APPLICATION OF A REAL-TIME LINEAR ARRAY ULTRASOUND SYSTEM TO THE EVALUATION OF LIVE CATTLE

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ABSTRACT

A real time linear array ultrasound machine was assessed for bias accuracy and precision. A total of 51 heifers, and steers were scanned for fat thickness over the longissimus muscle, the shoulder and rump; for *M. longissimus* area between the 12th and 13th ribs; and marbling was subjectively evaluated from M. longissimus scans. Ultrasound data were compared with a live judging committee estimates and with carcass values obtained during USDA grading. Data adjusted for live weight were analysed by correlation and regression techniques. Ultrasound estimates of fat thickness were lower ($P<.01$) than carcass measurements. Shoulder fat thickness estimation was the lowest in precision and accuracy. The residual standard deviations of ultrasound estimates of fat thickness were not ($P>.05$) influenced by fat thickness and sex. Ultrasound estimates of *M. longissimus* area were not different ($P>.05$) from carcass values and were high in precision (RSD: 2.6 to 6.5cm^2). The precision and accuracy of data collected by real time linear array ultrasound system indicate a potential for the application of the ultrasound technique to grading of livestock and carcasses.

Key words: Beef Cattle, Ultrasonić Evaluation, Instrument Grading

INTRODUCTION

Three important factors in predicting percent fat free muscle in beef were identified as adjusted fat thickness, marbling score and *M. longissimus* area (Kauffman et al. 1975;C rose and Dikeman, 1976). Ultrasound techniques have been reported for estimating all these factors (Andersen er al., 1982; Eveleigh et al., 1985; Henningsson et al., 1986) except marbling.

Ultrasound is valuable for live animal evaluation (Andersen et al., 1982; Lister, 1984) and the introduction of new techniques and equipment such as real time scanners would further improve data reliability (Simm, 1983)

Since the early work of Temple et al. (1956) and Stouffer et.al. (1961), correlation between ultrasonic and carcass data has been used to estimate accuracy of the scans. Such correlations are highly influenced by total variation in weight and carcass composition (Andersen, 1975). Regression is better for evaluating the relationship between ultrasonic and carcass estimates as it takes account of the variation in both (Kempster, 1984).

In this study, live cattle were scanned to evaluate a new real time linear array machine for bias, precision and accuracy, to attempt an estimation of marbling and to obtain USDA yield grades from ultrasound data.

MATERIALS AND METHODS

A total of 51 animals (26 steers and 25 heifers) of varying breeds and sources were used. Live weight ranged from 355 to 686 kg.

Cattle were placed in a squeeze chute and scanned with a Technicare Utrasound Linear Array System 210 DX[1]. This equipment is small, reasonably robust and features a frame-freeze oscilloscope screen. Scans were made with the Technicare connected to a one-half inch video cassette recorder. Transducers can be quickly interchanged and both the 3 MHz and 5 MHz transducers were used; 3 MHz for longissimus muscles area and 5 MHz for fat thickness. Cattle were scanned

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for fat thickness at the shoulder, between the 12th and 13th rib and over the rump.

Shoulder fat thicknees was measured between the fifth and sixth ribs, off the posterior edge of the scapula. The rump fat thickness was measured 5 cm lateral from midline at the center of the pelvic bone. Screen displays of scans were "frozen" and fat thickness measured with a built-in cursor. The date, animal number, sex and a code number for the measurements were also recorded on-screen. From the skin line, the cursor was also separated into two and one moved down to the innermost backfat layer adjacent to the *M. longissimus*. To measure *M. longissimus* area between the 12th and 13th ribs, two separate scans were made because the muscle was longer than the Technicare unit's screen width. A plastic clamp was used as an external marker of the point of overlap for the two scans - one scan ending and anothe beginning from the clamp. The screen images, with animal information, were recorded on video cassette. The recorded scans were played back on a 30cm separate monitor to produce life-size images of the scans which were traced from the screen onto acetate paper and the *M. longissimus* area measured by planimeter. Scan interpretation was by one operator throughout the study. Marbling was subjectively evaluated from the scans of the 12th to 13th rib position by comparison with USDA standards.

A commitee of four experienced personnel visually appraised each animal for live weight, dressing percent, fat over the 12th to 13th rib, and *M. longissimus* area. Animals were slaughtered and conventionally dressed and chilled before a USDA grader estimated carcass yield and quality grade variables. The judging commitee also evaluated each carcass for *M. longissimus* area, fat over the *M. longissimus* muscle, marbling, kidney, pelvic and heart fat and gave their judgment on yield and quality grades.

