
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

Ultrasonic fat depths in Romney lambs and hoggets from lines selected for different production traits

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ABSTRACT

Real-time (B-mode) and simple (A-mode) ultrasonic instruments were evaluated in 2 experiments to assess their potential for measuring carcass fat and muscle variables. In a third experiment, progeny of five Romney selection lines were ultrasonically scanned at regular intervals from 5 to 14 months of age to record backfat thickness (C), GR and the width (A) and depth (B) of the *L. dorsi* muscle.

In the one calibration experiment where the Toshiba machine was used, the machine was found to be particularly appropriate for measuring GR depth acheiving a weight adjusted partial correlation of 0.81 with the carcass measurement and a repeatability of 0.86. Comparable figures for the AIDD scanner in two experiments averaged 0.75 and 0.82 respectively for C fat depth measurement. Prediction equations for the chemical carcass lipid content showed that including either C or GR ultrasonic fat depths provided significantly improved estimates over those using only live weight. The addition of ultrasonic muscle widths or depths provided little additional advantage.

The ultrasonic C and GR measurements confirmed that the production index line, selected on an index comprising dam's number of lambs born and the animals own weaning and hogget fleece weight, was the leanest. The single trait line selected on dam's number of lambs born, was slightly leaner than the controls, while the hogget fleece weight line was similar to the control line. The ranking of the 100 day weight selection line was found to vary with year of birth measured, but on average was similar to the control line. In contrast no major differences were detected in muscle width or depth among any of the selection lines

Keywords Ultrasound; selection; sheep; fat depth measurement; carcass composition

INTRODUCTION

The development of simple methods for assessing fatness is an important research objective in developing methods for selection of leaner sheep. Real-time ultrasonic scanners offer the possibility of measurement of both fat and muscle depths in contrast to simple A mode instruments such as the AIDD scanner (Gooden *et al.*, 1980; Purchas and Beach, 1981) which are limited to fat depths. However using the AIDD scanner, McEwan *et al.* (1984) reported that the ultrasonic subcutaneous backfat thickness was moderately heritable based on half-sib analyses in the Woodlands Romney selection lines. Additionally lines of sheep selected for fecundity related traits had reduced weight adjusted ultrasonic backfat thickness, relative to a control population at 8 months of age. As these differences among the lines were unexpected it was decided that the study should be repeated and extended. In parallel studies, real time scanners were also evaluated. This paper reports 3 experiments that were conducted at Woodlands Research Station. Two experiments investigated the interrelationships between ultrasonic and carcass measurements, whilst a third experiment used the ultrasonic machines in a serial scanning program, with measurements at approximately monthly intervals, on ewe lambs from the Woodlands selection flocks over two additional years.

METHOD

Evaluation of the AIDD and Toshiba Scanner; Experiment 1

Thirty, 14 month old Romney rams were independently scanned twice on the day prior to slaughter using a Toshiba Sonolayer SAL-22A (a real time B-mode scanner) with a 3 MHz linear probe 8.5 cm wide. Offsets (water filled latex bags) supplied by Toshiba were used to prevent the ultrasonic heads distorting the region of interest. The animals were clipped closely and vegetable oil

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applied to the region to be measured. When a suitable display was obtained the picture was frozen, distances being measured with in-screen calipers. Measurements recorded were A and B representing the width and depth of the *L. dorsi* respectively (Palsson, 1939). The GR tissue depth (Kirton and Johnston, 1979) was measured with the Toshiba, in a separate scan, by placing the ultrasonic head parallel to the backbone, but displaced 11 cm around the rib cage. This enabled the top of the 12th rib to be correctly identified for the depth measurement. The AIDD scanner (an A mode machine) was used to measure C, the depth of fat covering the top of the *L. dorsi* at the 12th rib (Palsson, 1939). Only one side of the animal was measured with the Toshiba, but with the AIDD both sides were measured and the results averaged. After slaughter at a commercial freezing works the hot carcass weight was recorded and after chilling for 24 hours, independent duplicate measurements were taken of C, GR, A and B using a steel rule.

