A NEW PERFORMANCE INDICATOR

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Have you ever wondered how to grade fleeces when they all have the same comfort factor of 100% and the fibre diameters and standard deviations are all over the place? When some have lower fibre diameters but higher standard deviations how do you decide which is the most desirable fleece; assuming of course that all other factors are similar? Will it be the one with the lowest fibre diameter or should the standard deviation also be considered? This article attempts to answer these questions and in the process a new performance indicator has been developed that I have called the Score of Uniform Micron or SUM. Applications for this performance indicator are discussed and its reliability has been verified using statistical analysis of data from a range of herd sizes.

INTRODUCTION

Three commonly used measurements from fleece test results are the average fibre diameter (FD), the standard deviation (SD), and the comfort factor (CF). The FD is measured in microns (µ) and is an indication of the average fineness of the sample. The SD is also measured in µ and indicates the degree of uniformity of the fibre diameters. It is the range of fibre diameters each side of the FD that together includes 68% of the fibres. When the FD is 20µ and the SD is 4µ then 68% of all the fibres in the sample will be between 16 and 24µ. The CF is measured as a percentage and represents the number of fibres in the sample that are less than 30 microns and therefore indirectly measures the percentage of fibres over 30µ. If the CF is 95% then 5% of the fibres will be over 30µ. Fibres start to become medullated or hollow as their diameter approaches 20µ and has been found in fibres as low as 17µ (Watts, 2010). The fibres start to lose their crimp and become straighter and stiffer as their diameter increases. Above about 35µ, fibres increasingly become fully medullated with large hollow centres (Watts, 2010). They become straight and rigid and include the guard hairs of a fleece (Watts, 2010). The degree of medullation over 30µ is considered sufficient to make garments start to feel prickly and when the CF falls below 95% they are considered uncomfortable on soft skin. The CF is therefore an indication of how comfortable garments made from these fibres will be. The aim of any commercial fleece breeding program should therefore be to produce fleece that has a CF of at least 95% and ideally 100%.

The test results usually include a histogram of the fibre diameters (Figures 1 and 2). This is a visual representation of all the fibres in the tested sample. The horizontal axis of the histogram represents the range of fibre diameters and the vertical axis indicates the percentage of fibres of each diameter. The FD determines the position of the histogram along the horizontal axis and the SD determines the shape of the histogram. As the FD increases the histogram moves along the horizontal axis, away from the vertical axis and as the SD increases the shape changes. When the SD is small, the histogram is tall and narrow with only a small coarse fibre tail and as the SD increases the shape flattens and broadens and the tail becomes longer.

