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# Quantitative Genetic Analysis of Micron Blowout in Alpacas



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# **Quantitative Genetic Analysis of Micron Blowout in Alpacas**

by Kylie Munyard and Johan Greeff

June 2013

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# Foreword

This report describes the research conducted for the alpaca genetics project entitled “Quantitative genetic analysis of micron blowout in alpacas”. Some alpacas maintain fine fibre throughout life, while others suffer from significant coarsening of fibre as they age, a trait known as micron blowout. Micron blowout results in reduced productivity, through reduced yield of high quality fibre over the life of an animal.

Data from a well-established alpaca herd in Peru was used in a complex quantitative genetics analysis to determine if genetics plus environment, or environment alone was responsible for micron blowout in alpacas. This project has shown that micron blowout has a moderate heritability in alpacas, and that selection against micron blowout would be successful in reducing the extent of the problem.

This project was funded by RIRDC core funds. Pacamarca S.A. (Grupo Inca, Peru) also provided extensive in-kind contributions through their generous provision of over 10 years of herd phenotype data. The salary of the principal investigator, in-kind assistance and facilities were provided by Curtin University.

This report is an addition to RIRDC’s diverse range of over 2000 research publications, and it forms part of our Rare & Natural Animal Fibres R&D program. This program aims to foster the development of rare fibre industries.

Most of RIRDC’s publications are available for viewing, free downloading or purchasing online at [www.rirdc.gov.au](http://www.rirdc.gov.au). Purchases can also be made by phoning 1300 634 313.

**Craig Burns**  
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# About the Author

Dr Kylie Munyard obtained her undergraduate degree in Biology, with Honours in Veterinary Biology, from Murdoch University in 1990. After working as a Clinical Cytogeneticist, she went on to complete a PhD (“The Ecology of Methanogens in the Rumen”) at UWA/CSIRO in 2000.

Between 2002 and 2005 Dr Munyard was a Postdoctoral Researcher at the Centre for High-throughput Agricultural Genetic Analysis (CHAGA), specialising in animal and instrumentation projects. Her projects within CHAGA included the invention of a (now commercially available) DNA extraction method, as well as provision of parentage assessments for cattle breeding experiments, and the development of an online database that allows fast and easy assignment of parentage to individuals. Two provisional patents and one full patent have arisen from that work.

Dr Munyard is currently a Senior Lecturer/Researcher in Molecular Biology at the School of Biomedical Sciences & Curtin Health Innovation Research Institute, in the Faculty of Health Sciences at Curtin University. Her areas of research interest are alpaca genetics, conservation genetics of Australian quail, genetic markers of pain in humans, and Diabetes. In 2006, with funding from the AAA, she worked with alpaca breeders to perform a survey of the incidence of staggers in Australian alpacas. A two-year project investigating microsatellite markers in alpacas (funded by the Morris Animal Foundation) has also been completed. The results from both projects have been published in peer-reviewed scientific journals. In 2008 she was an invited speaker at two seminal events, the Inaugural World Alpaca Conference (Sydney) and the 1<sup>st</sup> International Workshop on Camelid Genetics. In 2011, the results of a RIRDC funded project aimed at identifying genes involved in alpaca fibre colour were completed. Four peer-reviewed publications and a RIRDC report have already been published describing that work, with data and papers continuing to be generated from this project.

# Acknowledgments

This project and report would not have been possible without the generous assistance of Pacomarca S.A. (Peru) in providing access to their extensive herd data.

# Abbreviations

FD: fibre diameter

CVFD: coefficient of variation of fibre diameter

SDFD: standard deviation of the fibre diameter

CF: comfort factor

$h^2$ : heritability

SE: standard error

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# Executive Summary

## What the report is about

Successful animal breeding is supported and assisted by fundamental knowledge about the interaction of genetics and environment. This project has generated essential information about the role of genetics in micron blowout: the coarsening of alpaca fibre over time. Maintenance of low fibre diameter is one aspect of fibre biology that is of importance for the alpaca industry to assist in increasing yield and productivity.

## Who is the report targeted at?

This report is targeted at Australian alpaca breeders. Whilst the data has been collected from a Peruvian alpaca herd, the results described herein are applicable to alpacas all over the world, both Huacaya and Suri, and of all colours.

## Background

It has been well established in many fibre-producing species that fibre diameter increases with increasing animal age; a phenomenon known as micron blowout. For alpacas, as is the case with many fibre-producing species, the finest fibre is of the greatest value. Micron blowout is particularly problematic for alpacas, because alpacas are kept as fibre producers for longer than sheep. Micron blowout is a significant cost to fibre producers. McGregor and Butler (2004) calculated that the average micron blowout for alpacas over seven years is 7.5 $\mu$ m. This variation can lower the value of the fibre from \$2.70/ kg (Extra Fine) to \$0.93/Kg (Medium) or even \$0.30/Kg (Adult) based on 2011 Australian Alpaca Fleece Limited (AAFL) prices. And, because alpacas are retained as breeding and production animals for much longer than seven years, this can mean that the majority of the animals' productive life is of the lesser economic value.

The Australian Alpaca Association (AAA), commercial breeders in Peru, and many scientists have recognised the potential benefit to the alpaca industry of identifying animals that have minimal micron blowout. It would be advantageous for breeders to know whether or not a young animal will be pre-disposed to excessive micron blowout. However, because many factors can affect fibre diameter, identifying such animals isn't as easy as simply looking at fibre diameter measurements over time. Poor nutrition can decrease fibre diameter, making a genetically blowout animal appear fine, and vice versa. The age of the dam at parturition can also affect fibre diameter. Therefore, to accurately identify animals from each group, longitudinal data on a group of animals kept under the same conditions, with accompanying extensive phenotype and pedigree records, must be used so that the underlying genetic potential of the animals can be revealed.

The principal investigator has developed a collaborative relationship with Grupo Inca (Peru), who own and manage a large (over 2500) alpaca herd at Pacamarca S.A. Pacamarca has kept extensive phenotype records on their animals, and has developed and successfully implemented in house selection measures to generate estimated breeding values on their animals. Grupo Inca and Pacamarca have been exceptionally generous in providing access to that data. Without access to this dataset, the current project would not be possible.

## **Aims/objectives**

Objective 1: To use mixed model analysis (i.e. quantitative genetics) to determine the underlying genetic contribution to lifelong fibre quality traits.

Objective 2: To identify a group of alpacas that is genetically pre-disposed to retain fibre fineness throughout life (i.e. has low micron blowout).

Objective 3: To identify a group of alpacas that is genetically pre-disposed to increased fibre diameter throughout life (i.e. has high micron blowout).

## **Methods used**

The fibre diameter data collected at different ages was standardised to the same variation before fibre diameter blowout was estimated, as the increase in the fibre diameter from one age to the next. Pacamarca S.A. supplied their dataset of phenotype records in excel format. The data was cleaned for any extreme values lying four or more standard deviations from the mean value for each trait. The standardised micron blowout data was analysed with mixed model methodology using ASREML, a statistical mixed model methodology package widely used in quantitative genetic analysis. As full pedigrees are available, an animal model was fitted to the standardised data while fitting the fixed factors such as sex of the animal, birth status, age of the dam, year and season of birth and time of shearing. A repeatability model was fitted as multiple measurements exist on each animal. The animal solutions were used to identify high and low micron blowout animals.