Evaluation of the AIDD and Aloka Scanner; Experiment 2

Thirty, 15 month old Coopworth rams were used with a design similar to experiment 1. The B-mode scanner was manufactured by Aloka and featured a 11 cm 3 MHz head. Additionally carcass water was estimated by freeze drying, lipid by soxhlet extraction ash in a muffle furnace at 550°C, with protein being estimated by difference.

Repeated Scanning of the Selection Flocks; Experiment 3

The Woodlands Romney selection flock (McEwan *et al.*, 1984; Tate, 1983) consists of 5 self contained selection lines, with selection having commenced in 1973. Three lines are selected for a particular trait, viz. dams number of lambs born (dam NLB), 100 day weight and hogget fleece weight. The fourth line is selected on an index comprising all three traits, while the fifth is a randomly selected control.

Ewe lambs born in 1984 and 1985 (approximately the fourth generation since selection commenced), were selected for fatness assessment using the following criteria: within each year, 2 single and 2 twin born lambs (the latter born to separate dams) were randomly selected within each sire group. Five new sires were used in each selection line per year.

The selected animals were weighed and the Toshiba Sonolayer SAL-22A scanner used to measure A, B and GR and the AIDD scanner to measure C as detailed for the previous experiments. Measurements were made at approximately 5, 6, 7, 8, 10, 11 and 14 months of age. At each measurement age all animals were measured on one day and the same operators were used throughout the trial.

Analysis

The data collected from the evaluation experiments were analysed to obtain partial (live weight adjusted) correlations among the ultrasonic and carcass measurements. In the case of experiment 2, where carcass chemical composition was also determined, stepwise regression analysis was performed initially fitting preslaughter live weight and subsequently *in vivo* or carcass measurements. The data from experiment 3 was analysed by fitting least squares models with both fixed and random effects. Initial models included all fixed (year, selection line, birth/rearing rank, docking group, age of dam) and random effects (sire nested within subline and year), first order interactions and covariates (live weight or birthday) appropriate to the analysis; the means and standard errors presented are derived from models with non significant terms deleted.

RESULTS AND DISCUSSION

Interrelationships between Carcass and Ultrasonic Measurements

Results from experiments using ultrasonic machines have been presented in many ways by different workers. In his review on use of ultrasound to predict carcass composition, Simm (1983) proposed that partial correlations should

TABLE 1 Partial correlations among traits after adjustment for preslaughter live weight (Experiment 1).[1]

Trait [2]	C ult.	C	GR ult.	GR	A ult.	A	B ult.	B
C ult.	0.77							
C	0.71	0.91						
GR ult.	0.71	0.79	0.86					
GR	0.72	0.73	0.81	0.97				
A ult.	0.36	0.14	0.35	0.25	0.51			
A	0.06	0.27	0.03	0.19	0.38	0.76		
B ult.	0.31	0.27	0.48	0.41	0.43	0.19	0.62	
B	0.17	0.14	0.36	0.26	0.47	0.24	0.72	0.73
Mean	3.64	5.31	13.3	16.3	63.8	60.7	29.9	28.5
RSD	1.11	2.29	3.91	4.79	4.20	4.14	2.70	2.82

[1] Correlations (repeatabilities) on the diagonal; off-diagonal correlations are averages of two independent estimates available for each correlation (averaged using Fischer's Z transformation).
[2] C ult. (ult.=ultrasonic) was measured using the AIDD scanner. GR ult., A ult. and B ult. were obtained using Toshiba scanner. The other traits are carcass measurements obtained with a steel rule.

be presented after adjustment for live weight and that information be presented in a form to enable calculation of residual standard deviations, these being much more stable while also allowing comparisons across experiments.

