MEASURING THE HERITABILITY OF LEATHER TRAITS IN SHEEP AND DEERSKIN

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Abstract

This study explored the genetic variability in the New Zealand sheep and deer populations for a number of important skin traits.

Three hundred and five slaughtered progeny of Focus Genetics sheep-meat sires were evaluated for a number of pelt traits. DNA profiles were used to identify the skins collected post slaughter, the animals having previously been genotyped with Illumina 600K HD SNP chips as part of separate FarmIQ meat quality project. Considerable phenotypic variation for pelt traits was observed with around 30% of pelts identified as suitable for high value shoe leather production. Several key pelt traits associated with high value leather production were found to be moderately to highly heritable. This preliminary data will contribute to a larger study investigating if suitable lamb pelts can be bred or identified for use as high value shoe leather.

A more traditional approach was applied to deerskins. Slaughtered eleven-month-old progeny (n=310) from terminal (wapiti crossbred) and maternal (red) sire types were evaluated for 18 different quantitative and qualitative traits throughout processing to pearl-crust leather. For all traits except evenness grade of the pearl-crust leather, the relationship with pre-slaughter live weight covariate was significant ($p<0.05$) and positive. Sire had a significant effect ($p<0.01$) on eight traits including critical strength and finished-leather attributes ($p<0.01$) indicating genetic variability in these traits although larger numbers would be required for accurate heritability estimates.

This study provides a first insight into genetic variability in the properties of sheep and deerskins, and has wide-ranging benefits for other animal types; including cattle, where SNP chip technology is in an advanced stage of development.

Keywords: Heritability, leather, traits, phenotype

1.INTRODUCTION

The physical properties of lambskins have been measured in a number of studies (Milnes et al., 1977, Haines, 1981, Ward et al., 1965), as they are very important in determining the uses to which lambskin leather can be put. Traditionally, they have been used for clothing, a relatively low-value use, but if strength was improved they could be moved into the more lucrative and dependable

footwear market. In previous studies of large flocks of sheep (unpublished work) LASRA has identified significant variations between milk lambs (less than 3 months old) and more mature lambs (6-9 months), and between black-face and white-face sheep of the same age. This suggests there may be both genetic and age-related factors at play.

Estimates of the genetic parameters for skin and leather traits in mammals are extremely rare in the literature. In sheep Scobie et al (2006) investigated the relationship between skin wrinkles and leather quality finding that selecting animals without wrinkles improved pelt quality. Icelandic lambs were found to be particularly suitability for use in reverse fur clothing due to their relatively light weight and lower frequency of environmental faults such as insect bites (Hjartarson, 2000). Woolskin traits in Icelandic sheep were reviewed by Adalsteinsson (1983), and wool quality scored in a similar way to Gotland sheep, with the curl, lustre and wool density found to have low to moderate heritability across three studies

(Adalsteinsson, 1983). Eythorsdottir (1999) investigated a number of pelt traits in an Icelandic sheep breed, including thickness and double hiding in salted and tanned skins, with good correlation between traits measured on salted and tanned skins. Eythorsdottir estimated heritability scores for wool density (0.31) and lustre (0.28) on autumn lamb pelts. Age was found to have a negative impact on wool quality traits in all studies.

In subsequent work Nasholm and Eythorsdottir (2011) reviewed the characteristics and utilisation of special pelt products from Icelandic, Swedish (Gotland) and Karakul breeds of sheep, focusing on specific pelt traits associated with these breed, as well as Australian and New Zealand pelts, which are characterised by large quantities of Merino and Merino-derived breeds in Australia and a variety of different sheep breeds for woolskins and leather (Passman and Sumner (1987)) in New Zealand, and found that pelts with high loose wool bulk were best suited for double face production but not as well suited to leather tanning.

Similarly in cattle an autosomal recessive trait called vertical fibre hide defect (VFHD), which is a structural fault in collagen fibre orientation which leads to poor interweaving and weakness has been studied in Hereford cattle. VFHD phenotypes were diagnosed in pairs of offspring and dams by Cundiff et al (1987) and are broadly reflective of numerous analogous skin conditions in humans.