## **Results/key findings**

Age, sex, colour, birth year, measurement year and measurement month affected micron blowout significantly ( $P < 0.01$ ). White and fawn animals were less prone to micron blowout than coloured animals (1.9 micron versus 1.9 micron versus 2.5 micron respectively), while males showed a higher blowout than females. This may not have been due to the effect of sex but rather, different management groups, because males and females were managed separately. There is some additive genetic variation for micron blowout in alpacas. The heritability of micron blowout from year one to year two is the highest, but very low in the subsequent age categories.

## **Implications for relevant stakeholders**

These results confirm that micron blowout has a genetic component in alpacas. Therefore, it is possible for breeders to select animals that do not exhibit the trait (or not as strongly) and thereby improve the yield of high quality fibre from the national herd.

## **Recommendations**

The recommendation arising from this research is that breeders should include change in year one to year two fibre diameter as a component in their selection process, to take into account predisposition for micron blowout. However, some analyses within this project contained anomalous elements, and it is probable that these are due to insufficient time-span in the available data. The data analysis should therefore be repeated on the same herd in two to three years' time to confirm the findings.

# Introduction

Fibre diameter is one of the most important fibre quality traits in apparel textiles, because it is strongly related to softness and comfort of the garment. Fibre diameter generally increases as an animal ages (Atkins 1990; Hickson *et al.* 1995; Turner and Young 1969). This phenomenon is called micron blowout, and is generally well known in the Merino industry. Previous research has shown that it is a heritable trait (Hickson *et al.* 1995; Cottle *et al.* 1995; Greeff, 2001). Therefore, it should be possible to select against micron blowout. However, it is unknown whether the same phenomenon is also found in alpacas, and whether it is heritable.

Micron blowout is normally measured as the difference between fibre diameter measured at consecutive ages. James (1998) showed that a non-zero heritability could arise simply due to a difference between the genetic variances of fibre diameter recorded at different ages. This implies that a non-zero heritability could be estimated which is due to a scale effect, and not due to differences in genes affecting fibre diameter at different ages. Hill *et al.* (1999) compared the effect of standardising the genetic variances of different ages, and showed that biased results could be obtained if no standardisation was carried out. The study described herein was carried out to estimate the heritability of fibre diameter, standard deviation of fibre diameter, coefficient of variation of fibre diameter, comfort factor, and whether micron blowout is heritable and important in alpacas, by standardising and not standardising the genetic variation of fibre diameter measured at different ages.

# Objectives

Objective 1: To use mixed model analysis (i.e. quantitative genetics) to determine the underlying genetic contribution to lifelong fibre quality traits

Objective 2: To identify a group of alpacas that is genetically pre-disposed to retain fibre fineness throughout life (i.e. has low micron blowout)

Objective 3: To identify a group of alpacas that is genetically pre-disposed to increase fibre diameter throughout life (i.e. has high micron blowout)

# Methodology

## Data

A dataset consisting of the fibre diameter (FD), standard deviation of fibre diameter (SDFD), coefficient of variation of fibre diameter ( $CVFD = SDFD / \text{Mean FD} * 100$ ) and comfort factor (Comfort = % fibres > 30 micron) was received from Pacamarca S.A., Peru to investigate the phenomenon of micron blowout in alpacas. The fibre traits were measured on an Optical Fibre Diameter Analyzer (OFDA). The data were collected from 2001 to 2010.

The total database consisted of 9252 repeated measurements on 4104 animals born from 1992 to 2010. Contemporary groups with small numbers per group measured in different months were pooled with larger groups. This differed from year to year depending on the number of samples per month. Age of the dam was reduced to 15 groups by pooling two year old dams with three year old dams, and also pooling 17 year old dams with the 16 year old group. A number of animals were recorded up to three times per year.

The final dataset consisted of 8335 records, of which 6068 records were from females and 2267 records from males. Full sire pedigrees were available on all the 4104 progeny. Ninety-two sires were used in this trial and 887 dams were known. This dataset was used to estimate fixed environmental factors.

For the genetic analysis, further pooling was carried out in that animals that were older than 10 years of age were pooled in the 10 year age group category, because very few males were available after 10 years of age. A number of records were deleted to ensure that each animal had only one record per year, which was necessary for the standardisation process. This dataset was used to estimate the heritability of FD, SDFD, CVFD and comfort factor across the total dataset, and also for each age group separately, in order to obtain the genetic standard deviation to adjust the records as explained under statistical analysis. This dataset consisted of 8039 records.

Micron blowout was calculated in two ways. First, as the difference between the current year's fibre diameter and the previous year's fibre diameter, and secondly, as the difference between the standardised fibre diameter at two consecutive ages using the method described by Hill *et al* (1999). Micron blowout was thus simply the difference between a (standardised) fibre diameter measured at two, three or four years of age, and the (standardised) fibre diameter recorded in the previous age group for a specific individual. Standardisation was carried out by subtracting the mean fibre diameter of the age group from the fibre diameter of each individual in that age group, and dividing the difference by the genetic standard deviation of that age group. According to James (1998), this should result in a uniform genetic variance for fibre diameter at different ages.

Calculating micron blowout resulted in a considerable number of records being lost because of the incompleteness of the dataset across all ages. Only the first four age groups were considered further, because this is where fibre diameter increased most, which resulted in 4620 records available for this analysis. The micron blowout dataset consisted of 734 micron blowout records from age group one to age group two, 641 records from age group two to age group three, and 379 records from age group three to age group four.

# Results & Discussion

## Statistical analysis

A multiple linear regression model was fitted to the Fibre diameter (FD), standard deviation of fibre diameter (SDFD), coefficient of variation of fibre diameter (CVFD), and comfort factor. Comfort factor was analysed as a normally distributed trait and also as a log transformed trait because it was not normally distributed. The dataset consisting of 8335 records was first analysed with Genstat, and the following fixed effect model was fitted;

$$Y_{ijklmn} = \mu + a_i + b_j + c_k + d_l + f_m + k_n + l_p + m_o + 2 \text{ trait interactions} + e_{ijklmn}$$

Where:

$a_i$  = year of birth (i=18 levels from 1992 to 2010)

$b_j$  = age of the dam (j=16 levels from 2 to 17 years)

$c_k$  = age of animal (k=13 levels from 1 to 13 years)

$d_l$  = month of birth (l=12 levels from January to December)

$f_m$  = year of measurement (m = 10 years)

$k_n$  = colour of animal (n=3 levels, white, fawn and coloured)

$l_p$  = sex of the animal (p=2 levels, male and female)

$m_o$  = birthing/calving/lambing (o=2 levels, birth and no birth)

$e_{ijklmn}$  = residual error

Year of birth, age of the dam, age of the animal, month of birth, year of measurement, colour of animal, sex, and birthing were fitted as fixed factors, while animal and the repeated measurement on each animal were fitted as random factors. The birthing effect included pregnancy and lactation. The above model was first run using only the females' data. Birthing had a significant ( $P < 0.001$ ) effect on fibre diameter and comfort factor. The effect was relatively small – females that gave birth were only 0.4 micron (23.0 versus 22.6 micron) finer and had a 2% higher comfort factor than females that were not pregnant). As such, these females' fibre diameter and comfort data were adjusted, and the above model re-run without the birth effect on the combined dataset which included both males and females. All interactions were initially fitted, and birth month x birth year and age x sex interactions were statistically significant ( $P < 0.01$ ).

