<u>End of project report</u>

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The relationship between various live animal scores/measurements and carcass classification for conformation and fatness with meat yield and distribution, and ultimate carcass value

Authors

M.J. Drennan[1], M. McGee[1], S.B. Conroy[1, 3], M.G. Keane[1], D.A. Kenny[3] and D.P Berry[2]

[1]*Teagasc, Grange Beef Research Centre, Dunsany, Co. Meath, Ireland.*

[2]*Teagasc, Moorepark Dairy Production Research Centre, Fermoy, Co. Cork, Ireland.*

[3]*School of Agriculture, Food Science and Veterinary Medicine, UCD, Belfield, Dublin 4, Ireland.*

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INTRODUCTION

Suckler cow numbers in Ireland have almost trebled over the last twenty-five years reaching 1.18 million in 2008 or 52% of the total cow population (Department of Agriculture Fisheries and Food (DAFF), 2004 and 2008). In addition there was a substantial increase in the use of late-maturing continental breeds in the national herd. Late-maturing continental breeds and crossbreds now account for over 70% of suckler cows, of which, 88% are bred to continental sire breeds (DAFF, 2008). Such a breeding policy has led to an increased proportion of animals suitable for the higher-priced continental EU market where prices are highest for animals of good conformation that are lean. As 85% of Irish carcass beef is exported, of which, 45% is destined for continental EU markets, it is important that the animals produced meet the requirements of those markets (Bord Bia, 2008).

Beef carcass classification plays an important role in Europe, as a marketing aid within and between countries and as a means of increasing the precision of price reporting for administrative purposes (Fisher, 2007). By attaching a pricing schedule to the various classes, producers are incentivised to supply the type of carcass required by the market (Allen, 2007). In the European Union (EU), beef carcasses are classified according to the official beef carcass classification scheme (Commission of the European Communities, 1982). The purpose of carcass classification is to categorise carcasses according to their conformation and fatness. For conformation, the classes EUROP are used with E denoting carcasses with the best conformation with an option of an S class for carcasses with extremely good muscular development, whereas fat cover is assessed on a five-point scale (1 to 5), with 1 being the leanest (Allen, 2007). In 2004, Ireland replaced visual assessment with mechanical classification using a video image analysis (VIA) system. Automated classification simply mimics the human assessor by analysing an image of the carcass (Fisher *et al.,* 2007). Machine classification is deemed preferable to visual assessment because of greater consistency and producers can have more confidence in the objectivity of the results (Allen *et al.,* 2007). The usefulness of carcass classification information for conformation and fatness, however, is dependent on their relationship to economically important traits such as meat yield, meat distribution in the carcass and, ultimately, carcass value (Drennan, 2006). Due to the differences in the value of different meat cuts, both meat yield and distribution are the primary determinants of carcass value (Drennan, 2006). Considering that payment for carcasses in the EU is based on carcass conformation and fat scores, and that these data are routinely available on carcasses, it seems logical to develop equations that predict carcass meat, fat and bone proportions using these scores.

An examination of steer and bull beef prices for 2007 shows that, when compared to Ireland the average prices in France and Italy were only 9 c/kg greater for conformation and fat score O3 carcasses (264 v 273 c/kg ex VAT) but were 63 c/kg (282 v 345 c/kg) greater for U3 carcasses (Bord Bia, 2007). Thus, the beef price difference in Ireland and the average for those two countries was 7 times greater for U conformation score than for O conformation score showing the extent to which carcasses of good conformation are under-priced in Ireland. Therefore, market outlet, in addition to carcass meat yield and distribution, is important in determining carcass value. Accurate equations to predict carcass characteristics from routinely collected data would facilitate payment systems based on carcass meat proportion which, in addition to the specific market, is the main determinant of carcass value. Having a beef price structure, which reflects the value of the animal, is in the long term interest of the beef industry. Price is the mechanism whereby the processor can indicate both to the farmer and to those involved in beef improvement programmes, such as breed societies and the Irish Cattle Breeding Federation (ICBF), the requirements of the market. Few studies have, however, examined the relationship between carcass conformation and fat scores as measured under the EU beef carcass classification scheme with carcass traits and value.

Additionally, live animal scores/measurements could be used to further assist the breeding and production of animals that meet market requirements through identification or screening earlier in life provided that there is a good relationship between these live animal records and the carcass traits of interest. Live animal records collected at present by breed societies and the ICBF, include muscular and skeletal scores, and scanned longissimus muscle size and fat cover. The most important use of live animal scores and measurements is with pedigree animals which are retained for breeding and thus, do not have any carcass data. Arguably, of less importance is their use in commercial animals, in that information will be available at an earlier stage but at greater cost than the carcass data, which is freely available. Despite the widespread use of live-animal scoring and measurements in beef breeding programmes there are few data showing the relationship of those variables with carcass meat yield and value.

Accordingly, the primary objectives of the following study were to:

(1) determine the relationship of live animal muscular and skeletal scores, ultrasonically scanned muscle and fat depth measurements of the *m. longissimus dorsi,* and carcass conformation and fat scores with kill-out proportion, carcass composition and value.

(2) Specifically develop and test the accuracy of prediction equations for carcass meat, fat and bone proportions, derived from carcass conformation and fat scores, and develop prediction equations for total carcass composition from hind-quarter composition.

EXPERIMENT 1: The value of muscular and skeletal scores in the live animal and carcass classification scores as indicators of carcass composition in cattle

Introduction

For those involved in beef cattle genetic improvement programmes, producers and processors, estimates of meat yield, meat distribution in the carcass (due to the differences in value between cuts), and ideally carcass value based on meat yield and distribution, is desirable. Accurate prediction of carcass value or quality based on body composition would enable the early selection of efficient animals by beef producers as well as seedstock breeders (Afolayan et al., 2007). Live-animal indicators of carcass meat yield and distribution include visual muscular and skeletal scores, whereas carcass indicators are conformation and fat scores. Carcass merit of animals in pedigree beef herds, which are destined for breeding, is dependent on having information on the relationship between measurements and scores taken on the live-animal and carcass meat yield and value. Data collected at present by breed societies and others involved in beef improvement programmes include muscular and skeletal scores, and scanned longissimus muscle size and fat cover. In the European Union (EU), data recorded for beef carcasses include scores for conformation (EUROP scale with E best for conformation) and fatness (scale 1 to 5, with 5 fattest), gender category (steer, heifer, young bull, cow, bull) and carcass weight. Conformation and fatness are based on visual examination of carcasses (Commission of the European Communities, 1982), which, since this study was carried out, has been replaced by mechanical classification in Ireland (Allen and Finnerty, 2000). In the EU, payment for carcasses within each gender category is based mainly on carcass scores, payment for which can differ substantially between countries particularly, for conformation. It is therefore desirable to acquire information on the effect of classification scores on meat yield and distribution. Such information, in addition to being useful for pricing purposes, can be used in beef improvement programmes where progeny are identified and classified at slaughter.

Tatum et al. (1986) showed that a subjective score for muscle thickness on the live animal was significantly associated with meat yield. Similarly, Perry et al. (1993a) reported a correlation of 0.70 between saleable meat and muscle score on the live animal. Afolayan et al. (2002) showed that prediction equations, using objective measurements recorded on the live animal, accounted for 56%, 56% and 39% of the variation in carcass meat, fat and bone proportions, respectively. Kauffman et al. (1973) found that animal or carcass shape was a significant factor in determining carcass composition, but its role was minor compared with carcass fatness. They concluded that the importance of muscularity may be overlooked when carcass composition is determined by techniques such as specific gravity or proportion of trimmed wholesale or retail cuts in which bone was not removed, and thus permitted to influence the net result. Earlier studies showed that carcass conformation score (shape due to muscle and fat layers) was of little value as an indictor of meat yield but that fat-corrected conformation score was valuable in commercial classification schemes (Kempster and Harrington, 1980; Kempster, 1986). Perry et al. (1993b) reported that carcass weight alone, carcass weight with carcass muscle score, and carcass weight with carcass muscle and fat scores accounted for 0.1%, 37.9% and 46.7%, respectively, of the total variation in saleable meat yield. Despite the widespread use of live-animal scoring in breeding programmes and the use of the EU carcass classification grid for pricing, there are few data showing the relationship of those with carcass meat yield and value.

The objective of the present study was to examine the relationships of live-animal visual muscular and skeletal scores, carcass weight and length, carcass fat depth over the longissimus dorsi muscle, and carcass conformation and fat scores, with killing-out rate, carcass composition and estimated carcass value of bulls and heifers.