Perhaps the major difference in sheep is that hair sheep normally have better quality pelts than wool sheep (Oliveira et al., 2007, Cloete et al., 2000, Carneiro et al., 2010, Jacinto et al., 2004) although results can be variable. Jacinto et al., (2004), found significant improvements in the tensile strength and load of the skins of non-wool Morada Nova sheep compared with those from the Ideal wool-on breed, the differences being partially explained by the relatively thicker grain layer on the wool-on sheep and increased follicular and glandular density. In a study by Teklebrhan et al, (2012) physico- mechanical strength properties were measured on both indigenous Ethiopian and cross-bred sheep, which had their diet closely monitored. The cross-bred sheep were Ethiopian sheep, sired by Dorper sheep imported from South Africa. Dorper sheep skins are highly regarded for their properties for clothing and gloving production (Terblanche, 1979). In this case, the cross-bred skins were found to have similar chemical characteristics and be of similar strength to those of the indigenous sheep, although native breeds tended to produce slightly higher quality leather.
The purpose of the two studies reported here was to investigate whether different physical skin properties, identified in the part-processed and resultant leathers were related to the genetic make- up of sheep and deer, two economically important species for New Zealand. If genetic variability exists, this can be exploited to improve the quality of deer and lamb pelts; and thereby increase their value to farmers and skin processors.

2. MATERIAL AND METHODS

Collection and processing of deerskins

The first of the two trials was the more traditional evaluation of traits in red deer skins (Cervus elaphus spp.) as part of the Deer Progeny Test (DPT), relying on progeny DNA pedigree information extracted from the DEERSelect database for analysis (Ward et al., 2014). It was conducted across three commercial deer farms in New Zealand between 2011-2013 years with the primary aim of genetic improvement, while reducing variation in important traits related to meat and skin quality. The skin traits reported here were measured on the 2011 birth cohort on hinds (N = 285) of the red deer subspecies from two different age classes; rising-three-year-old (R3) and mixed age (MA) (rising- four-year-old and above) on Invermay farm (Otago) and Whiterock Station (Canterbury) (Ward et al., 2015).
All progeny from each farm were transported and slaughtered on a single occasion during October 2012, Animals were kept in lairage overnight with access to water and separated by mob/sex, then slaughtered the following day (Ward et al., 2015). Following removal of the skin post-slaughter at Alliance Group Makarewa, they were screen-washed with cold water to cool for two minutes. They were drained, salted using a standard commercial recipe, stacked on wooden pallets and stored covered with plastic for approximately 12 months. Subsequently, the salted skins were wet back and processed through the commercial processing plant at New Zealand

Light Leathers Ltd. (Washdyke, New Zealand), following a conventional deer process, used for bulk production, with the only major difference being that the skins were undyed and left unshaved in the crust state prior to dry drumming.

Collection and processing of lambskins

The second trial was conducted on sheep progeny born in 2014 as part of the FarmIQ Awapai Progeny Test from terminal sire composites (Primera), mated to a variety of maternal breeds but predominantly Highlander ewes (Brito et al., 2015). The ewes were mob mated in large groups, with sires assigned to progeny through DNA pedigree. There were 75 sires represented in the data, with an average of 5 progeny per sire. All progeny were genotyped using the Ovine Infinium® HD SNP BeadChip (Anderson et al., 2014). Both male and female progeny were slaughtered in February 2015. Following removal of the skin post-slaughter, lamb skins were collected, and sent to Tomoana Pelt Processors (TPP), Whakatu, for processing. At TPP the green skins were fleshed, individually labelled, and a tissue sample collected for DNA identity matching. The skins were processed through to the pickle stage at the fellmongery using a standard commercial process and set aside at pickle grading for return to LASRA where they were converted to crust leather using a standard process known to provide good strength properties.

Grain strain was measured on the depickled pelts after treating with Sortassist®, Stahl Holdings BV, a pH-dependent blue pigment that highlights grain defects. They were then photographed and scored for the extent and severity of grain strain on the flanks on a scale of 0 (none) to 4 (the most severe/extensive seen). The two flanks of each pelt were assessed separately and the scores added