For the overall genetic analysis, a repeatability animal model was initially fitted using ASREML (Gilmour *et al* 2006) on the dataset with 8039 records. The above mentioned fixed factors that were significant were also fitted to the model, to estimate the genetic variances for all the fibre diameter traits. The initial analysis was a combined analysis over all ages, which was followed by a separate analysis for each age group in order to obtain the genetic variances needed to adjust the data as described above. In these models, age of the animal was not fitted.

Standardising the fibre diameter data to calculate a standardised micron blowout for each age group, and fitting an animal model to micron blowout, did not result in a uniform genetic variation across ages when all the relevant fixed factors were fitted in the model. This indicates that age was confounded with other factors in the model used to analyse this dataset. The standardisation approach was therefore abandoned.

Only the first four age groups were included in the genetic analysis of micron blowout because fibre diameter increased only up to year three for females (see Figure 2b). Males continued to increase but because of the small number of males in the older age groups, it was decided to use only the data up to year four. This resulted in three micron blowout age groups, i.e. from year one to two, two to three and from three to four year old animals. A repeatability animal model was fitted to micron blowout, and the same fixed environmental factors mentioned above were included in the model.

This was followed by a separate genetic analysis on each age category from one to two years of age, two to three years of age and from three to four years of age. The heritability and repeatability of all the traits, standardised FD, FD, SDFD, CVFD, comfort factor and micron blowout were estimated as described by Falconer and Mackay (1996).

## Fixed effects

Year of birth, age of the animal, month of measurement, sex of the animal and colour all had a highly significant ( $P < 0.001$ ) effect on the different traits. Year of birth, year of measurement and month of measurement and their interaction (measurement year x measurement month) were significant ( $P < 0.001$ ), but as these factors are normal environmental factors, they will not be discussed further. The age x sex interaction was also statistically significant ( $P < 0.01$ ), which could have resulted from management factors because males and females were managed in separate management groups.

The average fibre diameter for males and females measured from 2001 to 2010 is shown in Figure 1. It is clear that the average fibre diameter increased from 2001 up to 2007, after which it stayed relatively stable. This may indicate that feeding and/or management factors could have improved during the last 10 years, which would have resulted in an increase in fibre diameter.

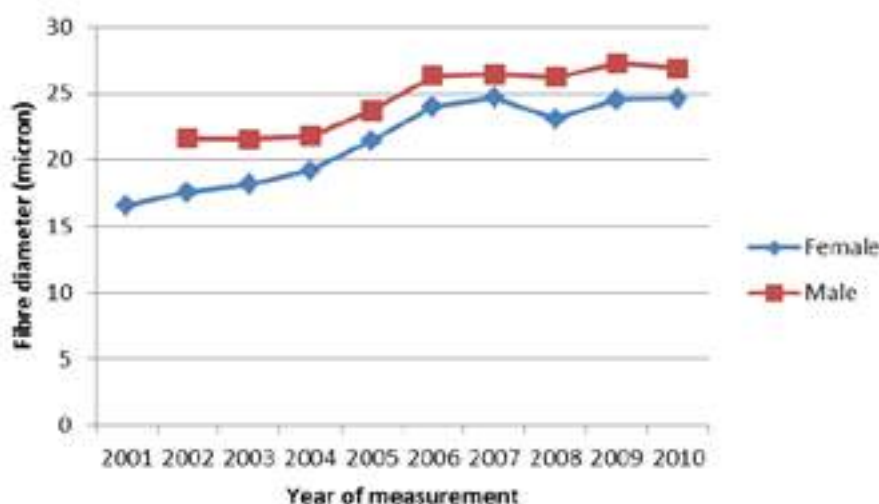


Figure 1. Average fibre diameter of males and females from 2001 to 2010

The unadjusted average, SD, minimum, maximum and number of animals for fibre diameter, SDFD, CVFD, and comfort are shown in Table 1. The results are also shown graphically in Figures 2a, 3a, 4a and 5a for males and females up to 13 years of age. Figures 2b, 3b, 4b and 5b show the adjusted predicted means from the model for the same traits. There are differences in trends between the predicted and raw averages because of the effects shown in Figure 1. Therefore, the predicted values should be used for interpretation purposes, as they give a more accurate indication of the true effect of age and sex on the fibre traits.

The unadjusted mean fibre diameter showed that as the animal aged, fibre diameter also increased, with a stronger increase in males. The predicted FD also increased as the animal got older; from about 20 micron at one year of age, up to 22.5 micron for females at four years of age. It stayed constant up to about 10 years of age and then declined slightly. Males showed a stronger increase from about 19 micron to 26.7 micron at 12 years of age. A slight decline occurred at year 13, but this is probably due to the small number of animals in this age group.

Figure 3b shows that the predicted SDFD of females declined with age, while that of males stayed relatively stable, except for a strong increase in years 11 and 12, after which it declined. This is probably an environmental effect and likely stems from the small number of males in these two categories.

The predicted CVFDs declined for females up to 13 years of age. Males also showed a decline, but increased at 11 and 12 years of age due to the increase in SDFD (Figure 4b).

Comfort factor (Figure 5b) decreased quite strongly in males up to 12 years of age, while that of females initially showed a slight decrease up to three years of age, after which it consistently increased up to age 13. This trend is mostly due to the increase in fibre diameter, which also increased SDFD.

Figures 6 to 9 show the effect of colour on the fibre traits. White animals were generally finer and had lower SDFD than the fawn or the coloured animals. This resulted in a lower CVFD and a higher comfort factor for white animals, with the fawn animals lying between white and coloured for these traits. This may be a true effect; however, this could also have been due to a selection response, in that selected white sires could have been genetically finer than fawn and coloured selected sires. As fibre diameter is a highly heritable trait, such white males would have produced progeny that have genetically finer fibres than progeny from fawn and coloured sires.

## **Genetic parameters**

The additive, permanent environmental and phenotypic variation is shown in Table 2 with the heritability and permanent environmental correlation.

Log likelihood ratio tests were carried out to determine whether the permanent environmental effect were significant for the fibre traits. The model that fitted the data best included both the additive and permanent environmental effects, and is shown in Table 2. Permanent environmental factors were only significant for CVFD.

All traits were heritable with SD and CVFD having the highest heritability, followed by fibre diameter. Comfort factor had a skewed distribution, and a log transformation was carried out in an attempt to normalise the data. However, the heritability on the normal scale was only slightly higher than that on the log transformed scale. All the traits were moderately heritable, which indicates that selection for fibre diameter should be effective.