All data were adjusted for variations due to live weight before analyzing the variance due to sex. To test each variable for bias, accuracy and precision, the mean difference, standard deviation of the difference and correlation, respectively, between ultrasound or committee and carcass data were obtained. For further analysis of ultrasound data for precision and accuracy, unadjusted data for fat thickness and *M. longissimus* area were subjected to correlation and multiple linear regression analyses before and after partition into groups based on actual carcass measures of fat thickness of 12mm and *M. longissimus* area of $90cm^2$. Live weight was included as an independent variable in each regression analysis in conjunction with one ultrasonic measurement. The significance of adding another ultrasonic measurement to regression models was calculated. A reduction in residual variance was interpreted as increased precision.

RESULTS AND DISCUSSION

For fat thickness measurements at the three positions, the mean of the ultrasound values were lower ($P<.01$) than the carcass values except for rump fat in heifers (Table 1). This discrepancy between live ultrasonic and carcass measurements is not unexpected (Wallace *et al.*, 1977) and is partly due to carcass deformation resulting from post-slaughter treatment particularly hanging (Miles *et al.*, 1972). The effect of hanging is more pronounced in the thoracic and lumbar regions as a result of cranial and caudal movement respectively of soft tissue and the distortion of the vertebral column (Miles *et al.*, 1972).

It would appear from Table 1 that the judging committee estimates of thickness of fat over the *M. longissimus* muscle (FT) were closer to the carcass value than ultrasound estimates. In fact, this is not so as the committee estimates had higher standand deviations of the difference and lower correlation coefficients than ultrasound estimates (Table 3). Separation of the mean difference by sex (Table 3) showed that while the committee underestimated FT in steers, it overestimated in heifers. Ultrasound was consistent in underestimation of fat for both sexes.

Amongst ultrasound estimates of fat thickness at different locations, precision and accuracy were poorest in the estimation of shoulder fat in steers while rump fat estimation in heifers was closest in precision and accuracy to fat over the M. longissimus. Similar findings were reported by Wallace, *et al.* (1977). These results are in agreement with the report of Miles *et al.* (1972) that bias was least and accuracy highest if fat thickness was estimated at the 13th thoracic rib even though absolute fat thickness at this location is small. The lower accuracy in the anterior position (shoulder) was attributed by Miles *et al.* (1972) to confusion of fat boundary with the ventral surface of the trapezius. This is not so in the present study because real time scanning allows choice of the best scan position and resolution before the image is frozen and measured. The real problem may be the accuracy of shoulder fat measurement in the carcass.

The *M. longissimus* area (MLA) estimated by ultrasound technique was not different (P>.05) from estimates from the carcass (table 1). *M. Longissimus* area bias is usually positive for static B mode scanners, e.g., Scanogram, indicating an underestimation of the muscle depth which is the parameter related to echo time (Andersen *et al.*, 1982). The ability of real time B mode scanners, such as used in this study, to constantly update recived signals improves the precision of scans of active tissues such as muscles.

Data for FT and MLA were subjected to simple and multiple regression analyses before and after partition into sexes, FT groups and MLA groups (Tables 4 and 6). The residual standard deviation (RSD) of ultrasound determination of fat thickness was not significantly influenced by fat thickness and sex (Table 5). For animals with 12mm FT or below, RSD was the same in heifers and steers. For animals with more than 12mm FT, RSD was much lower in steers (2.8) than in heifers (4.3). However, the regressions for the two sexes were not significant, and ultrasonic FT could account for only 32% of the variations in actual carcass FT in both sexes (Table 5). For MLA data (Table 7), sex and FT were both significant factors in the ultrasound determination of MLA. Prediction in heifers had lower (P<.01) RSD and higher r^2 while animals with FT>12mm had lower RSD but lower r^2 as well. Inclusion of FT in the regression was significant only in FT>12mm steers (Table 7). In groups based on MLA, RSD was lower (P<.01) for MLA in MLA<90cm^2 heifers and for FT in MLA>90cm^2 steers. In all cases inclusion of MLA and live weight in the regression of fat thickness did not (P>.05) reduce RSD or increase coefficient of determination. The RSD values for FT in this study are similar to the values reported by Wallace, *et al* (1977). The much larger variation in RSD for MLA in this study was due to sex, FT and live weight differences from the study of Wallace, *et al.* (1977), who used lighter weight steers (439 kg) as compared with heavier heifers (499 kg) and steers (522 kg) used in this present study.