Materials and methods

Animals and management

In all, 48 bulls and 37 heifers were used in the study. The animals were the progeny of late-maturing pure bred (Charolais and Limousin) or crossbred [Limousin x Friesian, Limousin x (Limousin x Friesian) and Simmental x (Limousin x Friesian)] beef suckler cow genotypes. Forty bulls and all of the heifers were the progeny of one Limousin sire, whereas the remaining eight bulls were the progeny of a Charolais sire. The animals used represent a major segment of the progeny from the Irish beef cow herd, which comprises 51% of total cows where 71 % are late- maturing breed crosses and 86% are bred to late-maturing sire breeds (CMMS, 2006). The animals were born in spring, spent the summer at pasture with their dams and were weaned at an average of 8 months of age. The bulls spent the subsequent 218 days indoors during which they were offered a diet based on well-preserved, high nutritive value grass silage (pH 3.7, dry matter (DM) 197 g/kg, crude protein (CP) 144 g/kg, in vitro dry matter digestibility (IVDMD) 774 g/kg) ad libitum and an average of 4.0 kg per head daily of a barley-based concentrate supplement. Daily liveweight gains of the bulls pre- and post-weaning averaged 1.00 and 1.19kg/day, respectively. They were slaughtered at an average age of 458 days. Forty were slaughtered on the same day and the remaining eight 7 days later. The heifers were offered the same grass silage as the bulls plus 1 kg of concentrate daily during the 5-month winter following weaning after which they spent a second season at pasture. They received an average of 3.3 kg of concentrates per head daily during the last 84 days before slaughter and grazed grass was replaced with grass silage (pH 3.8, DM 163 g/kg, CP 155 g/kg, IVDMD 713 g/kg) for the final 36 days. Daily live weight gains of the heifers pre- and post-weaning were 0.88 and 0.67 kg/day, respectively. All were slaughtered on the same day at an average age of 612 days. Final live weights were the mean of unfasted weights taken on two mornings before slaughter. All animals were slaughtered in the same commercial abattoir.

Live animal scores

Visual muscular scores were assigned to each animal using both the Irish Cattle Breeding Federation (ICBF) and Signet (Collins, 1998) scoring procedures at weaning and prior to slaughter. The ICBF system (ICBF linear scoring reference guide, 2002) involved assigning muscular scores (scale 1 to 15) at nine locations: (1) width at withers, (2) width behind withers, (3) thigh width, (4) development of hind quarters, (5) thickness of loin, (6) development of inner thigh, (7) loin width, (8) rump width and (9) thigh depth). Two trained Assessors from ICBF (A and B) scored the animals at slaughter but only Assessor A scored them at weaning. In the Signet procedure, muscular scores (scale 1 to 15) were assigned at three locations (roundness of hindquarter, width of rump and width and thickness of the loin) using two experienced Assessors (C and D) from the research centre on each occasion. For each Assessor the scores at the different locations were averaged to give one value for each animal at weaning and prior to slaughter. In addition, prior to slaughter all animals were assigned skeletal scores (scale 1 to 10) at three locations (length of back, pelvic length and height at withers) by the ICBF Assessors.

Slaughter and carcass records

Hot carcass weight and weight of kidney plus channel fat were recorded at slaughter. Cold weight was taken as 0.98 hot carcass weight. Carcasses were visually classified according to the EU Beef Carcass Classification Scheme (Commission of the European Communities, 1982), but on a 15-point rather than on a five-point scale, by assigning +, 0 or — to each score on the five-point conformation and fat scales.

Carcass meat, fat and bone proportions were obtained following dissection of each carcass using the commercial procedures practiced by the processor. The two sides of each carcass were quartered into hind- and fore-quarters between the 12th and 13th rib for bulls and 10th and 11th rib for heifers. There were seven joints in the hind-quarter (silverside, topside, striploin, rump, knuckle, fillet and flank steak) and six in the fore-quarter (chuck, cube roll, brisket, clod, shoulder blade and flat rib). The weight of meat in each joint (after bone and dissectable fat had been removed) was recorded individually. The weight of fat and bone from each joint was combined for each quarter separately, to give the total weight for both hind- and forequarters. The total weight of meat was the sum of the individual meat cuts plus lean trim. Carcass value (value per kg, c/kg) was the sum of the commercial values of each boneless, fat-trimmed meat cut and lean trim with a small deduction for bone expressed as a proportion of cold carcass weight.

Statistical analysis

Data were analysed using Statistical Analysis Systems Institute (SAS 2003). Correlations among the variables were determined using the Proc. CORR procedure and linear regression analysis was carried out using the Proc. GLM procedure.

Results

Animal details

Mean, s.d., minimum and maximum and CV values for the scores, slaughter and carcass traits of the bulls and heifers are presented in Table 1. Average carcass weights of bulls and heifers were 323 and 268 kg, respectively. Carcass conformation and fat scores (scale 1 to 15) for bulls were 11 .7 and 6.1, and for heifers were 10.1 and 8.9, respectively. Mean carcass meat, fat and bone proportions for bulls were 738, 89 and 173 g/kg, respectively. Corresponding figures for heifers were 720, 92 and 188 g/kg.

Correlations using live animal muscular scores

A preliminary examination of the data for the ICBF Assessors showed that correlations of muscular scores using the average of the entire nine locations with the various carcass traits were often lower than that obtained using only five locations (numbers 1 to 5) or just two locations (thigh width and development of the hind-quarters). Consequently, the data are presented for nine, five and two locations for both Assessors A and B. Correlations between muscular scores taken at weaning and at slaughter by Assessors A (using five locations), C and D were 0.73, 0.75 and 0.59 for bulls and 0.44, 0.42 and 0.51 for heifers, respectively. Correla¬tions between Assessors C and D using the same scoring procedure for bulls and heifers were 0.83 and 0.74 at weaning, and 0.82 and 0.83

at slaughter, respectively. Corresponding correlations between muscular scores at slaughter between Assessors A and B were 0.87 and 0.86.

Assessor A, using the ICBF procedure, found higher correlations for the muscularity scores at slaughter with killing-out rate and the various carcass traits than for those recorded at weaning (Tables 2 and 3). Data from Assessors C and D, using the Signet scoring procedure, generally showed good correlations between the muscular scores recorded at both weaning and pre-slaughter and carcass traits. Although correlations were generally better pre-slaughter than at weaning, some exceptionally low correlations were obtained by Assessor C for the heifers pre-slaughter. Using the data recorded by Assessor A at weaning, the only correlation that consistently showed r values of ~ 0.5 with muscular score was carcass conformation score. Correlations between muscular scores and various traits were greatest when using only two scoring locations (width and development of the hind-quarter) followed by five scoring locations. The lowest correlations were obtained when all nine muscular scoring locations were used. The results obtained using the muscular score (five locations) recorded by Assessor A pre-slaughter for both bulls and heifers showed significant positive correlations with killing-out rate (r= 0.50 and 0.61), carcass meat proportion (r= 0.39 and 0.65), carcass value (r= 0.30 and 0.66) and carcass conformation score (r= 0.70 and 0.69). High negative correlations were obtained between muscular score and carcass bone proportion (r= -0.51 and -0.68). Correlations with the proportion of high-value cuts were positive but variable, whereas those with carcass fat proportions and carcass fat score were generally low and negative. The results with Assessor A are in general agreement with those obtained with the other *Assessors.*

Correlations using live animal skeletal scores

Correlations between each of the three individual ICBF skeletal scores (length of back, length of pelvis and height at withers) recorded at slaughter by both Assessors A and B with killing-out rate and the various carcass traits were low and generally not significant.

Correlations using carcass measurements

Significant (P< 0.001) positive correlations were obtained in both bulls and heifers for carcass fat depth with carcass fat proportion (r= 0.73 and 0.70) and carcass fat score (r= 0.64 and 0.72). The only other consistently significant correlations with carcass fat depth were carcass meat proportion (r= -0.71 and -0.59) and carcass value (r= -0.64 and -0.51). Correlations with kidney plus channel fat weight reflected those with carcass fat depth except that the correlations with carcass fat score were considerably lower. Correlations with carcass length were either not significant or low and negative with carcass meat proportion and carcass value, or low and positive with carcass fat proportion. Correlations with carcass weight were generally not significant except for carcass conformation (r= 0.38 and 0.51).

Correlation of carcass class with carcass composition and value

High positive correlations (P< 0.001) were obtained (Table 4) with both bulls and heifers for carcass conformation score with killing-out rate (r= 0.68 and 0.57), carcass meat proportion (r= 0.57 and 0.52) and carcass value (r= 0.50 and 0.55). Significant negative correlations were obtained for carcass conformation with both carcass fat and bone proportions, whereas correlations were positive but variable with the proportion of high-value cuts in the carcass. Correlations of carcass fat score were high and positive with carcass fat proportion (r= 0.83 and 0.74) and negative with carcass meat proportion (r= -0.73 and -0.68), carcass value (r= -0.69 and -0.63), proportion of high-value cuts (r= -0.54 and -0.31) and killing-out rate (r= -0.54 and -0.32). Correlations between carcass fat score and carcass bone proportion were not significant.

Regression equations relating carcass class to carcass composition and value

Linear regression equations describing the relationships of carcass conformation and fat scores with killing-out rate, carcass meat, fat and bone proportions, the proportion of high-value cuts in the carcass and carcass value are shown in Table 5. Increasing conformation score resulted in a significant increase in killing-out rate, whereas increasing fat score had a negative effect (not significant for heifers). The effects of a one-unit change (scale 1 to 15) in carcass conformation and fat scores on meat proportion (g/kg) for bulls were 9 and -12 (R^2 = 0.70), and for heifers they were 8 and -10 (R^2 = 0.55), respectively. The corresponding figures for carcass value (c/kg) were 3.5 and -5.4 for bulls (R^2 = 0.59) and 4.4 and -3.8 for heifers (R^2 = 0.51). The proportion of the total variation in carcass fat proportion explained by carcass conformation and fat scores was 0.74 and 0.57 for bulls and heifers, respectively. Corresponding values were 0.34 and 0.30 for carcass bone proportion, and 0.29 and 0.34 for the proportion of high- value cuts in the carcass. Improving carcass conformation score had a negative effect on both carcass fat (not significant for heifers) and bone (P< 0.001) proportions. Increasing fat score had a positive effect (P< 0.001) on carcass fat proportion but had non-significant negative effects on carcass bone proportion.

