Background

Computer Tomography (CT) scanning has been incorporated into commercial terminal sire sheep breeding programmes in the UK for over 20 years and has been successful in accelerating genetic gains in carcass composition. This has been seen when implemented as part of a two-stage selection strategy, where all lambs are scanned on-farm using ultrasound, then the top 10 - 20% of ram lambs, based on growth and ultrasound data, are sent for CT scanning. By identifying 'elite' individuals with superior carcass composition, an increased rate of improvement has been seen in muscle weight (CT Lean), fat weight (CT Fat) and gigot muscularity (CT muscularity), when CT scanning has been used alongside ultrasound scanning, compared to ultrasound alone.

The ability to measure other valuable traits from the resulting CT images would add further value to the CT scanning process. Variation in spine traits of sheep has been studied at SRUC using images routinely collected during CT scanning and marked variation in spine traits has been apparent within both pure and cross-bred animals. It has also been shown that information on tissue densities collected during the CT scanning process provide very good in-vivo estimates of intramuscular fat (IMF) in the loin of Texel sheep. The prediction equations developed in this work were shown to be transferable across different breeds and crosses providing an objective proxy trait to predict meat eating quality in live animals. Additionally, although current breeding indices already include information for the depth of the eye muscle, as measured by ultrasound, CT has the potential to measure this dimension with greater accuracy, from the existing images routinely collected, as well as eye muscle area. It was therefore considered valuable to investigate genetic relationships of CT-measured eye muscle measurements with ultrasound muscle depth and other carcass traits, to provide information on the potential use of these traits in future breeding programmes.

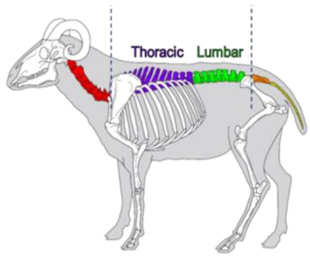
With Signet moving towards producing estimated breeding values (EBVs) from a combined breed analysis (CBA), genetic evaluations will incorporate data from different pure- and cross-bred performance recorded sheep. The CBA evaluations will also adjust some of the new and existing CT and ultrasound traits for live weight at the time of measurement, rather than the current adjustment for age at measurement. This follows on from previous work undertaken by Janet Roden for Signet to assess whether carcass composition predictions from ultrasound scanning should be adjusted for live weight, rather than age, which is currently used in UK breeding programmes. Adjusting traits for weight is expected to provide a better indicator of muscling and fatness at a fixed sale weight. Live weight adjusted traits could provide a more commercially focused breeding goal and help understand the challenges raised by producers regarding commercial lambs sired by high genetic merit rams that appear to lack finish at slaughter.

This project therefore combines investigation of the new CT traits (spine characteristics, CT-predicted IMF and CT-measured eye muscle measurements) in the context of the CBA genetic evaluation, and the impact of adjusting both the new, and current, CT traits by live weight, rather than age. Following on from this, the impact of including all CT traits alongside current growth and ultrasound breeding goal traits was also examined, to assess the potential for their incorporation into the upcoming CBA genetic evaluation.

Data

The 9 new, and 3 original, CT traits investigated in this study were:

CTFWT – CT carcass fat weight (kg)
CTMWT – CT carcass muscle weight (kg)
CTMusc – CT measured gigot muscularity (ratio of depth to width of leg muscle*100)
CTEMD – CT measured eye muscle depth (mm)
CTEMA – CT measured eye muscle area (cm^2)
SLThor – Thoracic spine region length (mm)
VNThor – Thoracic vertebrae number
SLLum – Lumbar spine region length (mm)
VNLum – Lumbar vertebrae number
SLTotal – Total thoracolumbar spine length (mm)
VNTotal – Total thoracolumbar vertebrae number
CTIMF – CT predicted intramuscular fat in the loin (%)



Approximately 6,000 records were available for each CT trait in the CBA, from male lambs CT scanned between 2005-2016. A summary of the data is given in Table 1.

Table 1. Summary of CT data available in the combined breed analysis

Trait	Count	Minimum	Maximum	Average	S.D.
CTFWT	5,952	1.0	15.2	5.71	2.29
CTMWT	5,952	7.6	27.8	16.70	3.01
CTMusc	5,952	37.7	87.0	65.48	7.62
CTEMD	5,952	20.0	54.5	37.37	4.48
CTEMA	5,952	12.4	47.1	27.17	4.70
SLThor	5,752	208	406	316.65	28.63
VNThor	5,752	12	14	12.96	0.36
SLLum	5,752	158	275	219.46	20.55
VNLum	5,752	6	8	6.61	0.49

SLTotal	5,752	386	651	535.14	43.43
VNTotal	5,752	18	21	19.55	0.54
CTIMF	5,887	0.3	4.2	2.15	0.64

Data was also available for the current growth and ultrasound carcass traits, from male and female lambs born between 2005-2016, a summary of which is given in Table 2.

Table 2. Summary of current growth and ultrasound carcass traits.

Trait	Count	Min.	Max.	Average	S.D.
USWT - Scan weight (kg)	124,667	11.50	100.00	46.67	10.71
UMD - Ultrasound muscle depth (mm)	124,671	9.00	46.50	28.77	4.21
UFD - Ultrasound fat depth (mm)	124,673	0.10	17.30	3.03	1.86

Analysis

The data were used to estimate genetic control and variability for each CT trait, at a fixed age or live weight. The genetic relationships amongst all traits (CT, ultrasound and growth) were also explored.

In addition to the live weight or age adjustments, the traits were also adjusted for: litter size the lamb was reared in; the age of the dam; flock; season of birth; management group; sex (for growth and ultrasound traits only) and dam breed at weaning.

Results

The results from the CBA comparing the age and live weight adjusted models are shown in Table 3. The main findings from the comparison of these analyses is that, although the amount of variation due to the genetics of the animals reduces for most traits, when adjustments are made for live weight, the heritability estimates generally increase. This is particularly evident for the CT eye muscle traits (CTEMD and CTEMA) and CT tissue weight traits (CTFWT and CTMWT) and suggests that selection based on live weight adjusted traits could lead to faster rates of genetic gain.

Table 3. Results from analyses adjusting for age and live weight

	Age Adjusted		Live Weight Adjusted

Trait	Genetic Variation	Heritability (h^2)		Genetic Variation	Heritability (h^2)
CTFWT	0.426	0.33		0.283	0.54
CTMWT	0.538	0.30		0.290	0.54
CTMusc	8.345	0.34		8.460	0.36
CTEMD	3.370	0.35		3.378	0.40
CTEMA	2.850	0.34		2.716	0.41
SLThor	83.64	0.35		60.38	0.32
VNThor[1]	0.028	0.24			
SLLum	49.93	0.25		41.90	0.23
VNLum[1]	0.026	0.14			
SLTotal	143.03	0.26		79.68	0.18
VNTotal[1]	0.045	0.20			
CTIMF	0.050	0.38		0.045	0.40

[1](note the vertebrae number traits were not adjusted for age or live weight)

When the relationships between the new CT traits and the current CT, ultrasound and growth traits were examined (after adjusting for live weight), some favourable and some less favourable genetic correlations were observed. The main, significant, results are shown in Figure 1.

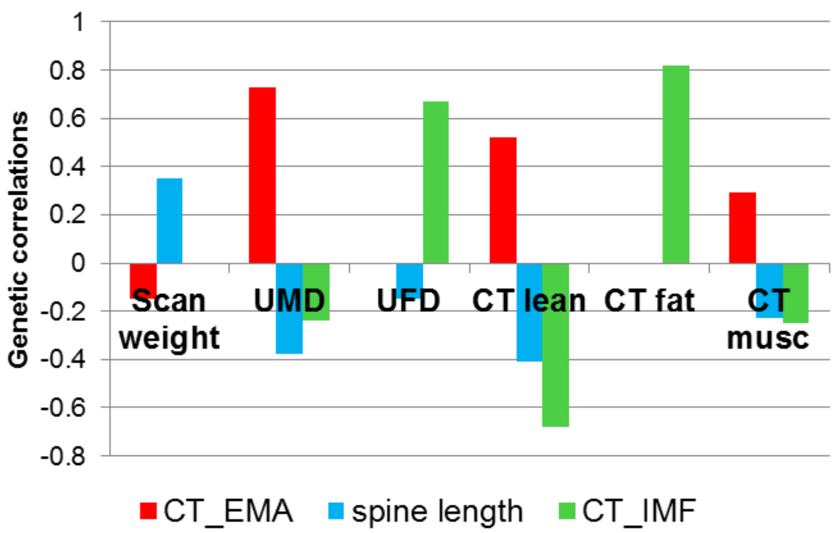


Figure 1. Correlations between the new CT traits and current CT, ultrasound and growth traits.

- The genetic associations with CT-measured eye muscle area (CTEMA) were mainly favourable, with increases in CTEMA associated with increases in UMD, CTMWT and CTMusc. The only exception to this was with USWT, where an increased CTEMA was associated with a slight reduction in scan weight.
- The correlations associated with spine lengths were mainly unfavourable, suggesting that animals with longer spine lengths will have a tendency to have reduced muscle proportions. However, animals with longer spine lengths would have a tendency to have heavier carcass weights.
- The correlations associated with intramuscular fat (IMF) were also unfavourable with both the muscle and fat related traits. Increases in IMF (which would benefit meat eating quality) would tend to be associated with higher levels of fat, and reduced levels of muscle, in the overall carcass.
- The majority of correlations associated with vertebrae number were mainly non-significant, suggesting that genetic selection for these traits would not affect other breeding goals..

Conclusions and recommendations

Could the new CT traits be included in the combined breed genetic evaluation?

The heritabilies estimated for the new CT traits (when adjusted for live weight) suggest that genetic selection would be possible. In the CBA most new CT traits showed a moderate heritability (in the range of 0.18 to 0.41), the highest being associated with the muscle traits (CTEMA, CTEMD) and CTIMF. The vertebrae counts had lower heritability estimates (0.14 to 0.24).

Selecting for longer spine length, or more vertebrae, would not be antagonistic with the breeding goal of increased growth to 21 weeks. However, there was a tendency for unfavourable genetic relationships between the current muscle related traits (UMD, CTMWT and CTMusc) and the spine traits. The majority of correlations estimated were low, but nonetheless indicate that animals with longer spines may have lower levels of muscling and muscularity.

What would be the effects of adjusting CT and ultrasound traits for live-weight, rather than age in the combined breed genetic evaluation?

The results suggest that selection for live-weight adjusted CT and ultrasound traits may lead to faster rates of genetic gain, for most traits, due to the increased heritability estimates. There was very little difference observed for the spine traits, therefore these would not alter significantly between age or live-weight adjustments.