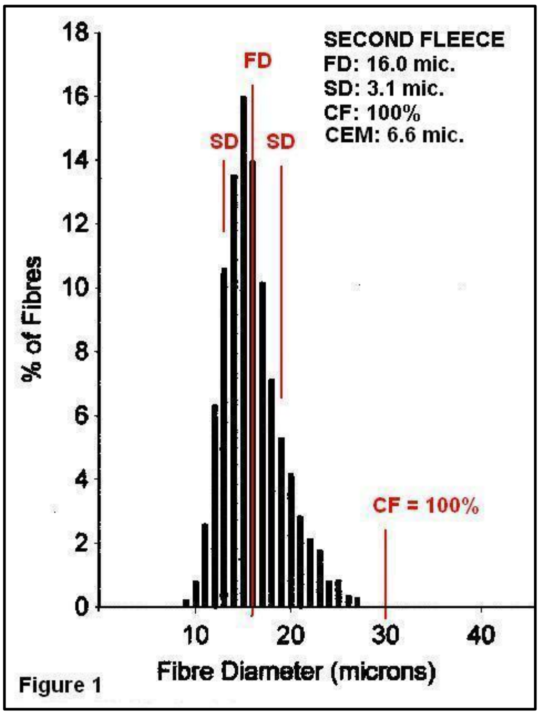

Figure 1

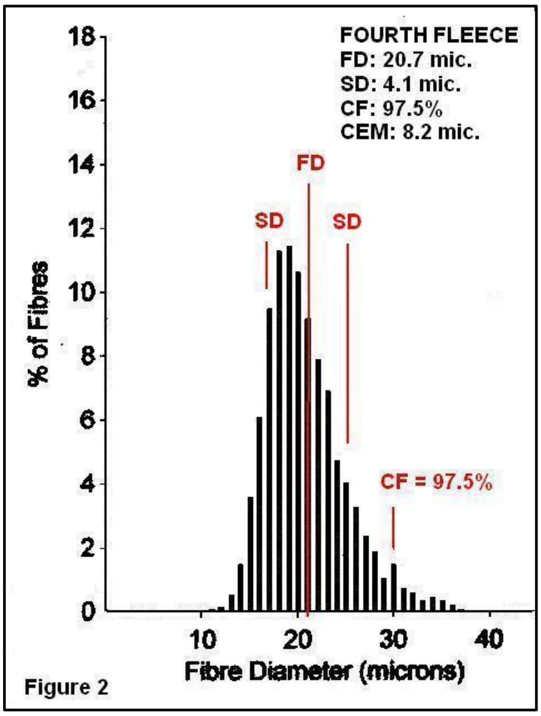

Figure 2

A fourth measurement, the coarse edge micron (CEM) measured in µ, is also available from fleece test results. Although this measurement appears to be rarely used by breeders, it is extremely useful in estimating the extent of coarse fibres and therefore the degree of medullation in a sample. This is because it is a measure of the extent to which the fleece histogram skews towards the coarse micron tail. It is the number of microns separating the FD from the coarsest 5% of fibres. Therefore when the CF is 95%, the CEM will be the number of microns between the FD and 30µ.

A very strong and statistically significant positive correlation ($r(65)=0.96, p<0.01$) has been found between the CEM and the SD where the CEM approximately equals twice the SD (Kingwell, 2010). This correlation demonstrates that the SD is also an indication of the extent of skewness in the fleece histogram. When a histogram is symmetrical about the mean, or in this case the FD, then 2SD each side of the mean together includes 95% of the fibres and then only half of the remaining 5% or 2½% of fibres would be coarser than FD+SD+SD. But a fleece histogram is rarely symmetrical which means that usually the coarsest 5% of fibres, which will also contain most of the medullation in the sample, will be above FD+CEM microns or alternatively above FD+SD+SD microns.

The histograms at Figures 1 and 2 show that as the FD and SD increase, the number of fibres over 30µ also increases. This suggests that there is a correlation between the sum of FD and SD and the CF.

THE SCORE OF UNIFORM MICRON

The graph at Figure 3 is a plot of FD+SD against CF for a herd of 122 alpacas and shows that there is indeed a very strong negative correlation between the two. The FD+SD has been called the Score of Uniform Micron or SUM where SUM=FD+SD. It is evident from the graph that when the SUM is less than or equal to 21 then the CF will usually be 100% and fibres are unlikely to be over 30µ. It is also evident that when the SUM is less than or equal to 26 the CF will usually be at least 95% and no more than 5% of the fibres are likely to be over 30µ.

The line of best fit on the graph indicates that the strength of the correlation between SUM and CF decreases as the SUM exceeds about 26 and the CF falls below 95%. It is therefore not uncommon to find fleece results in which the SUM would be more than 26 when the CF is still at or above 95%. For this reason it is recommended that the SUM only be used when its score is 26 or less.

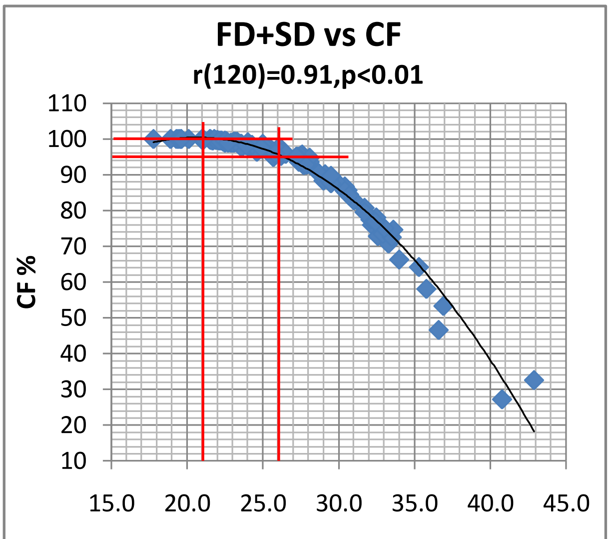

Figure 3

This strong correlation between SUM and CF indicates that the SUM can reliably be used to compare fleeces from alpacas of similar age that have a CF greater than 95% and is particularly relevant when the fleeces being compared all have the same CF of 100%. The SUM takes over when the CF reaches 100%.