Conclusions

The results show that carcass conformation and fat scores are effective in predicting carcass meat proportion, accounting for 0.55 to 0.70 of the total variation. Where breeding animals are concerned, a live animal muscular score can be used as an indicator of meat yield but such an assessment is only useful following the provision of a relatively high level of nutrition. Assessments carried out on progeny at weaning may not be useful where pre-weaning growth rates are low, resulting in poor body condition and thus, preventing animals from expressing differences in muscular development. In these circumstances, the scores would tend to be overly influenced by pre-weaning gain, which in suckled progeny is mainly a reflection of milk production of the dam. However, in the present study, muscular scores taken pre-slaughter were shown to explain from 25% to 50% of the variation in meat yield.

Table 1: Mean, standard deviation, range and coefficient of variation for live animal and carcass traits of bulls and heifers

	Bulls				Heifers			
	Mean ± s.d.	Minimum	Maximum	Coefficient of variation	Mean ± s.d.	Minimum	Maximum	Coefficient of variation
Muscular scores at weaning[a]								
ICBF Assessor A: 9 locations	7.9 ± 1.39	5.3	11.1	17.5	5.8 ± 0.85	3.9	7.4	14.8
5 locations	8.1 ± 1.50	5.2	11.4	18.6	5.9 ± 0.93	3.6	7.8	15.7
2 locations	8.5 ± 1.52	5.5	12.0	18.0	6.7 ± 1.26	3.5	9.5	18.9
Signet Assessor C	7.6 ± 1.60	4.3	10.3	6.9	7.1 ± 1.66	4.3	10.3	23.4
Signet Assessor D	7.4 ± 1.56	4.7	10.3	7.1	6.9 ± 0.69	6.0	8.7	10.0
Muscular scores at slaughter[a]								
ICBF Assessor A: 9 locations	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5 locations	8.6 ± 1.41	5.0	10.8	16.4	8.1 ± 1.11	6.4	10.6	13.8
2 locations	9.0 ± 1.60	4.0	11.5	17.8	8.6 ± 1.31	6.5	11.0	15.2
ICBF Assessor B: 9 locations	9.2 ± 0.95	6.3	12.3	10.3	8.7 ± 0.99	6.7	10.4	17.4
5 locations	9.3 ± 1.02	6.4	12.8	10.9	8.6 ± 1.14	6.2	10.6	13.3
2 locations	9.5 ± 1.10	6.5	13.0	11.6	9.1 ± 1.01	7.0	11.5	11.1
Signet Assessor C	8.5 ± 1.80	4.7	12.7	21.2	7.8 ± 1.42	5.0	11.0	18.1
Signet Assessor D	8.6 ± 1.47	5.3	11.7	17.0	7.9 ± 1.35	5.3	11.7	17.2
Slaughter weight (kg)	540 ± 74.8	406	688	13.9	495 ± 45.8	417.5	592.5	9.3
Cold carcass weight (kg)	323.1 ± 45.01	249.4	429.2	13.9	267.9 ± 26.4	217.1	319.0	9.9
Killing-out rate (g/kg)	599 ± 19.4	560	635	3.2	541 ± 18.3	498	575	3.4
Age at slaughter (days)	458 ± 20.3	415	494	4.4	612 ± 28.5	540	657	4.7
Live weight gain[b] (g/day)	1175 ± 130.8	950	1490	11.1	809 ± 62.3	710	930	7.7
Carcass weight gain (g/day of age)	704 ± 78.5	570	900	11.1	438 ± 37.8	360	510	8.6
Carcass conf. score (scale 1 to 15)	11.7 ± 1.35	9.0	15.0	11.6	10.1 ± 1.22	8.0	12.0	12.1
Carcass fat score (scale 1 to 15)	6.1 ± 1.51	3.0	11.0	25.0	8.9 ± 1.85	5.0	12.0	20.9
Kidney and channel fat (kg)	6.5 ± 2.48	2.2	11.7	38.0	6.2 ± 1.87	2.94	12.42	30.3
Carcass fat depth (mm)	3.1 ± 1.04	1.3	7.0	33.1	5.5 ± 1.78	0.77	9.73	32.5
Carcass length (cm)	126 ± 5.3	114	138	4.2	124 ± 4.4	117	134	3.5
Meat (g/kg)	738 ± 28.5	674	790	3.87	720 ± 31.5	665	772	4.38
Fat (g/kg)	89 ± 24.1	52	15.3	27.2	92 ± 26.4	50	140	28.8
Bone (g/kg)	173 ± 11.3	153	197	6.5	188 ± 11.4	170	217	6.1
High-value cuts (g/kg)	82 ± 4.1	73.8	90.1	5.0	87 ± 4.5	78.1	96.6	5.16
Carcass value (c/kg)	314 ± 13.5	287	344	4.3	317 ± 14.2	289	340	4.5

[a]Scale 1 to 15; [b]Birth to slaughter.

Table 2: Correlations of live animal visual muscular scores taken at weaning with killing-out rate, carcass composition, value and carcass classification scores

			Carcass proportions					Carcass classification scores	
		Killing-out rate	Meat	Fat	Bone	High-value cuts	Carcass value	Conformation	Fat
Muscular scores									
Assessor A									
9 locations	Bulls	0.19	0.06	0.10	-0.34*	-0.09	0.01	0.47***	0.04
	Heifers	0.32*	0.18	-0.12	-0.24	0.21	0.24	0.36*	-0.13
5 locations	Bulls	0.24	0.10	0.06	-0.39**	-0.04	0.04	0.49***	-0.01
	Heifers	0.45**	0.35*	-0.25	-0.39*	0.35*	0.40*	0.46**	-0.25
2 locations[a]	Bulls	0.44**	0.30*	-0.11	-0.54***	0.07	0.24	0.59***	-0.12
	Heifers	0.52***	0.58***	-0.44**	-0.56***	0.50**	0.57***	0.44**	-0.34*
Assessor C									
	Bulls	0.68***	0.53***	-0.31*	-0.67***	0.23	0.49***	0.73***	-0.15
	Heifers	0.68***	0.68***	-0.53***	-0.63***	0.59***	0.72***	0.64***	-0.39*
Assessor D									
	Bulls	0.53**	0.42**	-0.23	-0.58***	0.08	0.35*	0.61***	-0.21
	Heifers	0.51 **	0.49**	-0.35*	-0.53***	0.44**	0.54***	0.55***	-0.25

[a]Width and roundness of hind-quarters.

Table 3: Correlations of live animal visual muscular and skeletal scores taken pre-slaughter and carcass measurements with killing-out rate, carcass composition, value and carcass classification scores

