD Measurement (Commercial practices have been denoted by a "com" subscript).

95% Confidence Limit	Sampling Method	OFDA2000	FLEECESCAN	LASERSCAN
For a **Site**	Midside	± 0.90	± 0.60	**± 0.64**
	Right Flank	**± 1.12**	± 0.77	± 0.83
For a **Fleece**	Midside	**± 1.28$_{com}$**[b,c]	± 1.08	**± 1.19$_{com}$**[b]
	Right Flank	**± 1.41$_{com}$**[c]	± 1.17	± 1.35
	Entire Fleece	Not Possible	**± 1.02$_{com}$**[a]	± 1.09
Mob Characteristics	Average MFD	19.7	18.8	19.1
	Minimum MFD	16.8	16.2	16.4
	Maximum MFD	22.7	22.2	22.6

The traditional fleece testing procedures of providing a midside sample to a fleece-testing laboratory had a confidence limit for the particular site of ± 0.64µm by LASERSCAN compared to the OFDA2000 right flank sample of ± 1.12µm and midside sample of ± 0.90µm. When these values are converted to represent the entire fleece rather than the single site the values increase to ± 1.19µm for the LASERSCAN and ± 1.41µm for the OFDA2000 right flank and ± 1.28µm for the OFDA2000 midside). The increase in the Confidence Limits highlights the important role sampling plays. These latter results can now be compared to the full FLEECESCAN system, which had a confidence limit of ± 1.02µm. It is important to re-iterate at this point that it is the confidence limit for the fleece that is the more relevant parameter as all decisions that are to be made with respect to the measurement relate to the overall fleece characteristics.

Table 3: Summary of 95% Confidence Limits for Standard Deviation of Fibre Diameter Measurement (Commercial practices have been denoted by a "com" subscript).

95% Confidence Limit	Sampling Method	OFDA2000	FLEECESCAN	LASERSCAN
For a **Site**	Midside	± 0.4	± 0.5	**± 0.4**
	Right Flank	**± 0.5**	± 0.5	± 0.5
For a **Fleece**	Midside	**± 0.6$_{com}$**[a]	± 0.7	**± 0.7$_{com}$**[b]
	Right Flank	**± 0.6$_{com}$**[a]	± 0.8	± 0.9
	Entire Fleece	Not Possible	**± 0.8$_{com}$**[c]	± 0.7
Mob Characteristics	Average SDD	3.8	4.2	4.3
	Minimum SDD	2.9	3.1	3.1
	Maximum SDD	4.8	5.7	5.9

The differences between the precisions for the three measurement systems in Table 3 were small. The lower values and lower spread of individual fleece results could be a factor in the lower OFDA2000 confidence limit.

Table 4: Summary of 95% Confidence Limits for CVD Measurement (Commercial practices have been denoted by a "com" subscript).

95% Confidence Limit	Sampling Method	OFDA2000	FLEECESCAN	LASERSCAN
For a **Site**	Midside	± 1.9	± 2.3	**± 2.2**
	Right Flank	**± 1.8**	± 2.2	± 2.3
For a **Fleece**	Midside	**± 2.3$_{com}$** [a]	± 3.1	**± 3.0$_{com}$** [b]
	Right Flank	**± 2.2$_{com}$** [a]	± 3.4	± 3.4
	Entire Fleece	Not Possible	**± 3.5$_{com}$** [c]	± 3.2
Mob Characteristics	Average CVD	19	22	22
	Minimum CVD	14	16	15
	Maximum CVD	24	30	31

The differences between the precisions of the CVD measurements for the three measurement systems were smaller for the OFDA2000 but the measurement range reported for the mob was also much smaller (10% compared to approximately 15%).

Model Validation Using Independent Field Data.
A separate set of data (Hansford *et al* (2002)) enabled the validity of the proposed model for calculating the entire fleece precision to be investigated. As a mob of 2260 sheep had been commercially tested by OFDA2000 (at a site selected by the OFDA2000 operator), FLEECESCAN and midside sampled and tested by a Laboratory LASERSCAN it was possible to use the individual measurement differences from the FLEECESCAN result to derive an independent estimate of the precision for OFDA2000 and Laboratory LASERSCAN. The calculations are based on the simple relationship that: Variance (OFDA-FLSN) = Variance (OFDA) + Variance (FLSN), when OFDA and FLSN are independent estimates of the same quantity (Baird (1962)). It is therefore possible to calculate the Variance (OFDA) from the Variance (OFDA-FLSN) if one knows the Variance for (FLSN).

Table 5: A Comparison of the Derived 95% Confidence Limit and the 95% Confidence Limit calculated from the Model (see equation 2) presented in this report

	OFDA2000	LLSN
95% Confidence Limit MFD (μm) Derived From Independent Data	**± 1.40**	**± 0.88**
95% Confidence Limit MFD (μm) Calculated From the Proposed Model	**± 1.41**	**± 1.09**
95% Confidence Limit CVD (%) Derived From Independent Data	**± 2.3**	**± 2.3**
95% Confidence Limit CVD (%) Calculated From the Proposed Model	**± 2.2**	**± 3.2**

The agreement between the Derived Confidence Limits and the Model Confidence Limits was excellent for the OFDA2000 measurements. The agreement for the LLSN results was not as good but still acceptable enough to suggest that the proposed model gives a good estimate of the precision of the different measurement systems.

Conclusions

The objective of the trial was to determine estimates of the precision of the measurements made by the new technologies OFDA2000 and FLEECESCAN as they are used commercially on-farm or in-store to estimate overall fleece characteristics and to validate the statistical model used. The Confidence Limits relevant to the entire fleece were determined and the model used to calculate the Confidence Limits was validated. The impact of including the variation over the fleece in the Confidence Limit of the test was to increase the Confidence Limit by about 30-50%. As the reported results have been derived from one mob of sheep, it is also strongly recommended that the trial design be repeated on at least three other mobs from different wool producing areas.

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