From these results it can be seen that ultrasound data collected by the real time linear array technique are sensitive to live weight, sex and fat thickness. Precision of MLA estimation increased with increasing FT in this study (Table 7) in agreement with the reports of Watkins *et al.* (1967) and Bennett *et al.* (1982), and contrary to the report of Busk (1984) that there was no correlation between intermuscular fat thickness and ultrasound imaging. The effect of FT does not appear related to live weight as there was no correlation between these variables. There was a high correlation between live weight and MLA, and once data had been grouped based on MLA, live weight inclusion in the regression was not significant (Tables 5 and 7).

The marbling scores obtained from ultrasound scans were 1 to 1.6 points below scores from the carcass (Table 2). Marbling was the least accurate of the ultrasound measurements in this study. Usually, ultrasonic scanning of animals is directed at imaging the strong echoes of tissue interfaces; marbling however is imaged by the relatively weak echoes within tissues that are due to ultrasound scattering by tissue inhomogeneities

TABLE 1: MEANS AND STANDARD ERRORS OF VARIABLES MEASURED IN THE LIVE ANIMAL BY ULTRASOUND AND A JUDGING COMMITTEE AND IN THE CARCASS BY GRADING.

	Steers		Heifers		Both Sexes	
Variable	Mean	SE	Mean	SE	Mean	SE
Number	26		25		51	
Live weight (kg)						
Committee	517[b]	11.7	486[a]	5.7	502[ab]	6.8
Actual	521[b]	15.2	499[a]	7.7	510[b]	8.7
Hot Carcass						
Weight (kg)	336[b]	10.6	312[a]	5.8	324[b]	6.3
Dressing %						
Committee	63[a]	.2	63[a]	.1	63[a]	.1
Actual	64[b]	.4	63[a]	.5	63[ab]	.3
Shoulder Fat thickness (mm)						
Ultrasound	24[a]	2	26[a]	1	25[a]	1
Carcass	44[b]	1	41[b]	2	42[b]	1
Rump Fat thickness (mm)						
Ultrasound	32[a]	2	37[a]	2	34[a]	1
Carcass	44[b]	1	39[ab]	3	42[b]	2
Fat over M. longissimus (mm)						
Ultrasound	10[a]	.8	10[a]	.7	10[a]	.5
Committee	11[a]	.6	14[b]	1.0	12[b]	.6
Carcass	13[b]	1.0	12[b]	1.0	13[b]	.7
M. longissimus Area (cm^2)						
Ultrasound	87.1[b]	3.35	94.8[b]	3.08	91.0[b]	2.32
Committee	81.9[a]	2.17	79.3[a]	1.58	80.6[a]	1.34
Carcass	87.7[b]	2.79	92.9[b]	2.38	90.3[b]	1.86

[a,b]Variable means with different superscripts differ (P<.01)

TABLE 2: MEANS AND STANDARD ERRORS OF QUALITY AND YIELD GRADE VARIABLES.

Variable	Steers Mean		Steers SE	Heifers Mean		Heifers SE	Both Sexes Mean		Both Sexes SE
Number		26			25			51	
Marbling									
Ultrasound	4.0[a]		.27	4.7[a]		.26	4.3[a]		.19
Carcass	5.6[b]		.21	5.8[b]		.25	5.7[b]		.16
KPH fat (%)									
Committee	2.5[b]		.10	3.0[b]		.10	2.8[b]		.08
Carcass	1.9[a]		.09	2.1[a]		.08	2.0[a]		.06
r		.44			.36			.66	
Yield Grade									
Ultrasound+									
a	2.6[c]		.03	2.2[a]		.01	2.4[b]		.04
b	2.7[c]		.03	2.1[a]		.02	2.4[b]		.04
Committee	2.6[c]		.03	2.9[e]		.02	2.8[d]		.03
Carcass	2.7[c]		.04	2.1[a]		.02	2.4[b]		.04
Quality Grade									
Committee	4.6[a]		.34	5.3[b]		.32	5.0[ab]		.24
Carcass	5.1[b]		.21	5.3[b]		.27	5.2[b]		.17
r		.45			.68			.22	

+Ultrasound yield grade a used est. HCW = LWT x .635; while ultrasound yield grade b used actual HCW. Both a and b used 3.5 as %KP value while committee and carcass yield grades used actual %KPH value.

$P<.05$ is $r \geq .038$, .27; $P<.01$ is $r \geq .49$, .35 for $n = 25$ and 50 respectively.

KPH	=	Kidney, pelvic and heart
HCW	=	Hot carcass weight
LWT	=	Live weight
r	=	Correlation coefficient between committee and carcass data.

TABLE 3: DIFFERENCE AND CORRELATION BETWEEN ULTRASOUND OR COMMITTEE AND CARCASS DATA.