to give a minimum pelt score of 0 and a maximum pelt score of 8. Further testing was conducted on the crusted skins after they were staked and toggled. Samples for physical testing were cut out using press knives on a hydraulic press and conditioned at 20oC and 65% relative humidity (RH) for at least 24 hours before testing. Thickness of leather was measured in the neck, backline, midside area and belly. Leather thickness was measured using a Specht leather thickness gauge. Tensile strength and percentage extension of the leather was measured according to International Standard ISO 3376:2002 using an Instron® Model 4467 Universal Testing System. Testing was performed in parallel and perpendicular in relation to the backline in quadruplicate on each skin, the results being averaged. Tear strength of the leather was measured according to International Standard ISO 3377- 2:2002. Tests were performed in parallel and perpendicular in relation to the backline in quadruplicate for each skin using the same Instron tensile testing machine as above. The results were expressed both as the absolute force required to tear the leather (N) and as the force per unit thickness of the sample (N/mm), and the values for each skin averaged to give a skin value. Grain strength and extensibility was measured in triplicate for each skin using the ball burst test, International Standard ISO 3379:1976. The results for each skin were averaged to give a skin value. Results were expressed as Newtons (N) of force and mm of extension. Finally, evaluation of flatness was carried out by an experienced assessor, on a scale of 0 (completely flat) to 4 (extreme bumpiness of the surface) on the crusted material. Because values vary widely over the skin, with the neck region usually being significantly less flat than the rest of the skin, the neck area, the butt and the rest of the skin were assessed separately. The three figures were then added to give a whole skin grading between 0 and 12.

To match the skin number to individual animal ID, DNA was extracted from the tissue samples obtained from the lambskins. A Sequenom parentage panel was run on each sample (Clarke et al. 2014), and these results were used to match to animal ID using stored HD genotypes from the same animals.

3. RESULTS AND DISCUSSION

Deerskin data

Data were analysed using least squares means (LSM) analysis to test significance of the skin traits and responses of the various factors (i.e., farm, year, mob, sex and sire type) and predict overall responses of these factors including sire. Pre-slaughter live weight was independently fitted as a covariate. Sire had a significant effect ($p<0.01$) on eight traits; all six crust-leather-tearing traits, pearl-crust leather evenness grade and wet-blue thickness, measured mid-back. Range summaries of these traits with significant sire-effects are presented in Table 1. Farm had a significant effect (p<0.01) on eight traits ranging from wet-blue size and thickness, to crust leather strength. Wet-blue area, width behind fore legs, thickness mid-neck and mid-side were all significantly positive (p<0.01) for the Invermay Farm. Crust leather strength; parallel, perpendicular and mean were all highly significantly (p<0.001) positive for the Whiterock Station progeny. Crust leather tear strength perpendicular to the spine and wet-blue thickness mid-side were the only traits on which mob had a significant effect (p<0.05). The responses for these two traits were negative for progeny of R3 hinds. There was no significant effect of sex (p<0.05) on any of the traits measured. The discrete trait data (i.e. rank and grade) presented quite skewed distributions in some cases. Wet-blue quality was the most skewed with 204 skins in the top grade, 73 in the middle and only eight in the bottom grade.

Table 1 Deer-skin traits of the 2011 deer progeny test birth cohort predicted by least squares means analysis where sire (n=14) was a significant effect in the model.

Trait name	N progeny	Mean progeny response	Sire mean response	Sire maximum response	Sire minimum response	Sire response std	Sire response coefficient of variance %	Range of sire responses	SireID and Random (p score)	Covariate Weight Pre-slaughter (p score)	Covariate response	Covariate response % mean
Wet-blue skin thickness at middle of back (mm)	270	1.95	1.95	2.07	1.84	0.07	3.6	0.23	<0.01	<0.0001	0.01	0.5
Crust-leather tear-force parallel to spine (N)	282	213	215	235	197	11	5.1	37.8	<0.0001	<0.0001	1.84	0.9
Crust-leather tear force perpendicular to spine (N)	282	160	161	178	146	8.9	5.5	32.5	<0.0001	<0.0001	1.4	0.9
Crust-leather mean tear force of both axis (N)	282	186.1	188.3	206.5	171	9.96	5.3	35.5	<0.0001	<0.0001	1.62	0.9
Crust-leather tear strength parallel to spine (N/mm)	282	108.4	110	113.7	104	2.6	2.4	9.6	<0.01	<0.0001	0.26	0.2
Crust-leather tear strength perpendicular to spine (N/mm)	282	87.2	88.2	93.9	81	3.37	3.8	12.77	<0.0001	<0.01	0.18	0.2
Crust-leather mean tear force of both axis (N/mm)	282	97.8	98.86	104	92.3	3.03	3.1	11.7	<0.0001	<0.0001	0.22	0.2
Pearl crust evenness grade (Rank 1-3)	282	1.76	1.78	2.14	1.47	0.2	11.2	0.67	<0.01	<0.05	0.01	0.5