			Carcass proportions					Carcass classification scores	
		Killing-out rate	Meat	Fat	Bone	High-value cuts	Carcass value	Conformation	Fat
Muscular scores									
Assessor A: 9 locations	Bulls	0.49***	0.39**	-0.21	-0.53***	0.11	0.30*	0.71***	-0.20
	Heifers	0.59***	0.57***	-0.38*	-0.68***	0.69***	0.60***	0.73***	-0.24
5 locations	Bulls	0.50***	0.39**	-0.22	-0.51***	0.11	0.30*	0.70***	-0.22
	Heifers	0.61***	0.65***	-0.48***	-0.68***	0.73***	0.66***	0.69***	-0.32
2 locations[a]	Bulls	0.61***	0.50***	-0.34*	-0.55***	0.18	0.48***	0.74***	-0.26
	Heifers	0.63***	0.69***	-0.55***	-0.65***	0.70***	0.70***	0.73***	-0.37*
Assessor B: 9 locations	Bulls	0.43**	0.40**	-0.23	-0.53***	0.12	0.32*	0.66***	-0.18
	Heifers	0.68***	0.59***	-0.43**	-0.64***	0.61***	0.61***	0.78***	-0.39*
5 locations	Bulls	0.50***	0.47***	-0.29*	-0.58***	0.20	0.40**	0.68***	-0.23
	Heifers	0.68***	0.63***	-0.48**	-0.64***	0.64***	0.65***	0.76***	-0.44***
2 locations[a]	Bulls	0.57***	0.56***	-0.36*	-0.65***	0.32*	0.53***	0.69***	-0.23
	Heifers	0.60***	0.52**	-0.34*	-0.63***	0.61***	0.53***	0.74***	-0.26
Assessor C	Bulls	0.69***	0.60***	-0.41**	-0.62***	0.23	0.52***	0.81***	-0.34*
	Heifers	0.37*	0.28	-0.13	-0.46**	0.37*	0.31	0.65***	-0.25
Assessor D	Bulls	0.69***	0.58***	-0.37*	-0.69***	0.20	0.51***	0.71***	-0.27
	Heifers	0.65***	0.57***	-0.38*	-0.68***	0.64***	0.58***	0.82***	-0.36
Assessor A:									
Height at withers	Bulls	-0.35	-0.42**	0.36*	0.30	-0.27	-0.41**	-0.12	0.29*
	Heifers	0.05	0.03	-0.06	0.06	-0.05	-0.05	0.27	-0.03
Length of back	Bulls	0.00	-0.16	0.13	0.13	-0.16	-0.21	0.02	0.18
	Heifers	0.22	0.00	0.05	-0.13	-0.07	-0.05	0.20	0.03
Length of pelvis	Bulls	-0.11	-0.10	0.08	0.08	-0.13	-0.13	0.11	0.18
	Heifers	0.29	0.15	-0.16	-0.04	0.15	0.20	0.29	0.12
Assessor B:									
Height at Withers	Bulls								
	Heifers	-0.18	-0.40*	0.32	0.38*	-0.42**	-0.37**	-0.17	0.26
Length of back	Bulls	-0.14	-0.30*	0.26	0.21	-0.30*	-0.37**	0.01	0.27
	Heifers	-0.15	-0.30	0.25	0.26	-0.35	-0.26	-0.07	0.07
Length of pelvis	Bulls	-0.27	-0.35*	0.27	0.31*	-0.26	-0.39**	-0.02	0.31*
	Heifers	0.03	-0.21	0.19	0.14	-0.23	-0.15	-0.03	0.15
Carcass									
Fat depth	Bulls	-0.61***	-0.71***	0.73***	0.25	-0.39**	-0.64***	-0.37**	0.64***
	Heifers	-0.21	-0.59***	0.70***	0.02	-0.24	-0.51**	-0.28	0.72***
KCF[b]	Bulls	-0.59***	-0.65***	0.65***	0.26	-0.42**	-0.66***	-0.37*	0.46**
	Heifers	-0.25*	-0.62***	0.69***	0.11	-0.30	-0.56***	-0.11	0.39*
Length	Bulls	-0.22	-0.33*	0.30*	0.20	-0.22	-0.39**	-0.06	0.25
	Heifers	-0.05	-0.37*	0.33*	0.26	-0.23	-0.34*	0.04	-0.04
Weight	Bulls	0.12	-0.02	0.13	-0.22	-0.20	-0.16	0.38**	0.08
	Heifers	0.36*	0.01	0.08	-0.21	0.12	0.05	0.51**	0.01

[a]Width and roundness of hind-quarters: [b] KCF = Kidney & channel fat

Table 4: Correlations of carcass conformation and fat score with killing-out rate, carcass meat, fat and bone proportion, proportion of high-value meat cuts in the carcass and carcass value

		Carcass proportions				
	Killing-out rate	Meat	Fat	Bone	High-value meat cuts	Carcass value
Bulls						
Conformation score	0.68***	0.57***	-0.41**	-0.58***	0.14	0.50***
Fat score	-0.54***	-0.73***	0.83***	0.07	-0.54***	-0.69***
Heifers						
Conformation score	0.57***	0.52***	-0.39*	-0.54***	0.57***	0.55***
Fat score	-0.32	-0.68***	0.74***	0.17	-0.31	-0.63***

Table 5: Regressions on carcass conformation and fat scores (s.e.) of killing-out rate (g/kg) carcass meat, fat and bone proportions (g/kg), the proportions of high-value meat cuts in the carcass (g/kg), and carcass value (c/kg)

	Intercept	Conformation score	Fat score	R^2	Residual s.d.
Bulls					
KO	531	8.5 (1.36)***	-5.2 (1.22)***	0.62	12.3
Meat	706	8.9 (1.78)***	-11.9 (1.60)***	0.70	16.0
Fat	60	-4.0 (1.40)**	12.4 (1.25)***	0.74	12.6
Bone	234	-4.9 (1.04)***	-0.5 (0.93)	0.34	9.4
High-value cuts in carcass	90	0.04 (0.39)	-1.4 (0.35)***	0.29	3.5
Value	305	3.5 (0.98)***	-5.4 (0.88)***	0.59	8.8
Heifers					
KO	473	7.9 (2.24)**	-1.2 (1.48)	0.34	15.3
Meat	723	8.1(3.17)*	-9.7 (2.09)***	0.55	21.7
Fat	34	-2.9 (2.63)	9.9 (1.73)***	0.57	17.9
Bone	243	-5.2 (1.44)***	-0.2 (0.95)	0.30	9.8
High-value cuts in carcass	70	2.0 (0.55)**	-0.3 (0.36)	0.34	3.8
Value	306	4.4 (1.50)**	-3.8 (0.99)***	0.51	10.2

KO = killing-out rate.

EXPERIMENT 2: The relationship of various muscular and skeletal scores and ultrasound measurements in the live animal, and carcass classification scores with carcass composition and value of bulls

Introduction

Beef carcass classification plays an important role as a marketing aid within and between European countries, and as a means of increasing the precision of price reporting for administrative purposes (Fisher, 2007). Beef carcasses are classified according to the official EU beef carcass classification scheme (Commissions of the European Communities, 1982) for conformation (E, U, R, O, P scale with E best and with an additional score S for superior double-muscled carcasses) and fatness (1-5 with 5 fattest). This classification scheme, which is based on visual assessment for conformation and fatness, was recently replaced in Ireland by mechanical scoring (Allen, 2007). Both meat yield and distribution, due to differences in the value of meat cuts are primary determinants of carcass value (Drennan, 2006). Very few studies have looked at the relationship between carcass scores (using the EU classification scheme) and carcass composition and value. Delfa *et al.* (2007) using 69 bull carcasses, found that hot carcass weight and EU carcass classification for conformation and fatness explained 97, 60 and 85% of muscle, fat and bone weight respectively. Recent studies (Drennan *et al.*, 2008; Conroy *et al.*, 2008) have shown that carcass classification for conformation and fatness explained from 0.55 to 0.70 of total variation in carcass meat proportion. These findings are supported by Perry *et al.* (1993b) who reported that carcass weight alone, carcass weight with carcass muscle score and carcass weight with carcass muscle and fat scores, accounted for 0.1, 37.9 and 46.7%, respectively, of the total variation in saleable meat yield. However, Kempster and Harrington (1980) reported that conformation classes rarely accounted for more than 0.30 of the total variation in meat yield.

In addition to carcass classification in breed improvement programmes, repeatable live animal scores and measurements can be used in the identification of animals with superior genetic merit for killing-out proportion, carcass composition and value. Studies (Perry *et al.*, 1993a; Conroy *et al.*, 2008) have shown correlations of 0.6 to 0.7 between muscular scores on the live animal and meat yield. Ultrasound measurements have also shown a good relationship with meat yield (Greiner *et al.*, 2003; Tait *et al.*, 2005). Robinson *et al.* (1992) stated that ultrasound scanning was accurate and effective in predicting carcass measurements and has potential use in breeding decisions.

The objectives of the study were to determine the relationship of live animal muscular and skeletal scores, ultrasonically scanned muscle and fat depth measurements of the *m. longissimus dorsi,* and carcass conformation and fat scores with kill-out proportion, carcass composition and value.

Materials and Methods

Animals and management

Seventy-four bulls slaughtered at 13 to 17 months of age were used in the experiment. Fifty-three were late-maturing continental breed crosses from crossbred suckler dams, bred using artificial insemination to Belgian Blue (n=6), Charolais (n=23), Limousin (n=16) and Simmental (n=8) sires. These bulls were suckled and were purchased following weaning at 8 to 9 months of age from November 2005 to January 2006. The remaining 21 animals were Holstein-Friesian, purchased as calves and artificially reared at the Grange research farm. They received an *ad-libitum* concentrate diet from early life. Following purchase, the continental crossbred weanlings were offered grass silage (dry matter digestibility, 671 g/kg) *ad-libitum* and a concentrate supplement (barley, 865 g/kg; soya bean meal, 70 g/kg; molasses, 50 g/kg and minerals/vitamins, 15 g/kg). The daily concentrate allowance was gradually increased and silage gradually reduced over a period until animals were offered concentrates to appetite and approximately 1 kg of grass silage dry matter per head daily. All bulls remained on this diet from 28th January until slaughter on 26th June. Following purchase, the suckled animals were treated for the control of parasitic infections of the gastro–intestinal tract and lungs and Fascioliasis. All animals were also vaccinated with Covexin 8, Bovipast RSP and Infectious Bovine Rhinotrachietis (IBR) marker for control of clostridial and respiratory diseases. Treatment for the control of lice was given to all animals as deemed necessary.

Muscular and skeletal scores/measurements

At 8 to 12 months of age and again pre-slaughter, muscular and skeletal scores were carried out by the same two trained assessors from the Irish Cattle Breeding Federation (ICBF). Muscular scores were also obtained at those times using the Signet scoring system (Collins, 1998) by two experienced staff members from Grange research centre. All scoring was carried out by visual assessment except for height at withers, which was recorded by the members of ICBF using a measuring pole. Linear scoring (ICBF, 2002) by the ICBF assessors involved assigning muscular scores on a scale of 1 (poor) to 15 (excellent), at six locations (width at withers, width behind withers, loin development, development of hind-quarters, width of hind-quarters and development of the inner thigh) and skeletal scores (scale of 1-10) at three locations (length of back, pelvic length and height at withers). The six muscular scores were then averaged to give one score per animal for each assessor on each occasion. Skeletal scores were also averaged in a similar manner. Allowances were made for subcutaneous fat by the assessors when assigning muscular scores. The Signet muscular score was also based on a 1 to 15 point scale extending, where appropriate, to 18 for double-muscled animals. The three scoring locations used were roundness of hind-quarters, width of hind-quarters, and depth and width of loin. Each animal was given a score for each of the three locations, which were again averaged to give a mean score per animal for each assessor.