	Mean Difference[a]			SD of Difference			r[a]		
Variable	S	H	Both	S	H	Both	S	H	Both
For over M. longissimus (mm)									
Ultrasound	-3.0	-1.8	-2.4	.27	.13	.67	.79	.79	.78
Committee	-2.8	1.4	-0.7	.54	.27	2.11	.66	.73	.61
Shoulder Fat (mm)									
Ultrasound	-19.8	-15.3	-17.6	5.04	2.50	4.58	.06	.11	.06
Rump Fat (mm)									
Ultrasound	-11.8	-2.4	-7.2	3.30	1.63	5.41	.35	.69	.53
M. longissimus Area (cm^2)									
Ultrasound	-.12	1.99	.91	.216	.129	1.085	.86	.86	.87
Committee	-5.31	-13.55	-9.35	5.350	2.647	5.915	.64	.45	.52
Marbling Score									
Ultrasound	-1.67	-1.09	-1.38	1.536	1.631	1.596	.20	.20	.21
Yield Grade									
Ultrasound									
a	-.01	.04	.015	.135	.105	.122	.81	.55	.93
b	.03	-.001	.016	.099	.080	.091	.93	.77	.96
Committee	-.01	.81	.391	.212	.105	.443	.37	.61	.48

[a]Differences and correlations were between ultrasound or committee values and carcass values.

TABLE 4: MEANS, STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS OF FAT THICKNESS MEASURED LIVE BY ULTRASOUND AND IN THE CARCASS OF CATTLE GROUPED BY FAT THICKNESS AND M. LONGISSIMUS AREA.

Group Variable	n	Sonic Mean	SD	Carcass Mean	SD	r
H	25	10	3.4	12	5.0	.79**
S	26	10	4.2	12	4.9	.79**
Both Sexes	51	10	3.8	13	4.9	.78**
$FT \leq 12mm$						
H	17	9	2.5	10	2.7	.65**
S	14	8	3.9	10	2.8	.72**
Both Sexes	31	9	3.2	10	2.7	.67**
$FT > 12mm$						
H	8	14	2.4	18	4.2	.43
S	12	13	3.0	17	3.4	.67**
Both Sexes	20	13	2.8	17	3.7	.56**
$MLA \leq 90cm^2$						
H	10	11	3.7	12	5.5	.90**
S	15	11	4.6	13	5.6	.82**
Both Sexes	25	11	4.2	13	5.5	.83**
MLA>90cm2						
H	15	10	3.3	13	4.7	.73**
S	11	10	3.7	13	4.1	.75**
Both Sexes	26	10	3.4	13	4.4	.73**

**$P<0.01$,
*$P<0.05$

H = heifers,
S = steers,
MLA = M. longissimus area,
FT = actual fat thickness over the M. longissimus,
LW = live weight,
ULMLA = ultrasonic M. longissimus area,
UFT = ultrasonic fat thickness.

TABLE 5: RESIDUAL STANDARD DEVIATIONS AND COEFFICIENTS OF DETERMINATION FOR PREDICTION OF CARCASS FAT THICKNESS BY ULTRASOUND DATA.

Variable	Group RSD	r2	Live weight (kg.)
H	3.2	0.62**	499 ± 38
S	3.1	0.63**	522 ± 78
Both Sexes	3.1	0.61**	510 ± 62
FT<12mm			
H	2.0	0.51**	489 ± 39
S	2.1	0.53**	512 ± 90
Both Sexes	2.0	0.47**	500 ± 67
			355 - 686
FT>12mm			
H	4.3	0.27	519 ± 29
S	2.8	0.45	532 ± 61
Both Sexes	3.2	0.32*	527 ± 51
			405 - 630

	Regression without MLA		Prob.> T		Regression with MLA		Prob.> T		
	RSD	r2	LW	FT	RSD	r2	LW	FT	UMLA
MLA≤90cm2									
H	2.6	.83**	.50	.0007	2.5	.87**	.73	.0009	.22
S	3.5	.67**	.70	.0004	3.3	.73**	.30	.0003	.14
Both Sexes	3.2	.69**	.64	.0001	3.3	.69**	.64	.0001	.90
MLA>90cm2									
H	3.2	.60**	.19	.001	3.4	.60**	.26	.007	.90
S	2.8	.65**	.21	.006	3.0	.65*	.33	.01	.95
Both Sexes	3.1	.55**	.33	.0001	3.1	.56**	.54	.0001	.40

**P<0.01,
*P<0.05

H = heifers,
S = steers,
MLA = M. longissimus area,
FT = actual fat thickness over the M. longissimus,
LW = live weight,
ULMLA = ultrasonic M. longissimus area,
UFT = ultrasonic fat thickness.