**Table 1. Average FD, SDFD, CVFD and Comfort factor of males and females at different ages**

Age	Sex	n	Fibre diameter (micron)				SDFD				CVFD				Comfort factor			
			Mean	Min	Max	SD	Mean	Min	Max	SD	Mean	Min	Max	SD	Mean	Min	Max	SD
1	F	879	19.9	14.6	30.1	2.1	5.1	2.9	11.8	0.9	26.1	17.5	39.6	3.1	98.1	65.0	101.8	3.9
1	M	950	19.6	14.6	35.3	2.2	5.1	3.3	13.3	0.9	25.9	17.1	39.4	3.0	96.0	44.8	99.8	4.4
2	F	720	21.2	14.4	39.6	2.9	5.1	3.0	12.3	1.1	24.2	13.8	37.9	3.7	93.9	23.6	99.6	7.5
2	M	721	21.4	15.0	39.3	3.1	5.2	3.3	11.7	1.1	24.3	15.9	39.3	3.6	93.1	20.5	99.9	9.2
3	F	524	23.4	14.6	35.4	3.6	5.3	2.9	10.7	1.2	22.7	14.0	36.2	3.6	89.0	2.9	101.6	12.7
3	M	311	23.8	16.5	38.6	3.5	5.6	3.2	11.8	1.2	23.4	15.1	35.1	3.5	87.0	17.8	99.5	12.8
4	F	487	23.9	15.7	41.6	3.9	5.3	2.3	12.4	1.2	22.3	13.8	34.4	3.4	88.4	8.1	101.7	14.2
4	M	114	25.9	17.7	36.0	4.1	5.8	3.2	10.6	1.2	22.6	16.4	35.9	3.5	77.9	27.9	99.3	19.1
5	F	577	23.6	15.8	44.0	3.8	5.3	3.0	12.4	1.2	22.7	6.7	37.6	3.3	88.6	9.3	101.6	14.0
5	M	53	25.9	19.0	33.9	4.0	5.7	3.9	8.5	0.9	22.4	16.3	30.1	3.5	77.9	26.1	98.2	18.0
6	F	427	24.3	16.1	41.1	3.8	5.4	2.1	13.1	1.2	22.4	4.8	36.2	3.3	87.0	15.3	101.4	15.1
6	M	30	28.3	20.4	36.5	3.7	6.3	4.3	8.6	1.1	22.3	15.6	30.0	3.5	67.4	11.3	97.8	20.8
7	F	461	24.8	15.0	41.1	4.0	5.4	3.4	11.5	1.2	22.2	14.2	33.7	3.1	85.5	9.2	101.7	17.6
7	M	28	29.1	22.3	39.3	4.3	6.7	4.7	9.1	1.1	23.1	16.9	31.9	3.6	64.5	9.7	95.9	24.8
8	F	508	25.7	16.9	43.8	3.9	5.6	3.0	12.7	1.2	21.9	15.3	32.2	3.1	83.3	11.8	101.7	16.9
8	M	18	29.6	23.0	36.1	3.1	7.0	4.8	9.2	1.2	23.9	16.7	30.3	4.2	61.8	19.7	92.6	17.8
9	F	444	26.7	17.3	43.1	4.3	5.8	3.1	12.5	1.4	22.0	13.5	39.2	3.3	78.4	11.5	101.2	20.7
9	M	17	29.7	20.3	35.5	4.9	7.1	4.7	10.0	1.7	23.8	18.8	31.4	3.9	58.9	22.3	95.8	24.1
10	F	388	26.3	17.8	41.7	4.1	5.8	3.1	11.4	1.3	22.2	15.0	31.8	3.2	80.5	6.3	101.6	19.1
10	M	8	31.3	27.8	39.0	3.6	7.3	5.9	9.9	1.2	23.4	18.3	30.6	3.8	52.3	9.2	72.0	21.2
11	F	316	26.1	17.5	39.7	3.9	5.7	3.6	10.9	1.2	22.1	14.7	36.3	3.1	81.5	18.5	101.3	18.0
11	M	5	32.0	28.8	33.9	2.0	8.0	7.1	9.8	1.1	25.1	21.3	30.5	3.6	48.7	34.9	65.5	12.7
12	F	185	26.2	17.4	40.4	4.0	5.8	3.4	12.2	1.2	22.4	15.8	32.1	3.2	79.9	13.0	100.5	19.2
12	M	5	32.8	30.1	35.3	2.3	8.8	7.0	10.6	1.6	26.9	22.1	30.9	4.1	45.1	31.3	60.6	12.9
13	F	152	26.1	16.8	34.1	3.6	5.7	3.8	9.1	1.1	22.3	15.5	34.7	3.4	81.7	30.3	101.0	16.2
13	M	7	28.0	24.3	32.4	3.2	6.6	5.4	9.7	1.7	23.4	17.5	29.9	4.0	70.6	50.8	88.5	15.8

**Table 2: Variance components and genetic parameters of the fibre traits in Alpacas**

<b>Trait</b>	<b>Additive variation</b>	<b>Permanent environmental variation</b>	<b>Error variation</b>	<b>Phenotypic variation</b>	<b>h<sup>2</sup></b>	<b>SE</b>	<b>Permanent environmental component</b>	<b>SE</b>	<b>Log likelihood</b>
FD	3.98	0.00	4.16	8.15	0.49	0.012	0.00	0.000	-1755.3
SD	0.53	0.02	0.47	1.02	0.52	0.045	0.02	0.041	-3089.4
CVFD	4.71	1.14	4.21	10.07	0.46	0.046	0.11	0.042	-2210.1
Comfort	50.14	0.00	84.46	135.05	0.37	0.012	0.00	0.000	-3613.6
Log(comfort)	0.015	0.000	0.030	0.044	0.33	0.012	0.00	0.000	8842.2

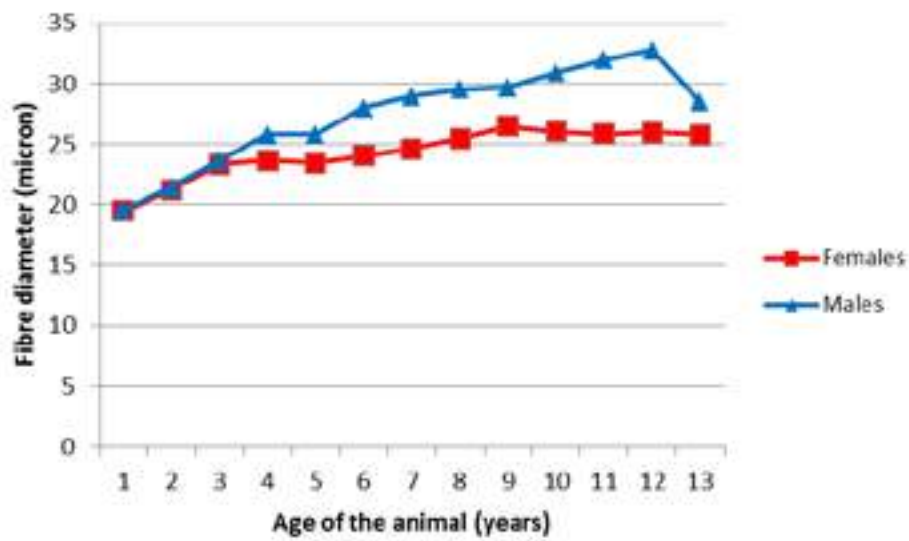


Figure 2a. Effect of age and sex on fibre diameter (unadjusted raw means)