THE SCORE OF UNIFORM MICRON AS A PERFORMANCE INDICATOR

It is generally recognised that the first fleece FD and SD for an alpaca are not reliable and that second fleece values are preferred and this also appears to apply to herd averages. When average herd values were calculated for a herd of 52 alpacas that each had a second fleece SUM < 26 it was found that average herd FD between first and second fleece increased by 3.9% and average herd SD decreased by 10.3%. However, when the average herd SUM for first and second fleece was calculated the results were almost the same with an increase of only 0.9%. Table 1 below summarises these results.

Table 1 52 ALPACAS	1st FD	2nd FD	1st SD	2nd SD	1st SUM	2nd SUM
AVERAGE	**18.1**	**18.8**	**3.9**	**3.5**	**22.0**	**22.2**
% DIFFERENCE		**+3.9**		**-10.3**		**+0.9**

This suggests that the average herd SUM would be a reliable means of assessing the progress of a breeding program and that the first fleece average would usually be as reliable as the second fleece average for a herd with individual SUM's equal to or less than 26. This means that breeding results could be assessed using first fleeces rather than having to wait another year until second fleeces become available.

If the intention is to assess whether or not a particular male is passing on the desired results of low FD and SD then this can be determined by calculating the average SUM for all his progeny for either their first or second fleece. The goal should be for this score to be less than 21 since the average herd CF will then usually be 100%. This procedure can also use the average SUM as an effective score for comparing the performance of different males over a particular herd.

Table 2 below is intended as an example and shows the average herd SUM's for progeny by 3 sires. The progeny from sires 1 and 2 in the first pairing are from a breeding herd of 7 females that have produced 9 progeny by each sire. Their low individual scores indicate that they are close to achieving the desired results. The average herd SUM's for each sire are similar and indicate that these two males have produced equally good results. The progeny from sires 2 and 3 in the second pairing are from a different breeding herd of 6 females that have produced 6 progeny by each sire, however some of these breeders have not been producing the desired results in their progeny. This is why the average herd SUM for sire 2 in the second pairing is higher than in the first. The average herd SUM's for this pairing indicate that although sire 3 has himself a very low SUM of 22.7 for his 5th fleece compared to sire 2's score of 29.8, he has not performed as well by passed this lower value on to his progeny. Last year he was mated to a larger number of females that have also produced progeny from sire 2 and therefore this year's progeny will give a better indication of his performance and will determine whether or not he remains in the program.

Table 2 DAM	SIRE 1 PROGENY		SIRE 2 PROGENY			SIRE 2 PROGENY	SIRE 3 PROGENY
	1st SUM	2nd SUM	1st SUM	2nd SUM		1st SUM	1st SUM
Arabella	21.6	22.8	21.8				
Arabella	19.9	19.9	24.2				
Bella						22.8	23.3
Bewitched	22.9	21.1	22.3				
Bluebelle	24.0	23.3	21.4	21.9			
Bluebelle			18.9				
Chumani	20.8	20.6	20.5	22.5		20.5	22.0
Chumani	22.7	21.7					
Fantacy						25.1	23.1
Jezabella	18.7	18.5	20.5	19.4			
Katinka	22.3	21.7	20.0	21.7			
Marzipan						23.1	25.7
Mistica						24.5	24.2
Nova						21.3	24.0
Scilla	19.2	17.5	19.5	21.1			
total	192.1	187.1	189.1	106.6		137.3	142.3
AVERAGE	**21.3**	**20.8**	**21.0**	**21.3**		**22.9**	**23.7**
Difference		-2.3%		+1.4%			

It is worth noting that although sire 1 has a much lower SUM than sire 2 (26.0 for 10th fleece compared to 29.5 for 6th fleece), they have both produced similar results for their progeny. This is consistent with the general belief that a sires genetic background has a strong influence on the quality of his progeny and that this background can sometimes be more important than the sires own traits.

These results indicate that the average herd SUM is a reliable indicator for assessing the performance of individual males and comparing the ability of different males to pass on the two traits of FD and SD to their progeny. Its reliability however will improve as the herd size increases and the numbers of progeny from each female also increase.

LIMITATIONS WITH USING SUM

The graph at Figure 4 is a plot of first fleece SUM's against second fleece SUM's for individuals from the above herd of 52 alpacas and shows that there is a good correlation between the two scores. This is however only a correlation and a first fleece FD + SD does not necessarily equal the second fleece FD + SD. This is evident from the data in Table 2 above which clearly shows that an individual first SUM is rarely the same as the second SUM. It is therefore not recommended that one alpacas first SUM be compared with another's second SUM. If individual SUM's are being compared then it is suggested that these be confined to fleeces from alpacas of similar age. At the herd level however average first SUM's will approximately equal average second SUM's so that either can be reliably used.