Ultrasound measurements

At 8 to 12 months of age and again pre-slaughter eye muscle depth was measured at the 3rd lumbar vertebra and fat depth at both the 3rd lumbar vertebra and 13th thoracic rib using a Dynamic Imaging real time ultrasound scanner (model – *Concept MLV*, with 3.5 MHz transducer). All measurements were obtained on the right side of each animal by the same operator. Hair was clipped from areas to be scanned and vegetable oil was applied to obtain adequate acoustic contact. Cattle were restrained by the head in a chute and physical palpation was used to accurately ascertain the scanning sites. The animals were only scanned when they were in a relaxed posture thus permitting more accurate measurement. The transducer had a built-in stand-off with a silicone rubber strip attached which facilitated contact with curvature of the animal's body. The probe was placed perpendicular to the horizontal trajectory of the rib eye muscle (*M. longissimus dorsi*) at the 3rd lumbar vertebra and 13th thoracic rib until bones appeared on the monitor. When a satisfactory image was achieved, it was frozen on the monitor and the depth of the eye muscle and fat were then measured using an internal electronic callipers and measurement software. Fat depth was measured at 3 points at the 3rd lumbar vertebra across the width (0.4, 0.6 and 0.8) of the muscle and at four points (0.2, 0.4, 0.6 and 0.8) at the 13th vertebra. Fat depth was calculated by taking the mean of the average values at the 3rd lumbar and 13th thoracic rib. Muscle depth was obtained at the deepest point (0.25) of the muscle (from the bottom of the backfat to the top of the bone) at the 3rd lumbar vertebra.

Carcass measurements

Carcass conformation and fat scores were recorded using a mechanical grading system (Allen, 2007) on a 15 point continuous scale rather than the 5 point EU Beef Carcass Classification Scheme scale (Commission of the European Communities, 1982). Hot carcass weight was recorded and cold carcass weight was estimated as 0.98 of hot carcass weight. Weight of perinephric and retroperitoneal fat were also recorded at slaughter. Following a period of 24 hours at 4° C, the right side of each carcass was quartered at the 5th rib into an 8-rib pistola and the remaining fore-quarter. After recording the weight, the pistola was dissected into 13 cuts (leg, heel, silverside, topside, knuckle, rump, tail of rump, cap of rump, fillet, striploin, cube roll, cap of rib and salmon) from which, all visible fat and bone (where applicable) was removed. The weight of each individual meat cut and total fat from the pistola was recorded as was bone weight following removal of all adhering tissues. Lean trim was weighed separately and added to the meat cuts to give total pistola meat yield. A similar procedure was carried out with the fore-quarter, which was dissected into 11 cuts (front shin, neck, brisket, chuck, flat ribs (1-5), plate, leg of mutton cut, bladesteak, braising muscle, chuck tender and clod). Pistola and fore-quarter meat, fat and bone weights were combined to give the weight of each component in the half carcass. High-value cuts in the carcass were taken as meat in the cube roll, striploin and fillet. Carcass value was estimated as the sum of the commercial values on each meat cut with a small deduction for bone expressed as a proportion of half carcass weight.

Statistical analysis

Data were analysed using the REG and CORR procedures of SAS (2007). Pearson's correlation coefficients of live animal scores/measurements and carcass conformation and fat scores with the various carcass traits were derived. The relationships between muscular and skeletal scores, ultrasound muscle and fat depths, and conformation and fat scores and the dependant variables (carcass weight, kill-out proportion, meat, fat and bone proportions, proportion of high-value cuts in carcass and meat, and carcass value) were determined using multiple regressions. The contribution made to the estimation of each dependent variable by each independent variable was determined by comparison of the coefficient of determination (R^2) and the residual standard deviation (r.s.d.).

Results

The mean, range and standard deviations for live and carcass traits and yield components for the bulls are summarised in Table 1. At slaughter animals had a mean age of 458 days, a live weight of 575 kg and a cold carcass weight of 322 kg. Carcass conformation and fat scores (scale 1 to 15) ranged from 4.7 to 14.4 and 2.7 to 11.5, respectively. Mean carcass meat, fat and bone proportions were 712, 96 and 192 g/kg, respectively. The mean proportion of high-value cuts in the carcass and in meat were 72 and 102 g/kg, respectively.

Assessors

High correlations for muscular scores were obtained between the four Assessors (two ICBF and two Signet) at both 8 to 12 months of age (r = 0.88 to 0.93) and pre-slaughter (r = 0.86 to 0.94).

Correlations between live animal scoring methodologies and carcass characteristics

The association between live animal scores taken at 8 to 12 months of age and pre-slaughter and carcass characteristics are shown in Tables 2 and 3, respectively. Correlations of average muscular score on the live animal obtained pre-slaughter by ICBF Assessor A with kill-out proportion, carcass meat proportion, carcass conformation, the proportion of high-value cuts in the carcass and carcass value were 0.82, 0.72, 0.94, 0.49 and 0.72, respectively, all of which were highly significant (Table 3). Correlations of average muscular score pre-slaughter showed significant negative relationships with carcass bone (r = -0.89) and fat (r = -0.32) proportions. There was no association ($P > 0.05$) between live animal muscular scores pre-slaughter and the proportion of high-value cuts in meat, perinephric and retroperitoneal fat weight or carcass fat score. Correlations of live animal muscular scores at 8 to 12 months of age with the various carcass traits generally showed similar trends but lower absolute values than at pre-slaughter. The corresponding correlations obtained by Assessors B, C and D were comparable to those obtained by Assessor A. Correlation between hind-quarter development and the various carcass traits were similar to the correlations obtained using the average of all six individual muscular scoring locations with these carcass traits.

Correlation between skeletal scores and carcass characteristics

Correlation coefficients between the ICBF skeletal scores (individual or combined) recorded by both Assessors A and B and the various carcass traits were found to be poor and generally non-significant (Table 4).

Correlation between ultrasound measurements and carcass characteristics

Significant positive correlations were obtained for scanned muscle depth pre-slaughter and kill-out proportion (r = 0.71), carcass meat proportion (r = 0.68), proportion of high-value cuts in the carcass (r = 0.52), carcass conformation score (r = 0.83) and carcass value (r = 0.69) (Table 5). Significant negative correlations were obtained between scanned muscle depth pre-slaughter and both carcass fat (r = -0.34) and bone (r = -0.81) proportions. Although showing similar trends, corresponding correlations with scanned muscle depth at 8 to 12 months of age were generally lower. Correlations of scanned muscle depth at both 8 to 12 months of age and pre-slaughter with the proportion of high-value cuts in meat, carcass fat score and perinephric and retroperitoneal fat were not significant. Correlations of scanned fat depth at 8 to 12 months and pre-slaughter with the various carcass traits were inconsistent (Table 5). Significant positive correlations (r = 0.53 to 0.72) were obtained for scanned fat depth at 8 to 12 months and kill-out proportion, carcass meat proportion, carcass conformation score and carcass value, whereas a negative relationship (r = -0.67) was found with carcass bone proportion. Correlations of scanned fat depth at 8 to 12 months with carcass fat proportion, high-value cuts in meat, perinephic and retroperitoneal fat and carcass fat score were not significant. Positive correlation coefficients were obtained for scanned fat depth pre-slaughter with carcass fat proportion (r = 0.56) and fat score (r = 0.54). The only other statistically significant correlations obtained with scanned fat depth pre-slaughter were negative values (r = ~ -0.30) recorded with carcass meat proportion, proportion of high-value cuts in the carcass and carcass value.

Correlation between carcass conformation and fat scores and carcass characteristics

Significant positive correlations were obtained (Table 6) for carcass conformation score with kill-out proportion (r = 0.84), carcass meat proportion (r = 0.78), proportion of high-value cuts in the carcass (r = 0.50) and carcass value (r = 0.76), whereas negative correlations were obtained with carcass fat (r = -0.41) and bone (r = -0.90) proportions. Correlations of conformation score with high-value cuts in meat, fat score and perinephric and retroperitoneal fat were not significant. Correlations between carcass fat score and the various carcass traits were generally low and non-significant except for significant positive correlations with carcass fat proportion (r = 0.63) and perinephric and retroperitoneal fat (r = 0.29), and significant negative correlations with carcass meat proportion (r = -0.38) and value (r = -0.33).