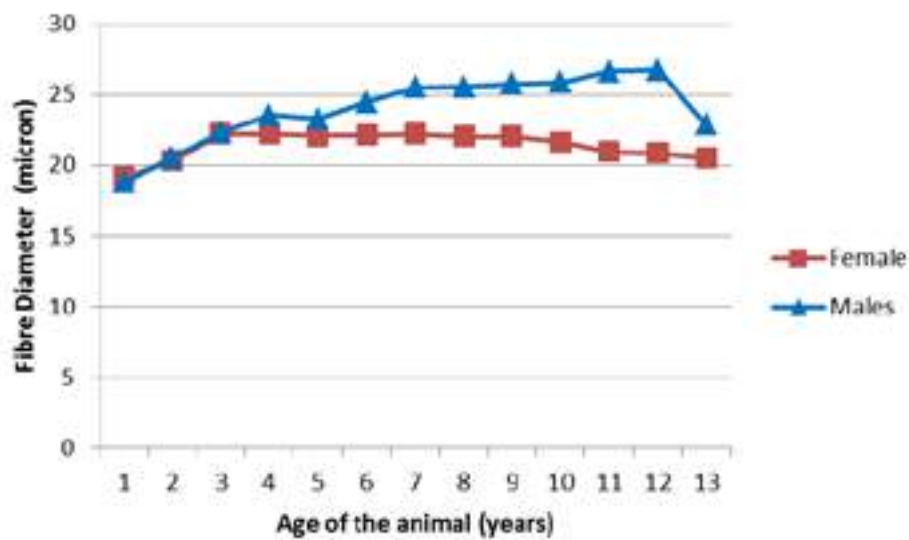


Figure 2b. Effect of age and sex on fibre diameter (predicted means from model)

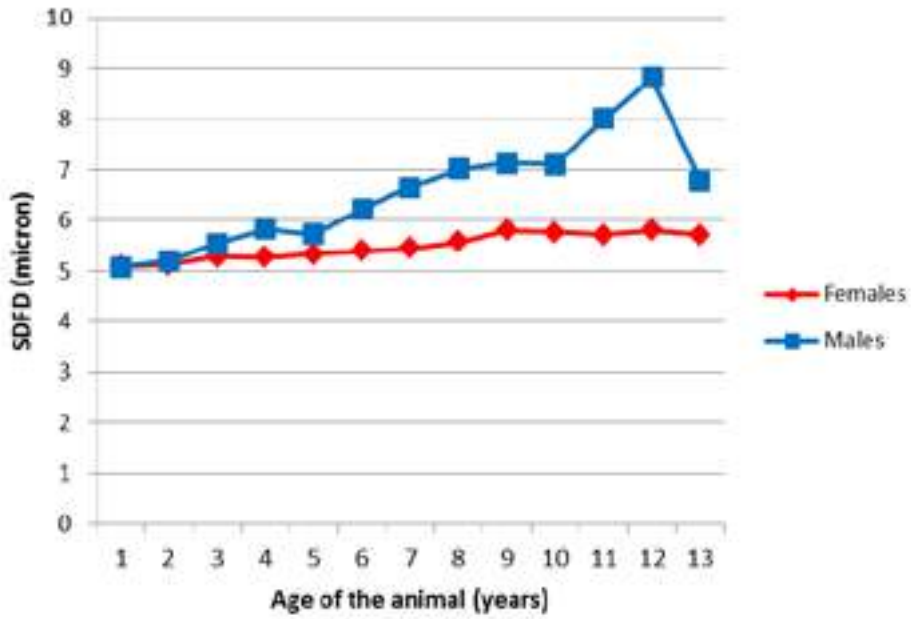


Figure 3a. Effect of age and sex on standard deviation of fibre diameter (unadjusted raw means)

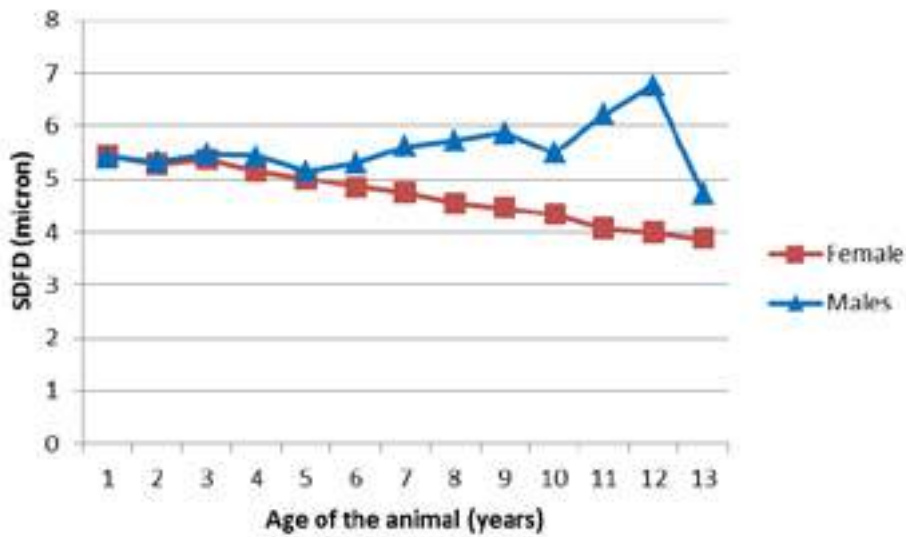


Figure 3b. Effect of age and sex on standard deviation of fibre diameter (predicted means from the model)

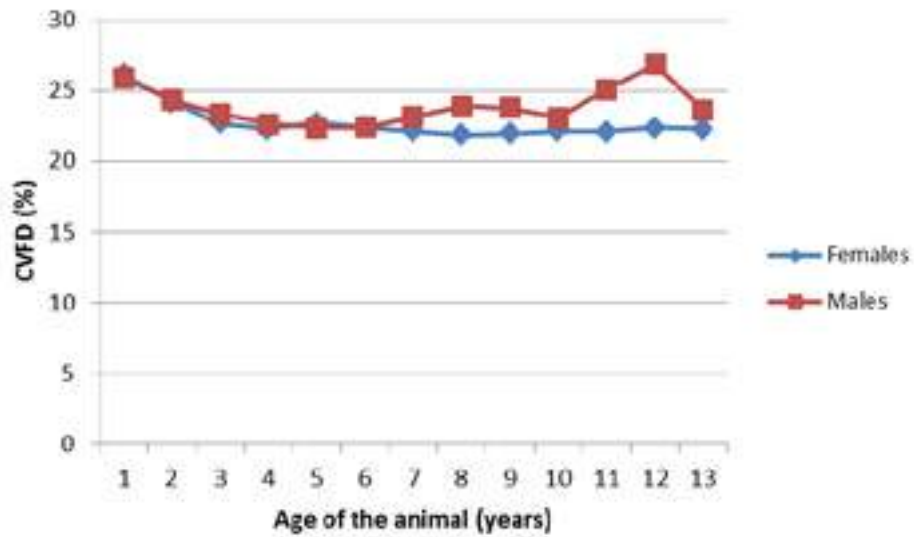


Figure 4a. Effect of age of the animal and sex on CVFD (unadjusted raw means)