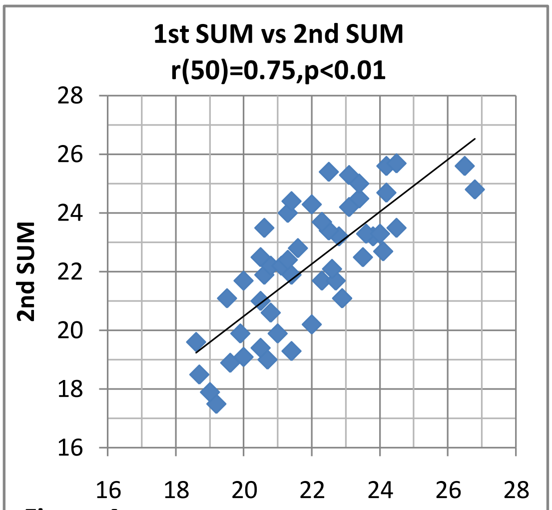

Figure 4

SAMPLING AND MEASUREMENT ERROR

Fleece sampling and testing is not a precise activity and replication rarely produces the same results. This is caused by sampling and measurement error at different stages of the process due to variability. Variability exists within a fleece and within a sample and when the initial sample is sub-sampled then additional variability occurs. Variability also occurs between tests during sample preparation and testing procedures.

The Victorian Department of Primary Industries (2007) has estimated that the 95% confidence limits for FD are ±1.6µ. This means that if a sample has an FD of 20µ and its accuracy is ±1.6µ then there is a 95% chance that it has the same value as other samples with FD's between 18.4 and 21.6µ. This represents an error of ±8% for an FD of 20µ.

If the accuracy of SD's is also about 8% then an SD of 4.0µ will have an accuracy of ±0.3µ and when an individual SUM is calculated, the error increases to ±1.9µ but remains at 8%. However when average herd SUM's are calculated the error is reduced and is dependent on the size of the herd. The larger the herd the smaller will be the error since there is greater opportunity for the positive errors to cancel out the negatives.

The Victorian DPI Note concluded that "Alpaca breeders need to exercise caution when interpreting absolute fibre test results" and that "Evaluation of fibre attributes among alpacas should take into account the 95% confidence limits of the sampling procedure".

If care is taken when removing fleece samples and this is performed by the same person and testing is carried out as a single batch by the same operator then the variations mentioned above will be kept to a minimum. It is therefore suggested that breeders consider this when comparing SUM's between different herds, different years and different properties.

RESULTS AND CONCLUSIONS

A strong negative correlation was found between FD+SD and CF for a herd of 122 alpacas (r^2=0.83). This correlation was also found to be statistically significant with only a 1% chance that a correlation does not exist ($r(120)=0.91, p<0.01$). When the SUM was 21 or less, the CF was generally found to be

100% and when the score was 26 or less, the CF was usually at least 95%. This indicates that when a number of alpacas have a CF of 100%, they can still be compared by using the SUM. It also indicates that when alpacas have an FD+SD score between 21 and 26 then their FD and SD can also be compared by using their SUM however in this case the CF could equally be used. An advantage of using the SUM is that, although it is referred to as a score, its unit is microns. This gives it mathematical advantages when estimating the extent of coarse fibres and therefore the degree medullation in a sample since the coarsest 5% of fibres will generally be above the micron obtained from the formula SUM+SD. This is because FD+CEM is approximately equal to FD+SD+SD which in turn approximately equals SUM+SD. Maybe the SUM+SD should be called the SUUM. This SUUM would then be a reasonable measure of the extent of medullation since it would be the micron above which the coarsest 5% of fibres occurred.

These findings demonstrate that the comfort factor is largely determined by the sum of the average fibre diameter and the standard deviation of the fibre diameters and gives the CF a far greater depth of meaning than simply being a comfort measurement. It is also an indication of both the fineness and uniformity of a sample.

The average herd first fleece SUM for a herd of 52 alpacas that each had a SUM less than 26 was found to be almost the same as their average herd second fleece SUM. The difference was 0.9%. This indicates that, rather than waiting for second fleece results, first fleece herd averages can be reliably used to assess and compare the performance of stud males over a particular herd.