Regressions using live animal scores/measurements

Multiple regression equations using live animal muscular scores obtained by Assessor A and ultrasound muscle and fat depth measurements to predict carcass meat, fat and bone proportions are shown in Table 7. Both muscular score alone and scanned muscle and fat depth alone at 8 to 12 months of age and pre-slaughter, were significant in predicting carcass meat proportion. Muscular score alone explained slightly more variation at 8 to 12 months than the scanning measurements (R^2 = 0.43 v 0.39), whereas scanned muscle and fat depth explained a greater proportion of total variation pre-slaughter than the muscular score (R^2= 0.51 v 0.62). Although muscular scores were significant in predicting carcass fat proportion, a very small proportion of total variation was explained at 8 to 12 months of age (R^2 = 0.09) and pre-slaughter (R^2 = 0.10). Likewise, scanned muscle and fat depth at 8 to 12 months were poor predictors of carcass fat proportion (R^2 = 0.10), whereas pre-slaughter they accounted for 48% of the total variation. Both muscular score and scanned muscle and fat depth measurements at 8 to 12 months of age and pre-slaughter were significant in predicting carcass bone proportion with muscular score explaining more variation than scanned measurements at 8 to 12 months (R^2 = 0.65 v. 0.58) and pre-slaughter (R^2 = 0.80 v. 0.65). The residual standard deviation (r.s.d) was generally higher at 8 to 12 months than at slaughter. Multiple regression equations using the combined effects of live animal muscular scores and scanned muscle and fat depth measurements to predict kill-out proportion, the various carcass traits and carcass value are shown in Table 8. At slaughter, the combined muscular score and scanned measurements explained a high proportion of total variation (R^2= 0.69 to 0.81) in killing-out rate, carcass meat proportion, bone proportion and carcass value. The corresponding R^2 values at 8 to 12 months were always lower than those obtained pre-slaughter. When predicting carcass fat proportion, 49% of the total variation was explained pre-slaughter using the combined muscular score, and scanned measurements, whereas there was no significant relationship at 8 to 12 months of age. The amount of total variation explained when predicting the proportion of high-value cuts in the carcass was low to moderate at 8 to 12 months (R^2 = 0.19) and pre-slaughter (R^2 = 0.42). The R^2 values for the proportion of total variation in predicting high-value cuts expressed as proportion of meat and perinephric and retroperitoneal fat were minimal on both occasions. In all of the above cases the r.s.d was lower at slaughter than for the corresponding regressions at 8 to 12 months of age.

Regressions using carcass conformation and fat scores

Regression analysis showed that carcass conformation and fat scores explained from 68% to 80% of the total variation in predicting kill-out proportion, carcass meat and bone proportions and carcass value, 55% of the total variation in predicting carcass fat proportion and 28% of the variation in predicting the proportion of high-value cuts in the carcass. Little or no variation was explained in using carcass conformation and fat scores to predict the proportion of high-value cuts in the meat.

Conclusion

The results show that pre-slaughter live animal scores and measurements are good predictors of kill-out proportion, carcass meat and bone proportions and carcass value, modest predictors of carcass fat proportion and proportion of high-value cuts in the carcass and poor predictors of high-value cuts as proportion of meat. Records taken at 8 to 12 months of age were not as good in predicting carcass traits as those taken pre-slaughter. A simplified muscular scoring system using three locations, which were roundness of hind-quarter, width of hind-quarter and depth and width of the loin is as effective as the six locations used by ICBF in predicting carcass composition and value. Live animal skeletal scores showed a poor relationship with the various carcass traits. Carcass classification for conformation and fatness were shown to be good predictors of carcass traits accounting for about 0.7 of total variation in carcass meat proportion and carcass value. The relationship developed between carcass conformation and fat scores with carcass composition provide a basis on which to develop a carcass pricing structure that better reflects carcass value in terms of meat yield and distribution.

Table 1: Mean, standard deviation and range for live and carcass measurements and yield components for 74 young beef bulls

	Mean	Standard Deviation	Minimum	Maximum
At 8 to 12 months				
Muscular scores				
Width between withers (ICBF assessor A)	6.0	2.29	1.0	10
Width behind withers (ICBF assessor A)	5.3	2.22	1.0	9.0
Loin development (ICBF assessor A)	6.0	1.91	1.0	10.0
Hind-quarter development (ICBF assessor A)	6.3	2.22	2.0	12.0
Hind-quarter width (ICBF assessor A)	6.3	1.76	2.0	10.0
Inner thigh development (ICBF assessor A)	6.0	2.14	2	10
Average muscular score (ICBF assessor A)	6.0	2.04	1.5	10.2
ICBF muscular score at 5 locations (assessor A)	6.0	2.03	1.4	10.2
ICBF muscular score at 2 locations (assessor A)	6.3	1.95	2	11
ICBF average muscular score (assessor B)	5.8	1.98	2.3	10.5
Signet muscular score (assessor C)	5.9	2.17	1.7	12.3
Signet muscular score (assessor D)	6.3	2.94	1.0	13.0
Scanned eye muscle depth (mm)	57.6	9.64	38.9	87.5
Scanned fat depth (mm)	1.0	0.37	0.4	2.5
Pre-slaughter				
Pre-slaughter weight (kg)	575	84.6	408	857
Muscular scores				
Width between withers (ICBF assessor A)	8.8	3.06	1.0	13.0
Width behind withers (ICBF assessor A)	8.0	2.99	1.0	12.0
Loin development (ICBF assessor A)	8.6	2.35	3.0	13.0
Hind-quarter development (ICBF assessor A)	8.4	2.62	2.0	14.0
Hind-quarter width (ICBF assessor A)	8.7	2.09	4.0	13.0
Inner thigh development (ICBF assessor A)	8.3	2.51	2.0	13.0
Average muscular score (ICBF assessor A)	8.5	2.53	3	13
ICBF muscular score at 5 locations (assessor A)	8.5	2.55	3.2	13
ICBF muscular score at 2 locations (assessor A)	8.5	2.32	3	13.5
ICBF average muscular score (assessor B)	8.1	2.22	3.3	12.16
Signet muscular score (assessor C)	7.8	2.75	2.3	15
Signet muscular score (assessor D)	7.2	2.79	2.3	14.7
Scanned eye muscle depth (mm)	67.7	9.71	46.2	87.5
Scanned fat depth (mm)	1.8	1.07	0.3	6
Post-slaughter				
Cold carcass wt (kg)	322	57.6	207	475
Kill-out (g/kg)	569	36.9	494	680
Slaughter age (days)	458	41.0	386	569
Perinephric plus retoperitioneal fat (kg)	6.2	2.38	2.2	12.5
[1]Conformation score (scale 1 to 15)	9.6	2.60	4.7	14.4
[2]Fat score (scale 1 to 15)	7.9	1.33	2.7	11.5
Meat (g/kg)	712	39.6	627	840
Fat (g/kg)	96	25.2	31	163
Bone (g/kg)	192	22.8	129	251
High-value cuts (g/kg)	72	5.6	57	85
High-value cuts in meat (g/kg)	102	6.1	87	12
Carcass value (c/kg)	305	19.8	260	358

[1]15 = best conformation; [2]15 = fattest.

Table 2: Correlation coefficients for the association of live animal muscular scores recorded at 8 to 12 months of age with carcass weight, kill-out proportion, carcass meat, fat and bone proportions, proportion of high-value cuts in the carcass and meat, perinephric and retroperitoneal fat, carcass conformation and fat scores and carcass value

			Proportion in carcass						Carcass		
	Carcass weight	[1]KO	Meat	Fat	Bone	[2]HVC	[2]HVC in Meat	Perinephric + Retroperitoneal fat	Conformation Score	Fat Score	Value
Width between withers (A)	0.73***	0.76***	0.64***	-0.29*	-0.79***	0.49***	0.06	-0.08	0.86***	0.00	0.64***
Width behind withers (A)	0.71***	0.75***	0.65***	-0.33**	-0.76***	0.46***	0.01	-0.12	0.84***	-0.07	0.64***
Loin development (A)	0.73***	0.75***	0.63***	-0.30*	-0.77***	0.45***	0.02	-0.07	0.84***	-0.02	0.62***
Hind-quarter development (A)	0.72***	0.80***	0.67***	-0.33**	-0.81***	0.48***	0.02	-0.11	0.84***	-0.01	0.67***
Hind-quarter width (A)	0.77***	0.74***	0.63***	-0.28*	-0.79***	0.44***	0.01	-0.04	0.81***	-0.00	0.62***
Inner thigh development (A)	0.77***	0.79***	0.67***	-0.31**	-0.82***	0.42***	-0.06	-0.09	0.85***	-0.03	0.65***
ICBF average muscular score (A)	0.76***	0.78***	0.66***	-0.32**	-0.81***	0.47***	0.01	-0.09	0.86***	-0.02	0.66***
ICBF muscular score - 5 locations (A)	0.75***	0.78***	0.66***	-0.31**	-0.80***	0.48***	0.02	-0.09	0.86***	-0.02	0.65***
ICBF muscular score - 2 locations (A)	0.75***	0.78***	0.66***	-0.31**	-0.81***	0.47***	0.02	-0.08	0.84***	-0.01	0.66***
ICBF average muscular score (B)	0.81***	0.71***	0.60***	-0.26*	-0.76***	0.46***	0.04	0.03	0.81***	0.02	0.60***
Signet muscular score (C)	0.75***	0.78***	0.70***	-0.35**	-0.82***	0.45***	-0.04	0.007	0.85***	-0.01	0.66***
Signet muscular score (D)	0.81***	0.78***	0.70***	-0.33**	-0.85***	0.48***	-0.01	0.006	0.89***	0.00	0.67***

[1]Kill-out proportion; [2]High-value cuts. Assessors A and B: ICBF linear muscular scoring system. Assessors C and D: Signet muscular scoring system.