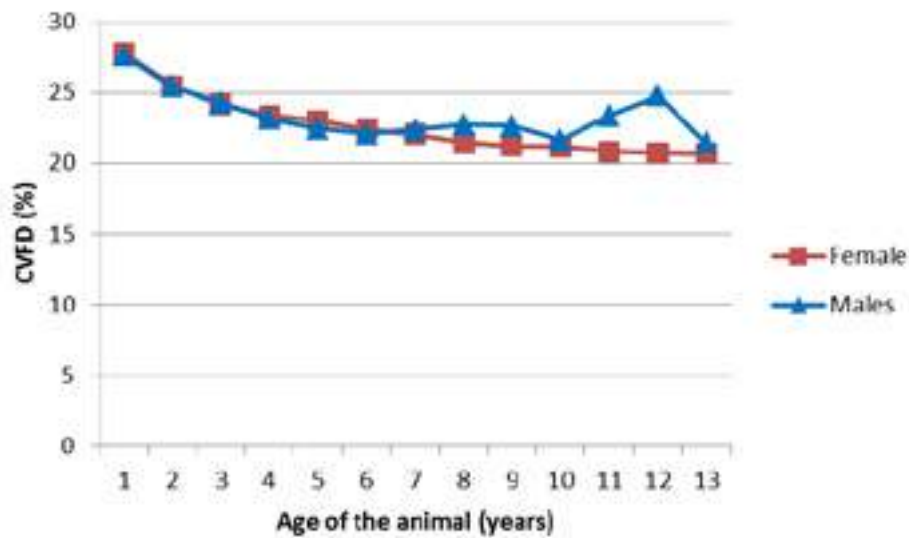


Figure 4b. Effect of age of the animal and sex on CVFD (predicted means from the model)

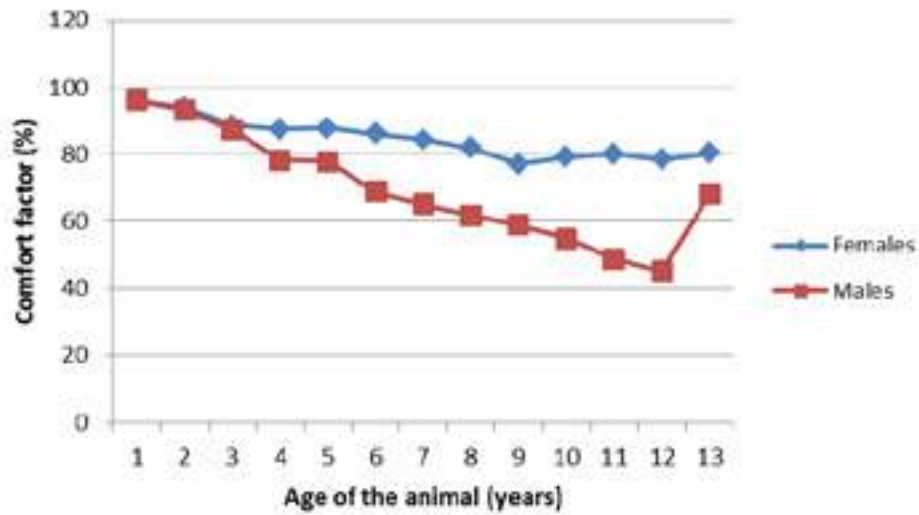


Figure 5a. Effect of age of the animal and sex on comfort factor (unadjusted raw means)

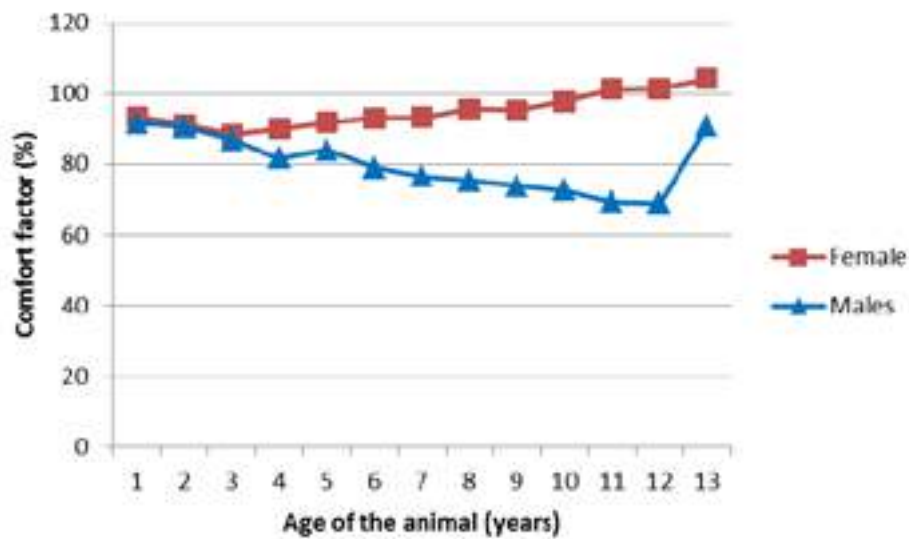


Figure 5b. Effect of age of the animal and sex on comfort factor (predicted means from the model)

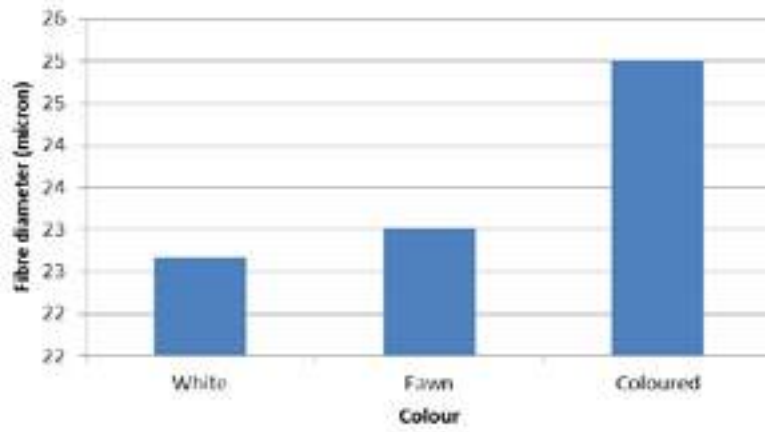


Figure 6. Effect of colour on fibre diameter

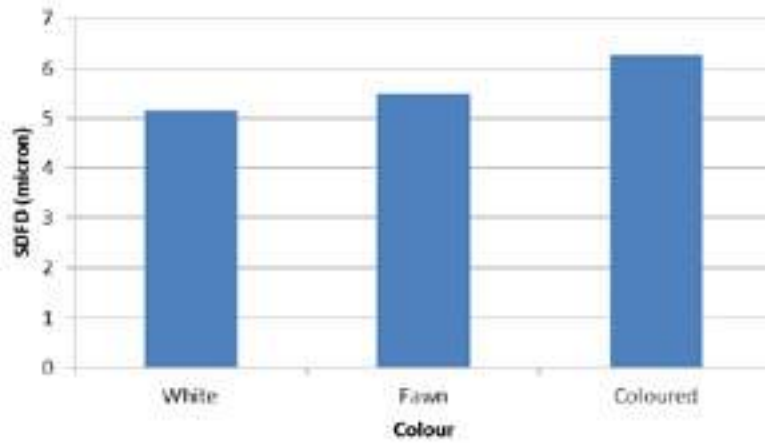


Figure 7. Effect of colour on SDFD (micron)