The partial correlations after correction for preslaughter live weight in Experiments 1 and 2 (Tables 1 and 2) had several interesting features. Firstly, the partial repeatabilities (intraclass correlations) of C and GR measured ultrasonically were high and similar to the correlations with the corresponding carcass measurements. However, the repeatability observed for GR in experiment 2 was lower and may have been due to operator inexperience and the unavailability of a foot-activated freeze frame. The mean fat depths measured ultrasonically were generally somewhat lower than those measured on the carcass, probably due to operator compression of the fat layers. This problem has been noted by Purchas and Beach (1981). The B-mode machines were not used to estimate C in these experiments because their resolution is low (1.0-1.4 mm) relative to the live weight-adjusted residual standard deviation

TABLE 2 Partial correlations among traits after adjustment for preslaughter live weight (Experiment 2).[1]

Trait [2]	C ult	C	GR ult.	GR	A ult.	A	B ult.	B	fat% [3]
C ult.	0.86								
C	0.78	0.93							
GR ult.	0.47	0.47	0.52						
GR	0.71	0.81	0.54	0.93					
A ult.	0.20	0.00	0.08	0.05	0.41				
A	-0.36	-0.51	-0.14	-0.30	0.04	0.93			
B ult.	-0.07	0.18	-0.04	-0.08	0.10	0.23	0.51		
B	-0.26	-0.43	-0.04	-0.19	0.16	0.57	0.41	0.92	
Fat%	0.63	0.76	0.35	0.71	-0.05	-0.49	-0.24	-0.32	
Mean	4.42	6.68	10.9	13.0	53.5	63.0	29.1	29.4	25.0
RSD	1.19	2.30	2.34	2.61	4.94	4.36	2.47	4.06	3.04

[1,2] As for Table 1.
[3] Percentage chemical fat in the hot carcass.

for C of around 2.3 mm. However the machines are able to detect fat layering at position C, which commonly causes measurement errors when using the AIDD machine in older animals.

The live weight-adjusted repeatabilities of ultrasonic muscle depths and widths were generally poorer than for fat depths, with best results being obtained for the depth of the *L. dorsi*. In the case of muscle depth, the problem is due to the relatively low variability of this trait. While muscle width has a higher variability, the resolution of the B-mode machines for horizontally separated objects is lower and the vertical boundary edge of the muscle has poor reflective characteristics with particularly poor definition between the *L. dorsi* and *M. multifidus* boundaries.

Prediction of Carcass Composition

Carcass composition data from Experiment 2 allowed evaluation of the various ultrasonic measurements (Table 3). Live weight was initially fitted as it is normally available and is cheap to measure. It accounted for 44% of the variation in percentage carcass fat. Ultrasonic C was the best single additional trait after live weight, accounting for a further 23% of the variation with live weight and ultrasonic GR was the next best predictor set. In neither case did live weight account for any significant additional variation after fitting ultrasonic C or ultrasonic GR, so the prediction equations from models where this effect was removed are presented in Table 3. Fitting further ultrasonic traits gave no significant improvement.

TABLE 3 Value of ultrasonic measurements and preslaughter live weight in predicting the percentage chemical fat content of the hot carcass (Experiment 2).[1]

Model	R^2	RSD	
-	-	3.98	
Live weight	0.44	3.04	***[2]
Live weight + C ult.[3]	0.67	2.36	***
Live weight + GR ult.	0.52	2.87	*
Best ultrasonic prediction equations			
C ult.[3] Fat% = 15.5 + 2.14 C ult.	0.64	2.42	
GR ult Fat% = 15.3 + 0.89 GR ult.	0.47	2.96	
Best carcass prediction equations			
C Fat% = 17.7 + 1.08 C ult.	0.78	1.92	
GR Fat% = 15.6 + 0.73 GR	0.72	2.14	

[1] Live weight was initially included in all models because of ease of measurement; additional terms were then included in order of effectiveness in reducing the RSD, except that the model including GR ult and carcass traits were included for comparative purposes. The mean of the two measurements collected was used for this analysis.
[2] Significance of the last term added to the model.
[3] Abbreviations as in Table 1.

The potential accuracy of ultrasonic measurements can be compared against linear carcass measurements. It was found that carcass C was the best predictor and accounted for 78% of the variation in carcass fat percentage. The results suggest that the ultrasonic C measurement with the AIDD achieved 83% of the potential of the best carcass trait examined for predicting percentage carcass fat.