Table 3: Correlation coefficients for the association of live animal muscular scores at slaughter with carcass weight, kill-out proportion, carcass meat, fat and bone proportions, proportion of high-value cuts in the carcass and meat perinephric and retroperitoneal fat, carcass conformation and fat scores and carcass value

			Proportion in carcass						Carcass		
	Carcass weight	[1]KO	Meat	Fat	Bone	[2]HVC	[2]HVC in Meat	Perinephric + Retroperitoneal fat	Conformation Score	Fat Score	Value
Width between withers (A)	0.81***	0.78***	0.68***	-0.30*	-0.85***	0.52***	0.05	0.04	0.90***	0.05	0.70***
Width behind withers (A)	0.82***	0.78***	0.67***	-0.27*	-0.86***	0.52***	0.06	0.06	0.92***	0.07	0.68***
Loin development (A)	0.82***	0.76***	0.66***	-0.26*	-0.85***	0.45***	-0.02	0.10	0.87***	0.10	0.66***
Hind-quarter development (A)	0.82***	0.85***	0.77***	-0.41***	-0.88***	0.47***	-0.09	-0.08	0.94***	-0.03	0.74***
Hind-quarter width (A)	0.87***	0.80***	0.72***	-0.33**	-0.89***	0.47***	-0.05	0.05	0.92***	0.04	0.70***
Inner thigh development (A)	0.83***	0.83***	0.71***	-0.32**	-0.88***	0.42***	-0.10	-0.05	0.90***	0.07	0.68***
ICBF average muscular score (A)	0.85***	0.82***	0.72***	-0.32**	-0.89***	0.49***	-0.02	0.02	0.94***	0.05	0.72***
ICBF muscular score - 5 locations (A)	0.85***	0.82***	0.72***	-0.32**	-0.89***	0.50***	-0.00	0.03	0.94***	0.05	0.72***
ICBF muscular score - 2 locations (A)	0.85***	0.84***	0.76***	-0.38***	-0.90***	0.48***	-0.07	-0.02	0.94***	0.00	0.74***
ICBF average muscular score (B)	0.84***	0.77***	0.73***	-0.40***	-0.83***	0.46***	-0.06	0.03	0.93***	0.06	0.73***
Signet muscular score (C)	0.70***	0.83***	0.77***	-0.42***	-0.87***	0.56***	0.03	-0.07	0.89***	-0.04	0.78***
Signet muscular score (D)	0.77***	0.77***	0.73***	-0.40***	-0.83***	0.46***	-0.06	0.03	0.87***	-0.09	0.71***

[1]Kill-out proportion; [2]High value cuts. Assessors A and B: ICBF linear muscular scoring system. Assessors C and D: Signet muscular scoring system.

Table 4: Correlation coefficients for the association of live animal skeletal scores with carcass weight, kill-out proportion, carcass meat, fat and bone proportions, proportion of high-value cuts in the carcass and meat, perinephric and retroperitoneal fat, carcass conformation and fat scores and carcass value

			Proportion in carcass						Carcass		
At 8 to 12 months	Carcass weight	[1]KO	Meat	Fat	Bone	[2]HVC	[2]HVC in Meat	Perinephric + Retroperitoneal fat	Conformation Score	Fat Score	Value
Height at withers (A)	0.55***	0.11	0.01	0.14	-0.17	0.02	0.01	0.29*	0.13	0.14	0.03
Length of back (A)	0.60***	0.18	0.06	0.14	-0.26*	0.09	0.05	0.24*	0.27*	0.17	0.09
Length of pelvis (A)	0.34***	0.11	0.00	0.18	-0.21	0.02	0.03	0.34**	0.18	0.17	0.04
ICBF average skeletal (A)	0.51***	0.15	0.02	0.17	-0.23	0.05	0.03	0.31**	0.21	0.17	0.06
Height at withers (B)	0.26*	-0.04	-0.16	0.22	0.04	-0.20	-0.12	0.11	-0.03	0.15	-0.17
Length of back (B)	0.09	-0.01	-0.16	0.12	0.16	-0.23*	-0.17	-0.05	-0.16	0.05	-0.18
Length of pelvis (B)	0.09	-0.02	-0.02	0.09	-0.06	-0.08	-0.10	0.11	-0.04	0.07	-0.04
ICBF average skeletal (B)	0.19	-0.07	-0.15	0.18	0.06	-0.22	0.16	0.06	-0.09	0.11	-0.16
Slaughter											
Height at withers (A)	0.60***	0.11	0.05	0.01	-0.09	-0.08	-0.15	0.21	0.20	0.09	0.03
Length of back(A)	0.52***	0.00	-0.07	0.16	-0.05	-0.12	-0.09	0.22	0.10	0.13	-0.07
Length of pelvis (A)	0.52***	0.08	0.05	0.01	-0.10	-0.11	-0.19	0.20	0.12	0.03	0.025
ICBF average skeletal(A)	0.59***	0.07	0.01	0.06	-0.09	-0.10	-0.16	0.23	0.16	0.09	-0.00
Height at wither (B)	0.38***	0.00	-0.13	0.19	0.02	-0.30**	-0.28*	0.13	0.02	0.13	-0.16
Length of back (B)	0.47***	0.26*	0.18	-0.12	-0.19	0.01	-0.16	-0.03	0.20	0.07	0.17
Length of pelvis (B)	0.13	-0.09	-0.18	0.17	0.13	-0.37**	-0.30**	0.19	-0.14	0.16	-0.26*
ICBF average skeletal (B)	0.41***	0.08	-0.05	0.10	-0.02	-0.26*	-0.31**	0.12	0.05	0.15	-0.12

[1]Kill-out proportion; [2]High-value cuts. A= ICBF assessor A B= ICBF assessor B.

Table 5: Correlation coefficients for the association of ultrasonically scanned measurements with carcass weight, kill-out proportion, carcass meat, fat and bone proportions, proportion of high-value cuts in the carcass and meat, perinephric and retroperitoneal fat, carcass conformation and fat scores and carcass value

			Proportion in carcass						Carcass		
	Carcass weight	[1]KO	Meat	Fat	Bone	[2]HVC	[2]HVC in Meat	Perinephric + Retroperitoneal fat	Conformation Score	Fat Score	Value
At 8 to 12 months											
Muscle depth	0.81***	0.70***	0.61***	-0.32**	-0.71***	0.40***	-0.03	0.00	0.73***	-0.04	0.60***
Fat depth	0.64***	0.64***	0.53***	-0.22	-0.67***	0.37	-0.00	-0.06	0.72***	0.05	0.56***
Slaughter											
Muscle depth	0.80***	0.71***	0.68***	-0.34**	-0.81***	0.52**	0.05	0.04	0.83***	-0.03	0.69***
Fat depth	0.20	-0.01	-0.30**	0.56***	-0.09	-0.31**	-0.13	0.20	0.08	0.54***	-0.31**

[1]Kill-out proportion; [2]High-value cuts.

Table 6: Correlation of carcass conformation and fat scores with carcass weight, kill-out proportion, carcass meat, fat and bone proportions, proportion of high-value cuts in the carcass and meat, carcass conformation and fat scores, perinephric and retroperitoneal fat and carcass value

			Proportion in carcass						Carcass		
	Carcass weight	[1]KO	Meat	Fat	Bone	HVC	[2]HVC in Meat	Perinephric + Retroperitoneal fat	Conformation Score	Fat Score	Value
Conformation Score	0.80***	0.84***	0.78***	-0.41***	-0.90***	0.50***	-0.06	-0.08	1.00	0.03	0.76***
Fat Score	0.06	-0.11	-0.38***	0.63***	-0.04	-0.20	0.08	0.29*	0.03	1.00	-0.33**

[1]Kill-out proportion; [2]High-value cuts.