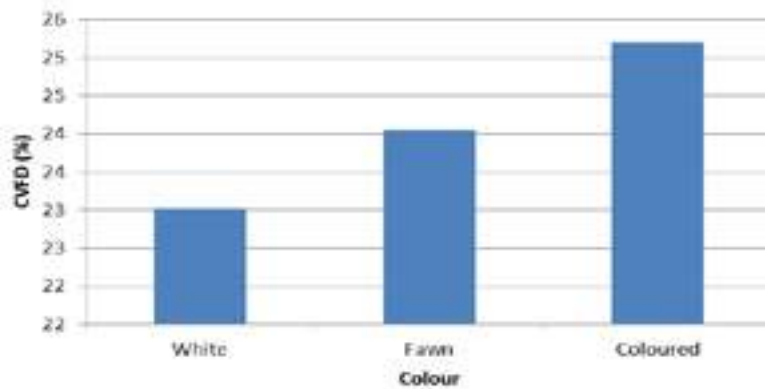
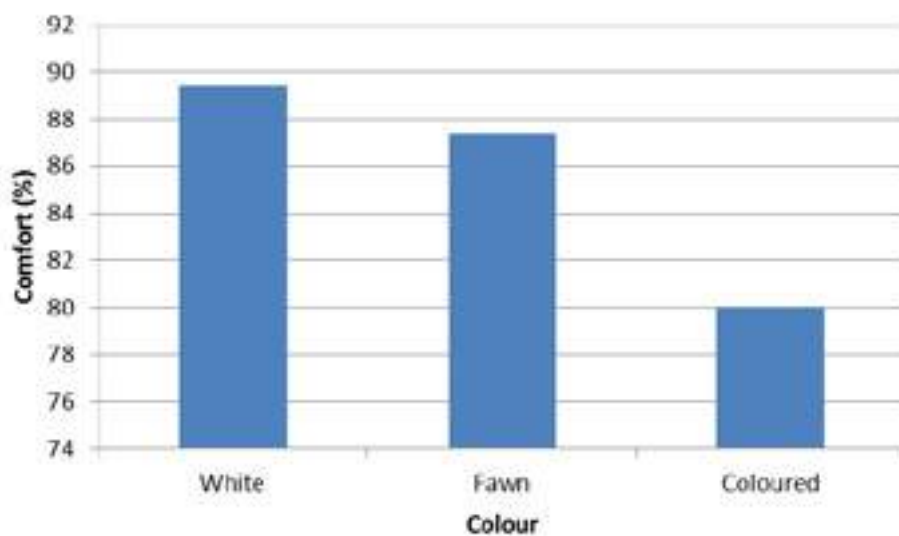


Figure 8. Effect of colour on CVFD



**Figure 9: Effect of colour on comfort**

### Heritability of fibre traits at different ages

The heritability of the different traits at different ages are shown in tables 3, 4, 5, 6 and 7 for FD, SDFD, CVFD, comfort factor and log(comfort factor), respectively.

Overall heritability was  $0.49 (\pm 0.01)$ ,  $0.52 (\pm 0.04)$ ,  $0.46 (\pm 0.05)$ ,  $0.37 (\pm 0.01)$  and  $0.33 (\pm 0.01)$  respectively for fibre diameter, SDFD, CVFD, comfort factor and log(comfort factor). All these parameters are very similar to genetic parameters that have been published for Merino sheep (Pollott and Greeff, 2005; Huisman and Brown, 2008). However, the heritability of the fibre traits at different ages varied quite considerably. The heritability of fibre diameter varied from 0.18 at four years of age, to 0.79 at nine years of age. The heritability of fibre diameter of 0.33 in year three was also relatively low compared to the estimate of 0.52 on one year old animals. This was mostly due to the fact that the error variance in year one was about half of that in year three, while the additive variance was relatively similar (3.66 and 3.08).

**Table 3: Variance components and heritability ( $\pm$  SE) of fibre diameter in Alpacas at different ages**

Age group	Number of records	Additive variance	Error variance	Phenotypic variance	$h^2$	SE
1	1829	2.68	1.38	4.07	0.66	0.06
2	1441	3.66	3.42	7.08	0.52	0.08
3	835	3.08	6.34	9.43	0.33	0.09
4	601	2.08	9.79	11.87	0.18	0.10
5	630	4.19	6.42	10.60	0.40	0.11
6	457	3.90	5.34	9.24	0.42	0.17
7	526	5.08	6.81	11.90	0.43	0.11
8	489	6.15	5.53	11.68	0.53	0.11
9	461	10.55	2.71	13.26	0.79	0.08
10 <sup>a</sup>	1066	9.16	3.96	13.12	0.69	0.02

<sup>a</sup> Pooled age groups 10, 11, 12 and 13.



Similarly, the heritability of SDFD varied from 0.24 at five years of age to 0.88 at two years of age. The lowest heritability of CVFD was 0.37 at six years of age, and the highest estimate was 0.79 at nine years of age. Large differences in heritability estimates were also found for comfort factor which varied from 0.20 at seven years of age to 0.84 at two years of age. The heritability of the transformed comfort factor varied from 0.20 at four years of age to 0.93 at nine years of age. These large changes across years are probably due to a data structure in which few sires were used in different years, and which had small sire progeny groups.

**Table 4: Variance components and heritability of standard deviation of fibre diameter in Alpacas at different ages**

Age group	Number of records	Additive variance	Error variance	Phenotypic variance	h <sup>2</sup>	SE
1	1829	1.32	0.17	1.49	0.88	0.05
2	1441	0.93	0.42	1.34	0.69	0.02
3	835	0.68	0.51	1.19	0.57	0.09
4	601	0.74	0.57	1.31	0.56	0.09
5	630	0.27	0.82	1.09	0.24	0.21
6	457	0.61	0.53	1.13	0.54	0.10
7	526	0.62	0.61	1.22	0.50	0.12
8	489	0.53	0.55	1.08	0.49	0.09
9	461	0.51	0.24	0.75	0.68	0.06
10 <sup>a</sup>	1066	0.48	0.40	0.87	0.55	0.07

<sup>a</sup> Pooled age groups 10, 11, 12 and 13.

**Table 5. Variance components and heritability of coefficient of variation of fibre diameter in Alpacas at different ages**

Age group	Number of records	Additive variance	Error variance	Phenotypic variance	h <sup>2</sup>	SE
1	1829	5.91	3.31	9.22	0.64	0.07
2	1441	5.78	5.93	11.71	0.49	0.07
3	835	5.80	5.23	11.03	0.53	0.10
4	601	7.95	3.44	11.40	0.70	0.10
5	630	6.77	3.84	10.61	0.64	0.08
6	457	3.89	6.71	10.60	0.37	0.16
7	526	6.91	2.48	9.39	0.74	0.06
8	489	5.14	4.09	9.23	0.56	0.09
9	461	8.42	2.22	10.64	0.79	0.09
10 <sup>a</sup>	1066	7.07	3.08	10.15	0.70	0.02

<sup>a</sup> Pooled age groups 10, 11, 12 and 13.

**Table 6. Variance components and heritability of comfort factor in Alpacas at different ages**

Age group	Number of records	Additive variance	Error variance	Phenotypic variance	h <sup>2</sup>	SE
1	1829	278.3	51.3	329.6	0.84	0.07
2	1441	185.3	104.8	290.2	0.64	0.03
3	835	177.8	78.1	255.9	0.69	0.07
4	601	116.9	119.7	236.7	0.49	0.11
5	630	77.5	94.1	171.6	0.45	0.17
6	457	66.5	96.8	163.2	0.41	0.11
7	526	38.1	151.5	189.6	0.20	0.11
8	489	42.8	96.4	139.2	0.31	0.09
9	461	8.4	6.4	14.8	0.57	0.06
10 <sup>a</sup>	1066	33.8	23.3	57.1	0.59	0.08

<sup>a</sup> Pooled age groups 10, 11, 12 and 13.