Lamb pelt data

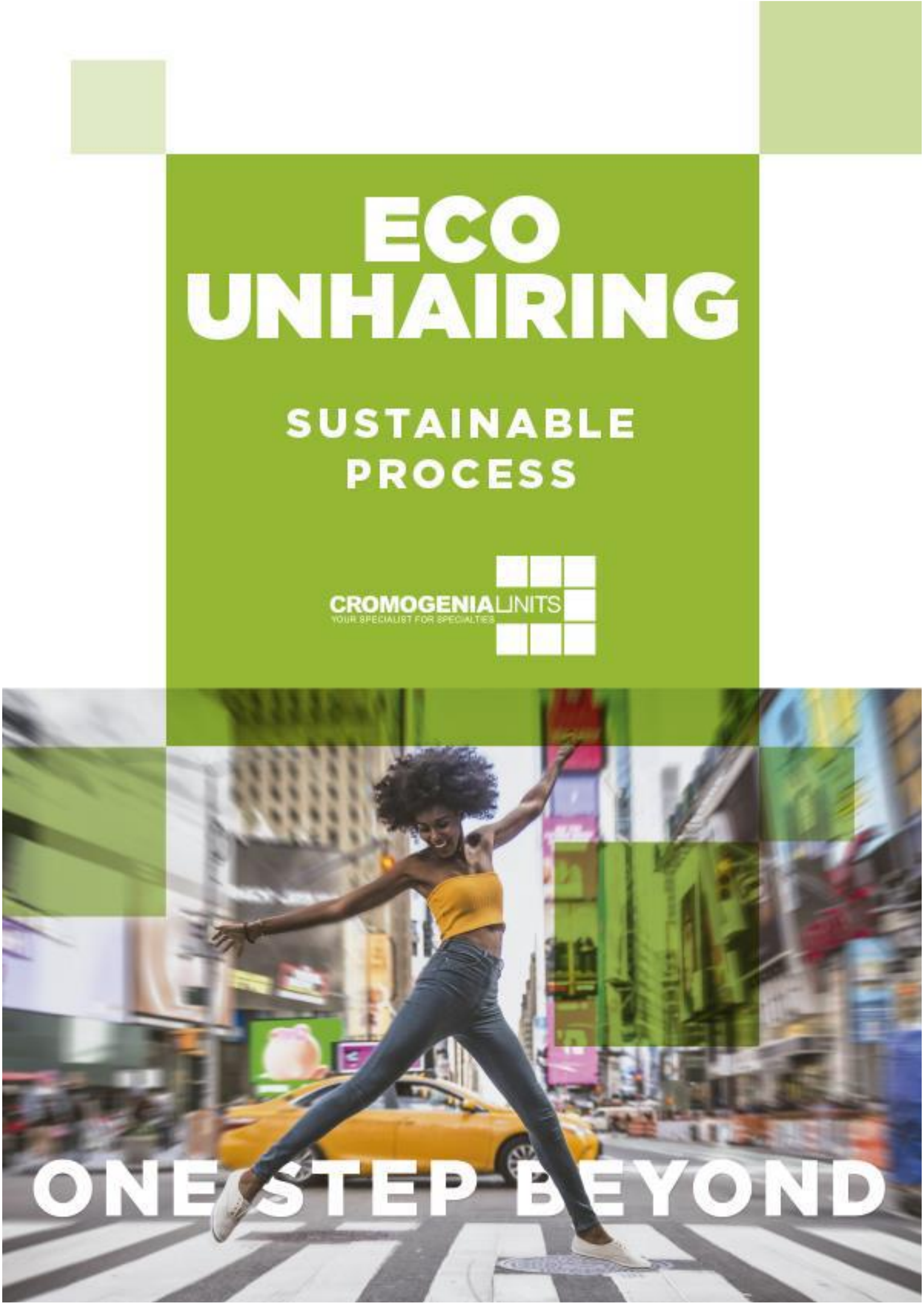
Data cleaning consisted of removal of records with duplicate animal IDs. For traits where multiple values were recorded, trait average was used. Considerable phenotypic variation for pelt traits was observed with around 30% suitable for high value shoe leather production. Parsimonious models for fixed effects and covariates were identified for each trait separately via backwards elimination using the GLM procedure (SAS Inst. Inc., Cary, NC). Fixed effects tested were sex, weaning mob (WWTm), pre-slaughter weight (PRESLTWT), carcass weight (CWT), and depth of tissue 110 mm off the mid line in the region of the 12th rib (CGRM). Sex and carcass weight were significant fixed effects for multiple traits (Table 2). The final dataset used in the analysis contained records for 287 (138 male and 149 female) lambs (Table 2). Variance components were then estimated using restricted maximum likelihood (REML) procedures fitting an animal model in ASReml (Gilmour et al., 2015), for fixed effect models previously defined along with the genomic relationship matrix (GRM) estimated in GenABEL (Aulchenko et al., 2007) using HD genotypes. Heritabilities were estimated via univariate analyses on the respective traits.