In summary the results suggest that all machines are useful for predicting carcass composition and fat depths. The AIDD is the easiest to use, requiring no clipping of the animals, and its commercial equivalent (the Delphi) is relatively cheap compared to the B-mode machines. It provided the best predictions of carcass composition. Our studies gave similar results to those previously reported (Gooden *et al*., 1980; Purchas and Beach, 1981; Bass *et al*., 1982; Nicol and Parratt, 1984; Nicol *et al*., 1988), especially in comparison with the 2 latter studies, which also used heavier and older animals.

Of the B-mode machines, the Toshiba was superior in these studies, possibly because of operator familiarity. The use of offsets with these machines to reduce compression artifacts is recommended, with GR as the measurement suggested if these machines are to be used to predict carcass composition. Comparison of the Toshiba and Aloka results with other B-mode machines (Leymaster *et al*., 1985; Cameron and Smith, 1985) and earlier reports summarized by Alliston (1983) suggest the present B-mode results are comparable with those of other workers. However, these machines seem no better than the AIDD, an A-mode instrument, for predicting carcass fat percentage.

TABLE 4 Live weights and fat depths adjusted for live weight in the Woodlands Romney selection lines expressed as percentage of the controls[1]

Selection line	Live weight	Live weight-adjusted fat depths					
	Nov	Feburary		May		November	
		C	GR	C	GR	C	GR
Control	43.6	1.73	6.3	3.09	8.7	3.91	13.4
	(100)	(100)	(100)	(100)	(100)	(100)	(100)
Prod index	110	81	79	91	85	85	93
Dam NLB	105	96	101	93	103	96	97
100 day wgt	116	98	99[3]	107	102	105	97
Hog. fleece	109	94	104	104	102	101	98
Approx SEM[2]	1.7	3.9	4.6	5.1	5.1	3.5	4.0

[1] The data presented were obtained from a model including year, subline, sire/ and birth/rearing rank, with the sire (nested within subline and year) used as an error term for subline differences. The live weight adjusted model included the above terms as well as live weight at the measurement time and the interactions; year by subline and live weight by year. The same test was used to determine differences between the sublines.
[2] Expressed as a percentage of the control value
[3] Year by subline interaction significant; see discussion.

Selection Line Differences in Live Weight

In experiment 3, selection line differences were examined. The final model included year, subline, sire, birth/rearing rank and an age covariate. Animals were 3 to 6 kg lighter at all measurement times during the second year. As expected twin reared animals were lighter than singles. There were highly significant selection line differences in the live weight at each of the measurement times. These differences in weight were relatively consistent, both in ranking and in percentage terms. Results are presented for November live weights at 14 months of age in Table 4. They are similar to those presented previously (McEwan *et al.*, 1984), with the 100 day weight selection line being the heaviest and all the other lines heavier than the controls, the amount depending on genetic correlation between the trait selected and live weight.

Weight-adjusted Selection Line Differences

As the selection lines differed in live weight and because fat and muscle depths are highly correlated with the live weight, some allowance has to be made for this factor when comparing ultrasonic depth differences between the selection lines. This was achieved by including live weight as a covariate in the analysis of the data. However, because of the repeated nature of the measurements spanning a wide liveweight range, the results obtained by adjustment for live weight at a single date, (using the within flock/measurement date regression of ultrasonic traits on live weight) could be contrasted with the live weight/ultrasonic trait relationship obtained across measurement dates either for individual animals or for group averages.The C and GR data for Feburary, May and November are presented in Table 4.

For the analysis of the fat measurements at a particular date; year, selection line, sire, and occasionally year by subline or live weight by year interactions were significant after adjustment to the mean live weight at that time. As expected the variation in the ultrasonic traits was largely due to liveweight effects. The live weight by year interactions were significant for only GR tissue depth in August and November and were due to lower slopes in the first year. The year by selection line interaction arose because the ranking of the 100 day weight line changed between years over the February to April period. During this time the 100 day weight selection line, was fatter than the controls by an average of 13% in first year and leaner by an average of 14% in the second year