**Table 7. Variance components and heritability of log(comfort factor) of fibre diameter in Alpacas at different ages**

Age group	Number of records	Additive variance	Error variance	Phenotypic variance	h <sup>2</sup>	SE
1	1829	0.001	0.001	0.002	0.517	0.057
2	1441	0.007	0.006	0.013	0.546	0.084
3	835	0.017	0.028	0.045	0.377	0.088
4	601	0.012	0.047	0.058	0.201	0.120
5	630	0.019	0.031	0.050	0.380	0.120
6	457	0.040	0.016	0.056	0.720	0.090
7	526	0.054	0.023	0.077	0.700	0.069
8	489	0.099	0.015	0.113	0.871	0.029
9	461	0.118	0.009	0.127	0.930	0.029
10 <sup>a</sup>	1066	0.064	0.038	0.102	0.630	0.027

<sup>a</sup> Pooled age groups 10, 11, 12 and 13.

## Micron blowout

The largest increase, of about 3 microns in average fibre diameter, occurred over the first four age groups, from year one to year four (Figure 2b). These four age groups consisted of reasonable numbers of animals (1829 in age group one, 1441 in age group two, 835 in age group three, and 574 in age group four), and was used to investigate the inheritance of fibre diameter blowout over the first four years of age.

Age, sex, colour, birth year, measurement year and measurement month affected micron blowout significantly ( $P < 0.01$ ). White and fawn animals were less prone to micron blowout than coloured animals (1.9 micron versus 1.9 micron versus 2.5 micron respectively), while males showed a higher blowout than females. This may not have been due to the effect of sex but rather due to different management groups, as males and females were managed separately.

## Heritability of micron blowout.

Table 8 shows the genetic variance and heritability estimate for micron blowout from year one to year two, year two to year three, and year three to year four over the first four years of age. As the dataset was not complete for each year, the number of records per age group category reduced quite considerably.

**Table 8: Heritability of micron blowout in Alpacas over the first four years**

Blowout age group	Number of records	Additive variance	Error variance	Phenotypic variance	$h^2$	SE
1-2	738	0.66	4.31	4.97	0.13	0.08
2-3	641	0.26	5.27	5.53	0.05	0.07
3-4	380	0.52	8.35	8.86	0.06	0.11

It appears that there is some additive genetic variation for micron blowout in alpacas. The heritability of micron blowout from year one to year two is the highest, but it is very low in the subsequent age categories. These results indicate that it would be difficult to make rapid genetic progress by selecting for reduced micron blowout.

Ponzoni *et al* (1995) have shown that FD in Merino sheep was the strongest correlated to micron blowout. Greeff (2001) found that FD was genetically lowly correlated to micron blowout, but that CVFD of the staple had a moderate low genetic correlation with micron blowout. However, he showed that CVFD along the staple was genetically the same trait as micron blowout, and it also had the strong phenotypic ( $r_p=0.77$ ) relationship with micron blowout in Merino sheep. The genetic and phenotypic correlations between fibre diameter in alpacas at two, three and four years of age with micron blowout at the same age were estimated, and the correlations are indicated in Table 9.

**Table 9: Environmental ( $r_e$ ) genetic ( $r_g$ ) and phenotypic ( $r_p$ ) correlations between fibre diameter at different ages and micron blowout ( SE in brackets)**

Age	Blowout	$r_e$	$r_g$	$r_p$
2	1-2	0.89(0.06)	0.77(0.10)	0.71(0.02)
3	2-3	0.71(0.06)	*	0.62(0.02)
4	3-4	0.67(0.07)	0.03(0.54)	0.56(0.03)

Generally high environmental and phenotypic correlations were estimated between blowout and fibre diameter across all age group categories. But a high genetic correlation was only estimated between fibre diameter at age two and micron blowout from age group one to year two of age. Very low genetic correlations were estimated between fibre diameter and blowout at years three and four. This probably resulted from very low, and probably inaccurate, additive genetic variation estimated in these age groups. Thus, it appears that the micron blowout from age one to age two is strongly correlated to fibre diameter of the second shearing, but not thereafter.

Table 10 shows the environmental, genetic and phenotypic correlations between CVFD and micron blowout in alpacas at different ages. The genetic correlations are very inaccurate, as shown by the

large standard errors. However, there is low negative phenotypic correlation between micron blowout and CVFD. This indicates that although CVFD is not a reliable predictor of micron blowout, FD is a better predictor of micron blowout in this alpaca herd.

**Table 10. Environmental (re) genetic (rg) and phenotypic (rp) correlations between coefficient of variation of fibre diameter (CVFD) at different ages and micron blowout ( SE in brackets)**

Age	Blowout	$r_e$	$r_g$	$r_p$
2	1-2	-0.03(0.11)	-0.00(0.27)	-0.02(0.04)
3	2-3	0.18(0.09)	0.20(0.50)	-0.10(0.04)
4	3-4	0.23(0.12)	0.16(0.74)	-0.16(0.05)

### **Micron Blowout Breeding Value (BBV)**

In order to identify groups of animals with high predisposition to retain fibre fineness (Objective 2) and another group with increased micron blowout (Objective 3), estimated blowout breeding value (BBV) was determined for each animal with appropriate records in the dataset. A positive BBV indicates a propensity for micron blowout to occur. Lower BBV indicates that the animal will contribute to improvement of blowout (i.e. less blowout). Of the 4233 animals assigned BBVs, 1350 (31.8%) had values >0; 1707 (40.4%) scored <0; and 1176 (27.8%) scored 0. The top 100 animals had values less than -0.94, and consisted of 59% females, while the bottom 100 had BBV above 0.895, and were 57% female.

# Implications

The results show that fibre diameter increases with age in alpacas, similar to what is found in Merino sheep. Fibre diameter and its related traits are all heritable in alpacas, which indicates that it should be possible to make genetic progress in these traits. Apart from CVFD, the other fibre traits were not repeatable; this implies that permanent environmental factors were not important for the other fibre traits.

The analysis also showed that the fibre traits were heritable at different ages, but that the heritability of the different traits varied quite dramatically from year to year. Apart from males and females, it was not known which animals were managed in which management groups and how animals were allocated to management groups. It is possible that certain sires' progeny could have been managed in separate groups with no linkage between contemporary groups. This would have resulted in biased estimates and the large differences experienced in this analysis.

The results also show that micron blowout has only low heritability during the first four years, and that the highest heritability (0.13) was found for micron blowout from age one to age two. CVFD is also not a reliable predictor of blowout, but FD at the second shearing (or at age two) appears to be an effective predictor of micron blowout. It would be possible to select for improvements in micron blowout in this population. However, the high level of variability in the older data means that in order to confirm these findings, a follow-up analysis (with at least two more years of additional data, plus more detailed herd management data) is required.

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## Quantitative Genetic Analysis of Micron Blowout in Alpacas

By Kylie Munyard and Johan Greeff

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Some alpacas maintain fine fibre throughout life, while others suffer from significant coarsening of fibre as they age, a trait known as micron blowout. Micron blowout results in reduced productivity, through reduced yield of high quality fibre over the life of an animal.

Data from a well-established alpaca herd in Peru was used in a complex quantitative genetics analysis to determine if genetics plus environment, or environment alone was responsible for micron blowout in alpacas. This project has shown that micron blowout has a moderate heritability in alpacas, and that selection against micron blowout would be successful in reducing the extent of the problem.

This report is targeted at Australian alpaca breeders.

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