Table 2 Descriptive statistics, repeatability and heritability for individual trait analyses in sheep. Significant values are shown in bold. All mixed models included animal as a random effect.

Trait	N	Mean ± SD	Range	Heritability	Fixed effects
Neck	287	2.8 ± 0.8	0.5 - 4	0.13 ± 0.16	sex
Butt	287	2.2 ± 1	0 - 4	0.21 ± 0.17	sex
Belly	287	1.8 ± 0.9	0 - 4	0.23 ± 0.18	-
Overall	287	6.8 ± 2.4	1 - 12	0.15 ± 0.17	sex CGRM
Tear parallel (N/mm)	283	47.7 ± 6.6	33.8 - 78.3	0.26 ± 0.18	sex CWT
Tear perpendicular (N/mm^2)	283	47.3 ± 58.7	28.1 - 1026.5	0.02 ± 0.12	-
Tensile parallel ext (mm)	286	35.6 ± 6.1	23.4 - 92.3	NE	-
Tensile parallel (N/mm^2)	286	**161.4 ± 24.2**	**105 - 245.7**	**0.85 ± 0.20**	**sex**
Tensile perpendicular ext (mm)	286	57.6 ± 11	32.4 - 90.4	NE	PRESLTWT
Tensile perpendicular (N/mm^2)	286	110.4 ± 17.4	62.3 - 196.4	0.35 ± 0.20	sex
Lastometer load (N)	285	**26.5 ± 6**	**12 - 44**	**0.54 ± 0.20**	**CWT**
Lastometer ext (mm)	285	8.9 ± 0.6	6.2 - 10.8	0.12 ± 0.15	CWT
Strain	287	**3.4 ± 1.8**	**0 - 8**	**0.86 ± 0.21**	**PRESLTWT CWT**

Note: NE = Not estimable

In general females and lighter lambs had pelts with lower strength characteristics. Several key pelt traits associated with high value leather production were moderately to highly heritable; three of the traits examined, tensile parallel, lastometer load, and strain, appear to have a significant genetic component. It must be noted that the lambskin results use only 287 animals (whose skins could be uniquely attributed to the individual), and therefore must be interpreted with caution. Further work is justified to more precisely estimate the genetic parameters, investigate year to year variability, examine a wider range of sire breed and define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the genetic relationships between pelt traits and production traits in sheep with greater precision. This will allow a formal evaluation of the potential for in-plant and genetic selection to produce lines of pelts suitable for shoe leather production.

4. CONCLUSION

The results from both of these studies indicate that there is genetic variability in the New Zealand sheep and deer populations for a number of important skin traits, which provides useful knowledge for predicting the properties of skins from animals of known genetic profile.

It is highly unlikely that farmers will breed either sheep or deer for their skin properties. Dual- purpose sheep breeds in New Zealand derive most of their value from the wool and meat they produce, with the skin being a by-product. Future work to identify traits of benefit to the farmer (such as weaning or carcass weight) that have a positive correlation with traits of strength in the animal's skin, would mean that there was an additional purpose and reason to actively improve these properties in the animal's genetic profile.

In lamb skins, several key pelt traits associated with high value leather production were found to be moderately to highly heritable, including grain and tensile strength. This preliminary data will contribute to a larger study investigating if suitable lamb pelts can be bred or identified for use as high value shoe leather. This study is an important milestone, as to our knowledge it is the first in which SNP-chip technology has been used to investigate skin and leather traits

Much the same principles apply to deerskins. While the hair of deer has no value, they are purposely bred for meat with by-products such as the pelt providing additional value. There was a significant sire effect, indicating a genetic component, for a number of important deerskin quality traits including tear strength, pearl-crust-evenness grade and mid-back thickness. These traits could be genetically selected for if a suitable cost-effective way of tracing finished skins to individual animals could be established. Environmental factors of farm and mob (effectively age-of dam) are also important factors in the quality of deerskins. These factors could offer the opportunity to select higher quality batches of skins based on farm information rather than fully tracing skins through the slaughter and tanning process.

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