In the example at Table 2 the differences of -2.3% and +1.4% between the first and second average herd SUM's for the small herd of 7 alpacas does not compare with the low value of -0.9% obtained for the much larger herd of 52 alpacas. However these differences are well within the limits of sampling and testing error for individuals estimated by the Victorian DPI. The results show that the larger the herd the smaller will be the error and the more reliable will be the results. This is why sire 3 will not be rejected until his performance can be evaluated from a larger herd that has also been mated to sire 2.

The assessment of a sire's performance will also be improved as more progeny from each female become available. This has been clearly demonstrated in embryo transfer programs where a number of fertilized eggs from a mating will usually only produce one good cria, or two if you're lucky.

A number of conclusions can be drawn from the findings and results:

1. The size of the standard deviation of fibre diameters indicates the extent of skewness of the fleece histogram towards the coarse micron tail.
2. The Score of Uniform Micron and therefore the Comfort Factor is a measure of the size of both the average fibre diameter and the standard deviation of the fibre diameters in a sample.
3. The Score of Uniform Micron is a means of expressing the comfort factor in terms of microns.
4. The Comfort Factor and therefore the Score of Uniform Micron is an indication of the extent of coarse fibres and therefore the degree of medullation in a sample.
5. The coarsest 5% of fibres in a sample will generally be above SUM+SD microns.
6. Regardless of the inherent errors in the determination of FD and SD, the Score of Uniform Micron is an effective means of comparing fleeces from alpacas of similar ages that all have a CF of 100% and as an average herd score for assessing and comparing the performance of different males over a particular herd.

DISCUSSION

Most alpaca fleeces are currently graded into bales based on their FD with little or no consideration given to their SD. However it has been shown that both FD and SD together determine the extent of coarse fibres and therefore the degree of medullation. If two fleeces each have an FD of 20µ and one has an SD of 3µ and the other an SD of 5µ then the first fleece with a SUM of 23 will contain less medullation than the second fleece with a SUM of 25. For the first fleece, the coarsest 5% of fibres will generally be above 23+3=26µ and for the second, above 25+5=30µ. Therefore if the degree of medullation as determined by the extent of coarse fibres is an important consideration in determining demand then a bale will contain less coarse fibres and less medullation if it is made up of fleeces selected for their SUM rather than their FD.

As an example, if a bale has a SUM of 26, its CF will be about 95% and the extent of medullation will be acceptable for most applications since no more than 5% of fibres will be over 30µ even though a few of these may be fully medullated. The FD will probably be between 21 and 23µ and the SD between 3.5 and 4.5µ. If the bale FD is 22µ, the CEM will be 30-22=8µ and the SD will be 8/2= 4µ. Alternatively the SD will be 26-22=4µ.

On the other hand, if the bale has a SUM of 21, the CF will generally be 100% and few if any fibres will be over 30µ and none will be fully medullated. The FD will probably be less than 18µ and the SD between 3 and 4µ. If the bale FD is 17.5µ, the SD will be 21-17.5=3.5µ and there will still be 5% of the coarsest fibres above 21+3.5=24.5µ and these fibres will have some degree of medullation.

For a bale to have no medullation, all the fibres would have to be less than about 20µ, which is probably not achievable. Even if the FD was 14µ, and the SD was 2.5µ, giving a SUM of 16.5, the coarsest 5% of fibres would still be above 16.5+2.5=19µ and a large proportion of these fibres would be over the 20µ limit for negligible medullation.

These are impressive requirements for FD and SD and there would not be too many breeders producing fleece of this quality and none producing any quantity. It does however indicate just how far the industry would have to go if it was to eliminate medullation from alpaca fibre.

It is suggested that a more realistic target might be the commercial production of fleece with a SUM of about 19. The bale FD would probably be between 15.5 and 16.5µ with an SD between 2.5 and 3.5µ. In this case, if the bale FD was 16µ, the SD would be 3µ and 5% of the coarsest fibres would be above 19+3=22µ. Small quantities of this quality are currently being produced which suggests that this would be a commercially achievable goal.

If reducing the extent of coarse fibres and therefore the degree of medullation is an industry priority then it is suggested that greater attention be given to the comfort factor and the coarse edge micron in breeding programs and that when the CF is greater than 95%, consideration be given to replacing it with the Score of Uniform Micron and using SUM+SD to estimate the extent of coarse fibres and the degree of medullation.

REFERENCES

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