Table 7: Multiple regression equations using live animal muscular scores obtained by Assessor A and ultrasound scanned measurements taken at 8 to 12 months and at slaughter for predicting carcass meat, fat and bone proportions

	Intercept	Muscular score (scale 1 to 15)	Scanned muscle depth (mm)	Scanned fat depth (mm)	R^2	RMSE
8 to 12 months						
Meat proportion						
Muscular score (g/kg)	635	12.9(1.71)***			0.43	29.8
Scanned muscle and fat (g/kg)	578		1.9(0.476)***	25.9(12.39)*	0.39	30.9
Fat proportion						
Muscular score (g/kg)	119	-3.9(1.38)**			0.09	24.1
Scanned muscle and fat (g/kg)	143		-0.76(0.372)*	-3.1(9.70)	0.10	24.2
Bone proportion						
Muscular score (g/kg)	246	-9.0(0.776)***			0.65	13.5
Scanned muscle and fat (g/kg)	279		-1.1(0.23)***	-22.8(5.94)***	0.58	14.8
Slaughter						
Meat proportion						
Muscular score (g/kg)	616	11.3(1.28)***			0.51	27.7
Scanned muscle and fat (g/kg)	534		3.0(0.30)***	-15.0(2.69)***	0.62	24.4
Fat proportion						
Muscular score (g/kg)	123	-3.23(1.111)**			0.10	24.0
Scanned muscle and fat (g/kg)	146		-1.12(0.222)***	14.5(2.01)***	0.48	18.3
Bone proportion						
Muscular score (g/kg)	260	-8.1(0.47)***			0.80	10.2
Scanned muscle and fat (g/kg)	320		-1.92(0.164)***	0.53(1.483)	0.65	13.5

Table 8: Regression equations using live animal muscle scores obtained by Assessor A and ultrasound muscle and fat measurements at 8 to 12 months and at slaughter for predicting the proportions of meat, fat, bone and high-value meat cuts in the carcass and carcass value

	Intercept	Muscular Score (scale 1 to 15)	Muscle depth (mm)	Fat depth (mm)	R^2	Residual Standard Deviation
8 to 12 months						
Carcass weight (kg)	73	5.7(3.40)	3.3(0.654)***	24.4(14.16)	0.69	31.9
Kill-out proportion (g/kg)	459	9.8(2.41)***	0.6(0.46)	15.9(10.0)	0.62	22.6
Meat proportion (g/kg)	604	8.4(3.16)**	0.8(0.61)	10.7(13.17)	0.44	29.7
Fat proportion (g/kg)	137	-2.1(2.59)	-0.5(0.50)	0.7(10.77)	0.07	24.3
Bone proportion (g/kg)	260	-6.3(1.40)***	-0.33(0.270)	-11.5(5.84)	0.67	13.1
Proportion of high priced cuts (g/kg)	63	1.0(0.53)	0.03(0.103)	1.3(2.23)	0.19	5.0
High-value cuts as proportion of meat (g/kg)	104	0.27(0.672)	-0.06(0.129)	-0.07(2.80)	0.00	6.3
Carcass value (c/kg)	252	3.8(1.58)*	0.38(0.304)	8.9(6.58)	0.44	14.8
Slaughter						
Carcass weight (kg)	84	13.3(2.56)***	1.8(0.66)**	2.5(3.28)	0.74	30.0
Kill-out proportion (g/kg)	466	11.8(1.766)***	0.2(0.46)	-5.6(0.23)*	0.69	20.5
Meat proportion (g/kg)	593	9.2(1.82)***	1.0(0.47)*	-16.4(2.34)***	0.72	21.0
Fat proportion (g/kg)	129	-2.5(1.56)	-0.57(0.403)	14.9(2.003)***	0.49	18.1
Bone proportion (g/kg)	277	-6.7(0.86)***	-0.47(0.222)*	1.5(1.10)	0.81	9.9
Proportion of high priced cuts (g/kg)	57	0.56(0.366)	0.21(0.094)*	-2.1(0.47)***	0.42	4.2
High-value cuts as proportion of meat (g/kg)	97	-0.5(0.54)	0.15(0.138)	-0.74(0.690)	0.03	6.2
Carcass value (c/kg)	241	4.1(0.90)***	0.6(0.233)**	-8.1(1.16)***	0.72	10.4

Table 9: Regression on carcass conformation and fat scores of carcass weight, kill-out proportion, carcass meat, fat and bone proportions, proportion of high-value cuts in the carcass and in meat and carcass value

	Intercept	Conformation Score (Scale 1 to 15)	Fat Score (Scale 1 to 15)	R^2	Residual Standard Deviation
Carcass weight (kg)	128	17.8 (1.56)***	2.8 (3.0)	0.64	34.5
Kill-out proportion (g/kg)	477	11.9 (0.89)***	-2.9 (1.73)	0.71	2.0
Meat proportion (g/kg)	685	11.9(0.91)***	-11.1 (1.77)***	0.74	20.2
Fat proportion (g/kg)	41.7	-4.0 (0.76)***	11.8 (1.48)***	0.55	16.9
Bone proportion (g/kg)	273	-7.9 (0.46)***	-0.7 (0.89)	0.80	10.2
Proportion of high priced cuts in carcass (g/kg)	68.6	1.1 (0.21)***	-0.9 (0.42)*	0.28	4.8
High-value cuts as proportion of meat (g/kg)	100	-0.1 (0.28)	0.4 (0.55)	0.01	6.3
Carcass value (c/kg)	287	5.8 (0.50)***	-4.9 (0.99)***	0.68	11.3

EXPERIMENT 3: The relationship of live animal muscular and skeletal scores, ultrasound measurements and carcass classification scores with carcass composition and value in steers

Introduction

Fisher (2007) has pointed out that beef carcass classification plays an important role in Europe, as a marketing aid within and between countries and as a means of increasing the precision of price reporting for administrative purposes. The purpose of carcass classification is to categorise carcasses according to their conformation and fatness. In the European Union (EU), beef carcasses are classified according to the official beef carcass classification scheme (Commission of the European Communities, 1982). For conformation, the classes EUROP are used with E denoting carcasses with the best conformation with an option of an S class for carcasses with extremely good muscular development, whereas fat cover is assessed on a five-point scale (1 to 5), with 1 being the leanest (Allen, 2007). By attaching a pricing schedule to the various classes, producers are incentivised to supply the type of carcass required by the market (Allen, 2007). However, the usefulness of carcass classification information for conformation and fatness is dependent on their relationship to economically important traits such as meat yield, meat distribution in the carcass and, ultimately, carcass value (Drennan, 2006). Delfa et al. (2007), using 69 bull carcasses, found that hot carcass weight and EU carcass classification for conformation and fatness explained 97%, 60% and 85% of muscle, fat and bone weight, respectively. Perry et al. (1993 a) reported that carcass weight and carcass muscle score accounted for 38% of the total variation in meat yield, with carcass muscle score accounting for nearly all of the variation. In contrast, other studies have shown poor relationships between carcass shape score or conformation score and meat yield (Kempster and Harrington, 1980; Taylor et al., 1990). Few studies have, however, examined the relationship between carcass conformation and fat scores as measured under the EU beef carcass classification scheme with carcass traits and value.

Information from carcass classification, which is based on visual examination of carcasses and has been replaced by mechanical classification in Ireland, could play an important role in breed improvement programmes. Additionally, live animal scores/measurements could be used to further assist the breeding and production of animals that meet market requirements through identification or screening earlier in life provided that there is a good relationship between these live animal records and the carcass traits of interest. Previous studies (Perry et al., 1993a; MacAodháin, 2004; Drennan et al., 2008) have shown that live animal muscular scores were useful in predicting meat yield. Furthermore, Greiner et al. (2003) found that live animal ultrasound measurements of the longissimus dorsi were useful predictors of retail product. Live animal ultrasound measurements were shown to have a good relationship with carcass meat proportion (Faulkner et al., 1990; Tait et al., 2005).

The objectives of this study were to determine the relationship of (i) live animal muscular and skeletal scores, and ultrasonically scanned muscle and fat depth measurements of the longissimus dorsi and (ii) carcass conformation and fat scores with carcass composition and value.

Material and methods

Animals and management

A total of 336 steers slaughtered over a 2-year period in eight different batches were used. The animals consisted of Holstein-Friesian, Aberdeen Angus 3 Holstein-Friesian and 0.5 to 1.0 late-maturing continental breed crosses. The finishing diet varied from grass silage only, grass or maize silage plus supplementary concentrates to concentrates offered ad libitum plus 1 kg of roughage dry matter per head daily. All animals were slaughtered at the end of a winter housing period when approximately 2 years old.

Muscular and skeletal scores/measurements

At 8 to 12 months of age and pre-slaughter, animals were linear-scored by two assessors (A and B) from the Irish Cattle Breeding Federation (ICBF). This involved assigning muscular scores on a scale of 1 (poor) to 15 (excellent), at six locations (width at withers, width behind withers, loin development, development of hind-quarter, width of hind-quarter and development of the inner thigh) and skeletal scores (scale of 1 to 10) at three locations (length of back, pelvic length and height at withers) (ICBF, 2002). The six muscular scores were then averaged to give one score per animal for each assessor. Skeletal scores were also averaged in a similar manner. Allowances were made for subcutaneous fat by the assessors when assigning muscular scores. Simultaneously, scores were also assigned using the Signet scoring system (Allen, 1990) by two staff members (assessors C and D) from the research centre. The Signet muscular score was also based on a scale of 1 to 15 extending to 18 for double-muscled animals. The three scoring locations were roundness of hind-quarter, width of hind-quarter and depth and width of loin, which were also averaged to give a mean score per animal for each assessor. All scoring was carried out by visual assessment except for height at withers, which was recorded using a measuring pole.

Of the 336 animals that were boned out under commercial abattoir conditions, the assessors A, B, C and D recorded pre-slaughter live animal scores on 336, 246, 336 and 280 steers, respectively. Corresponding numbers scored at 8 to 12 months of age were 85, 67, 67 and 67.

Ultrasound measurements

Scanned ultrasound measurements were recorded on the right side of a proportion of the animals at 8 to 12 months of age (n 5 85) and pre-slaughter (n 5 146). A dynamic imaging real-time scanner (model – Concept MLV, with 3.5 MHz head) was used and eye muscle depth was measured at the third lumbar vertebra, and fat depth at both the third lumbar vertebra and 13th thoracic rib. