AUSTRALIAN SHEEP BREEDING VALUES INCREASE % CARCASS LEAN AND REDISTRIBUTE LEAN TISSUE TO THE SADDLE REGION

F.Anderson[1,2], A.Williams[1,2], L.Pannier[1,2], D.W.Pethick[1,2], and G.E.Gardner[1,2]

[1] School of Veterinary and Life Sciences, Murdoch University, South Street, Murdoch, Western Australia, Australia

[2] Australian Cooperative Research Centre for Sheep Industry Innovation, Armidale, NSW, Australia

Lean meat yield % (LMY%) is selected for indirectly using sire Australian Sheep Breeding Values for post weaning weight (PWWT), eye muscle depth (PEMD) and C-site fat depth (PFAT). In this study we assessed the impact of sire breeding values on the weight and distribution of lean tissue in lamb carcasses as assessed by computed tomography (CT) scanning. Selection for increasing sire PWWT increased carcass lean weight (*P*<0.01), but only at some research sites. Sire PFAT and PEMD also increased whole carcass lean weight (*P*<0.01) by 9.5% and 8.1% across their respective breeding value ranges. All three breeding values redistributed lean tissue from the fore-section to the saddle region (*P* <0.05), although for PWWT this only occurred at some experimental sites. The combination of increasing lean in the carcass coupled with redistribution of lean to the saddle region would lead to increased carcass value as the saddle region is more highly valued.

Key Words – computed tomography, lean meat yield percentage, fatness.

- INTRODUCTION

The financial value of a carcass is influenced by LMY% as consumers prefer larger and leaner cuts [1], and processors have less carcass preparation time and less wastage at bone-out. Australian lamb producers indirectly select for LMY% using three sire breeding values: post weaning weight (PWWT), eye muscle depth (PEMD) and C-site fat depth (PFAT).

Sire PWWT has been assumed to increase LMY% due to its effect on increasing mature size [2]. Thus when compared at the same carcass weight the progeny of high PWWT sires should be less mature and therefore leaner [3]. None-the-less there is little data supporting this assertion. Likewise for PEMD there is little evidence showing an increase in LMY%, although a number of studies have shown an impact at its site of measurement – the C site [4, 5]. In particular this has resulted in a heavier eye of short loin [6]. Alternatively, LMY% has been shown to be heavily influenced by a decreasing sire PFAT which decreases overall carcass fatness and increases muscularity [6]. These effects appeared to impact broadly across the carcass rather than being focused on one particular research site as was the case for PEMD.

Therefore we hypothesised that when lambs are compared at the same weight: the progeny of sires with high PWWT or low PFAT breeding values will have more lean tissue within the carcass; and the progeny of sires with high PEMD breeding values will have more lean in the saddle region only.

- MATERIALS AND METHODS

Experimental design and slaughter details

Details of the design of the Sheep CRC's Information Nucleus Flock (INF) were presented by Fogarty *et al.* [7]. Lambs were born and raised at one of six research sites across Australia from 2007 to 2010. The sires used had a wide range of PWWT (-6 to 18kg), PEMD (-2.5 to 5.0mm) and PFAT (-2.5 to 2.5mm) breeding values. Lambs were slaughtered at one of 5 commercial abattoirs at a target average carcass weight of 23 kg.

Twenty-four hours following slaughter carcasses were transported to either Murdoch University or the University of New England for CT scanning to determine weights of bone, lean and fat. Data from 1612 lambs was used in the analysis, which were the progeny of 70 Maternal, 109 Merino and 154 Terminal sires.

Statistical analyses

All data was converted to natural logarithms in order to utilise Huxley's allometric equation.

$$y = ax^b$$

Where x is the independent variable, a is the proportionality coefficient and b the growth coefficient of y relative to x. Transformation of the data to natural logarithms linearises the equation (ie log y = log a + b.log x) and allows it to be solved by least squares regression. The use of natural logarithms enables differences in log y to be directly interpreted as percent differences [8]. It is on this basis that the data in this paper has been interpreted.

Linear mixed effects models

The log transformed CT data was analysed using linear mixed effect models (SAS version 9.0, SAS Institute, Cary, NC, USA). The examination of the data was divided into two key sections. Firstly we assessed percent changes in whole carcass lean by using the log total weight of carcass lean as the dependent variable, and log carcass weight at the time of CT scanning as the covariate. Secondly, to assess the distribution of lean between the fore-section, saddle, and hind-section, the log weight of lean within each of these 3 carcass sections was used as the dependent variable, and the log total weight of lean within the carcass was used as the covariate. These 3 models were constrained such that they maintained the exact same form across all three carcass regions, enabling the addition of differences in fore-section, saddle, and hind-section lean weight to approximately off-set each other.

Within all of the models described above, we tested a standard set of fixed effects, breeding values, and random terms. The fixed effects included site-year (combined effect of site and year of birth eg Katanning 2007), birth and rearing type, sire type (Maternal, Merino and Terminal), sex-dambreed (wether or ewe lambs from Border-leicester and Merino dams) within sire type, and kill group within site-year. Sire breeding values for PWWT, PFAT, and PEMD were included simultaneously as covariates, and sire and dam identification by year were included as random terms. All appropriate first order interactions between fixed effects and covariates were tested, and non-significant (P>0.05) terms were removed in a step-wise manner.

- RESULTS AND DISCUSSION

Sire PWWT increased whole carcass lean, but only at some sites in some years (P<0.01, table 1). The greatest magnitude seen was at Rutherglen in 2010 where whole carcass lean increased by 7.9% across the 24 unit range of sire PWWT (Table 2). Lean distribution was also affected (P<0.05, Table 1), but again only at some sites. When compared at the same lean weight the greatest effect was seen at Katanning in 2008 where lean tissue increased in the saddle by + 10.6% across the sire PWWT range (Table 2). On average, the increases in saddle lean were offset by reduced fore-section lean (P <0.05, Table 1).

The increase in whole carcass lean due to increasing sire PWWT was consistent with our hypothesis, and is likely to be associated with PWWT increasing mature size [2]. Yet in contrast to our hypothesis PWWT did affect lean distribution within the carcass, redistributing lean from the fore-section to the saddle. This redistribution effect may be explained by maturity. It has been shown that the spinal musculature is relatively early maturing [9], therefore less mature animals should have proportionally more lean tissue within the saddle region of the carcass. However in our analysis the b (proportionality) coefficients show lean tissue in all sections was developing at a similar rate. Therefore maturity is unlikely to explain the redistribution of lean to the saddle. The variability in whole body lean and in lean deposition between experimental sites indicates that nutrition may play a role in the expression of PWWT's impact on lean. This is supported by Hegarty 2006 [10] who showed the impact of sire PWWT on lamb growth was tempered by poor nutrition.

Decreasing sire PFAT had a marked impact on whole carcass lean weight (*P*<0.01, Table 1), increasing it by 9.5% across the 5 unit PFAT range (Table 2). This breeding value also redistributed lean to the saddle section at the expense of the fore-section (*P*<0.01, Table 1). Thus when compared at the same lean weight the saddle lean increased by 3.7% (Table 2), and fore-section lean decreased by 2% (Table 2) across the PFAT range. The impact of PFAT on whole carcass lean weight was consistent with our hypothesis, however the redistribution of lean to the saddle section was an unexpected finding. This may be attributable to the PFAT measurement being taken from a single site in the saddle section, placing more emphasis on reducing fat in this region.

Lastly, increasing sire PEMD increased the weight of lean within the whole carcass (*P* <0.01,

Table 1. F values for factors affecting lean weight in the whole carcass and lean distribution in the fore, saddle and hind sections of the carcass.

Effect	Whole carcass lean		Lean distribution between sections			
	NDF, DDF	Lean	NDF,DDF	Fore-section	Saddle	Hind-section
Site-year	8,171	9.66**	7,166	35.42**	13.97**	11.4**
Sex-Dambreed(sire type)	3,171	41.25**	3,166	15.82**	2.05	7.67**
birth type-rear type	ψ	ψ	5,166	1.55	0.43	2.9*
Sire type	2,171	18.52**	2,166	7.68**	0.8	7.4**
Kill group(site-year)	16,171	11.91**	15,166	7.82**	8.12**	3.83**
log (CT carcass wt (kg)) or log (CT carcass lean wt (kg)) #	1,171	8431.47**	1,166	6221.66**	4262.33**	10147.4**
Post weaning weight (PWWT)	1,171	2.85	1,166	4.29*	5.4*	0.18
Post weaning weight (PWWT) x site-year	8,171	2.75**	7,166	1.41	2.32*	1.45
Post weaning C-site fat depth (PFAT)	1,171	101.31**	1,166	3.89*	7.57**	1.54
Post weaning eye muscle depth (PEMD)	1,171	45.52**	1,166	12.24**	8.37**	0.14

Where whole carcass lean was analysed, carcass weight was the covariate and where lean distribution was analysed, whole carcass lean was the covariate. ψ birth type-rear type not significant in the whole carcass analysis of lean tissue. * *P*<0.05; **, *P* <0.01. NDF, DDF: numerator and denominator degrees of freedom.

Table 2. The impact of Australia Sheep Breeding Values on carcass lean weight and lean distribution between sections. Values represent percentage change in lean tissue weight per unit of breeding value.

Effect	Level	Whole carcass Lean	Fore-section Lean	Saddle Lean
		% change in whole carcass lean weight per unit of ASBV	*% change in section wei per unit of A*	
Post weaning weight (PWWT) x site-year	Kirby 07	**0.25±0.07**	-0.14±0.08	0.08±0.11
	Kirby 08	0.07±0.06	-0.01±0.06	0.01±0.09
	Rutherglen 10	**0.33±0.10**	-0.12±0.15	0.07±0.19
	Hamilton 09	-0.14±0.10	-0.03±0.18	0.03±0.23
	Struan 10	-0.03±0.08	-0.19±0.09	**0.25±0.12**
	Turretfield 09	-0.10±0.10	-0.16±0.10	**0.38±0.13**
	Katanning 07	0.04±0.10	NA	NA
	Katanning 08	**0.23±0.10**	-0.23±0.12	**0.44±0.26**
	Katanning 11	0.08±0.06	0.03±0.06	0.02±0.09
Post weaning C-site fate depth (PFAT)		**-1.90±0.20**	**0.40±0.20**	**-0.73±0.30**
Post weaning eye muscle depth(PEMD)		**1.08±0.10**	**-0.45±0.10**	**0.49±0.20**

NA: Data not available. Bold numbers are significant.

Table 1) by 8.1% across the 7.5 unit PEMD range (Table 2). PEMD also caused redistribution of lean from the fore-section to the saddle, (*P*<0.01, Table 1) with a 3.4% reduction in the weight of the fore-section lean offset by a 3.7% increase in saddle lean (Table 2) across the PEMD range.

This increase in saddle lean supports our initial hypothesis, however the greater lean proportion across the entire carcass was unexpected. It has previously been shown [6, 10] that selection for increased sire PEMD results in an increase in loin depth and weight, aligning well with the lean redistribution effect observed in this study. However these previous experiments demonstrated somewhat inconsistent variation in the weight of other muscle groups, particularly in the hind-section. The greater lean proportion in the carcass may be indicative of a less mature animal at the same carcass weight, suggestive of a larger mature size. However if this were the case then we would also expect to see proportionately more bone in the whole carcass due to the early maturation pattern of this tissue [11-13]. Likewise, evidence by Huisman and Brown (2008)[2] also demonstrated no phenotypic or genetic correlation between PEMD and mature weight. Alternatively, the redistribution of lean may be due to a change in muscle fiber type within sections of the carcass. There is evidence of a decrease in isocitrate dehydrogenase activity in the *M. longissimus thoracis et lumborum* associated with selection for increasing sire PEMD [14]. This indicates a move to less oxidative metabolism and may indicate a shift to more type IIX muscle fibres within the saddle, which have been associated with increased cross-sectional area and muscle hypertrophy. Further experiments detailing oxidative capacity on the fore and hind sections may elicit the cause of lean redistribution effects.

- CONCLUSION

This paper demonstrates the effectiveness of using Australian Sheep Breeding Values to positively impact on the quantity and distribution of lean tissue within the carcass. All breeding values examined redistributed lean tissue to the saddle region, which contains the most expensive cuts. This will positively impact on carcass value as the saddle cuts are the most expensive. The mechanisms that drive the redistribution effects are unknown, though investigation into the muscle metabolic type may unlock these mechanisms. CT scanning is an effective, but currently cost prohibitive method of measuring LMY % and carcass composition. It may be used to develop more cost effective lean meat yield measurement devices that can rapidly determine carcass composition and quantify the future impact of breeding values.

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REFERENCES

1. Laville, E., et al., Effects of a quantitative trait locus for muscle hypertrophy from Belgian Texel sheep on carcass conformation and muscularity. Journal of Animal Science, 2004. **82**(11): p. 3128-37.
2. Huisman, A.E. and D.J. Brown, Genetic parameters for bodyweight, wool, and disease resistance and reproduction traits in Merino sheep. 2. Genetic relationships between bodyweight traits and other traits. Australian Journal of Experimental Agriculture, 2008. **48**(9): p. 1186-1193.
3. Butterfield, R.M., et al., Changes in body composition relative to weight and maturity in large and small strains of Australian Merino rams 1. Muscle, bone and fat. Animal Science, 1983. **36**(01): p. 29-37.
4. Hall, D.G., et al., Growth and carcass composition of second-cross lambs. 2. Relationship between

estimated breeding values of sires and their progeny performance under fast and slow growth regimes. Australian Journal of Agricultural Research, 2002. **53**(12): p. 1341-1348.

5. Hegarty, R.S., et al., Effects of available nutrition and sire breeding values for growth and muscling on the development of crossbred lambs. 2: Composition and commercial yield. Australian Journal of Agricultural Research, 2006. **57**(6): p. 617-626.
6. Gardner, G.E., et al., Using Australian Sheep Breeding Values to increase lean meat yield percentage. Animal Production Science, 2010. **50**(12): p. 1098-1106.
7. Fogarty, N.M., et al. The Information Nucleus - A new concept to enhance sheep industry gentic improvement. in Proceedings of the Association for Advancement of Animal Breeding and Genetics. 2007.
8. Cole, T.J., Sympercents: symmetric percentage differences on the 100 loge scale simplify the presentation of log transformed data. Statistics in Medicine, 2000. **19**(22): p. 3109-3125.
9. Butterfield, R.M., et al., Changes in body composition relative to weight and maturity of Australian Dorset Horn rams and wethers. 2. Individual muscles and muscle groups. Animal Science, 1984. **39** (02): p. 259-267.
10. Hegarty, R.S., et al., Effects of available nutrition and sire breeding values for growth and muscling on the development of crossbred lambs. 1: Growth and carcass characteristics. Australian Journal of Agricultural Research, 2006. **57**(6): p. 593-603.
11. Berg, R.T. and R.M. Butterfield, Growth Patterns of Bovine Muscle, Fat and Bone. J. Anim Sci., 1968. **27**(3): p. 611-619.
12. Butterfield, R.M., et al., Changes in body composition relative to weight and maturity of Australian Dorset Horn rams and wethers. 1. Carcass muscle, fat and bone and body organs. Animal Science, 1984. **39**(02): p. 251-258.
13. Fourie, P.D., A.H. Kirton, and K.E. Jury, Growth and development of sheep. II. Effect of breed and sex on the growth and carcass composition of the Southdown and Romney and their cross. N.Z. J. Agric. Res, 1970. **13**: p. 753-770.
14. Kelman K..R., et al., Selection for lean meat yield in lambs reduces muscle oxidative metabolism. Meat Science 2013 (Submitted).