TABLE 6: MEANS, STANDARD DEVIATIONS AND CORRELATION COEFFICIENTS FOR SONIC AND CARCASS DATA FOR M. LONGISSIMUS AREA OF ANIMALS IN DIFFERENT GROUPS.

Group Variable	n	Sonic Mean	SD	Carcass Mean	SD	r
H	25	95.1	15.39	93.0	12.00	.86**
S	26	87.4	17.10	87.3	14.24	.87**
Both Sexes	51	91.1	16.58	90.1	13.36	.87**
MLA≤90cm2						
H	10	84.5	9.71	83.2	6.63	.85**
S	15	77.5	12.95	78.8	9.11	.65**
Both Sexes	25	80.3	12.06	80.5	8.36	.73**
MLA>90cm2						
H	15	102.1	14.53	99.7	9.95	.76**
S	11	100.8	12.28	99.4	10.90	.84**
Both Sexes	26	101.6	13.38	99.6	10.15	.79**
FT≤12mm						
H	17	95.6	17.29	93.0	13.03	.91**
S	14	86.2	17.81	87.7	16.41	.89**
Both Sexes	31	91.4	17.88	90.5	14.64	.89**
T>12mm						
H	8	93.9	11.22	93.5	9.87	.67
S	12	88.7	16.91	87.3	11.88	.86**
Both Sexes	20	90.8	14.79	89.8	11.29	.81

**P<0.01,
*P<0.05

H	=	heifers,
S	=	steers,
MLA	=	M. longissimus area,
FT	=	actual fat thickness over the M. longissimus,
LW	=	live weight,
ULMLA	=	ultrasonic M. longissimus area,
UFT	=	ultrasonic fat thickness.

TABLE 7: RESIDUAL STANDARD DEVIATIONS AND COEFFICIENTS OF DETERMINATION FOR PREDICTION OF CARCASS M. LONGISSIMUS AREA BY ULTRASOUND DATA.

Group Variable	RSD	r2	Live weight (kg.)
H	4.8	0.86**	499 ± 38
S	6.3	0.82**	522 ± 78
Both Sexes	5.9	0.81**	510 ± 62
$MLA \leq 90cm^2$			
H	2.6	0.87**	473 ± 33
S	6.5	0.54**	480 ± 64
Both Sexes	5.3	0.60**	477 ± 53
			354-598
$MLA > 90cm^2$			
H	5.8	0.71**	516 ± 32
S	5.2	0.82**	578 ± 57
Both Sexes	5.7	0.71**	542 ± 53
			468-686

	Regression without FT				Regression with FT				
			Prob.				Prob.		
	RSD	r2	LW	UMLA	RSD	r2	LW	UMLA	UFT
$FT \leq 12mm$									
H	4.8	.88**	.02	.0001	4.9	.89**	.02	.0001	.57
S	7.3	.83**	.10	.006	7.1	.86**	.53	.006	.24
Both Sexes	5.8	.85**	.003	.0001	5.8	.86**	.006	.0001	.47
$FT > 12mm$									
H	3.3	.92**	.003	.003	2.3	.97**	.001	.002	.07
S	5.0	.86**	.02	.01	3.3	.94**	.02	.0007	.009
Both Sexes	5.7	.77**	.01	.0004	5.6	.79**	.02	.0003	.20

**$P<0.01$,
*$P<0.05$

H	=	heifers,
S	=	steers,
MLA	=	M. longissimus area,
FT	=	actual fat thickness over the M. longissimus,
LW	=	live weight,
ULMLA	=	ultrasonic M. longissimus area,
UFT	=	ultrasonic fat thickness.

(Andersen *et al., 1982).

USDA yield grades based on ultrasound data were not different ($P<.01$) from yield grades based on carcass data (Table 2). Ultrasonic based yield grades using hot carcass weight had a higher accuracy and precision that those using estimates of hot carcass weight from live weight (Table 3). The lack of difference between the two populations of yield grades suggests that yield grades based on ultrasonic evaluation of live cattle may be used with some measure of confidence. The importance of this to live cattle marketing needs further investigation.

It appears from the results of this study that real time linear array ultrasound technique has potential for application to instrument grading of live and slaughter stock based on data reliability. The robustness of the machine used in this study and its ease of operation are added attractions. Further tests are going on to evaluate the technique for other livestock classes and over a wider range of live weights and larger sample sizes.

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