($P<0.05$ to $P<0.01$ for both C and GR) respectively. The other selection lines were considerably more stable in their rankings both between years and across ages although differences among lines were reduced during the winter period. No biological reason can be offered for this variation between years in the 100 day weight line. On average over the two years the 100 day weight line was ranked the same as the previous study (McEwan *et al.*, 1984). However in August, a time not previously examined, the 100 day weight line was significantly fatter than the controls ($P<0.05$). The production index selection line was considerably leaner in both the C and GR measurements, with the differences between it and the control line achieving or approaching significance throughout the experiment (table 4). The size of the effect was consistent with the results presented in McEwan *et al.* (1984). The hogget fleece weight selection was little different from the control line and very similar to the previously reported results. In contrast with the previous work there was a much smaller difference in C fat depths and no difference in GR tissue depths in the dam NLB line. Muscle depths and widths were affected by year and weight but no significant or consistent differences were apparent among the various selection lines. Significant sire effects (within year and subline) were observed but no attempt was made determine heritability estimates, because of the low number of progeny per sire.

Comparisons of Selection Lines Corrected for Live Weight by Different Methods

Plots of fat depth C against live weight for 3 of the selection lines at different ages (Fig. 1) highlights liveweight differences among the lines and shows the leanness of the production index line compared with the control line. The 100 day weight selection line was apparently leaner at low live weights and fatter at heavy weights than the control line although differences in the fat depth/live weight relationship were not significant. Other authors have also reported a shifting of the relationship during the winter period when growth is low (reviewed by Thorrold *et al.* 1988). Trends in GR tissue depth with live weight among the selection lines were similar to those for C fat depth, except that the individual points more closely approximated a linear relationship (data not presented).

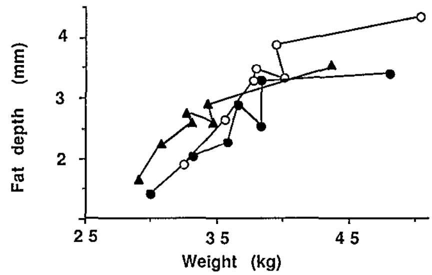

FIG. 1 Effect of live weight on fat depth C (experiment 3); the mean live weights and age-adjusted fat at each measurement time (control ▲, production index●, and 100 day weight ○ selection lines).

In a further series of analyses, curves for the relationship of measurement C and live weight were obtained for each individual animal. The parameters derived from this investigation were then examined in a model including year, selection line, sire within selection line and year, age of dam birth/rearing rank and birthday. The results and conclusions were similar to those from the within time analyses, with there being no difference in the fat/weight slopes among selection lines. However, intercepts were significantly different, the magnitude and significance depending to some extent on the weight at which lines were compared. Similar results were obtained for the GR tissue depth.

Since the initial observations by McEwan *et al.* (1984), Parratt *et al.* (1987) have examined a variety of other selection lines for the effects of selection for productive traits on subcutaneous backfat thickness and shown a variety of significant changes. In flocks of similar genetic origin to that reported in the present study, weight adjusted fat depths were reduced in the fertility index and dam number of lambs born lines by between 6 and 21%, while the Ruakura fertility line had a 7% weight adjusted reduction relative to its control line. In contrast they found a significant 10% increase in fat depth in another line selected on dams number of lambs born.

Additionally, significant changes in fecundity have been recently observed in lines selected for altered body composition with leaner lines being accompanied by higher fecundity (Fennessy pers. comm.). The variability of these results, between years and flocks, demonstrates the need to examine correlated responses over several replicated lines and over several years before general conclusions can be made.

CONCLUSIONS

The experiments have demonstrated the value and predictive ability of both A and B-mode ultrasonic machines, with the latter being especially useful for measurements of GR and *L. dorsi* muscle depth, particularly if offsets to prevent compression are used. The study confirmed reported reduction in fat depth in the production index line, but showed an inconsistent effect of selection in the 100 day weight line across years and a dimutation of the difference in the Dam NLB in comparison to an earlier assessment. This highlights the need for studies of correlated responses to selection to be measured over several years and preferably in several independent flocks.

ACKNOWLEDGEMENTS

To Mataura freezing works and the staff at Invermay abattoir for slaughtering the animals; M. Pile for carcass chemical analysis; K.J. Knowler, C.D. Mathieson. and C.G. Hughson for care of the animals and assistance with the measurements; J.P. Hanrahan, P.F. Fennessy and K.G. Dodds for statistical advice and discussion.

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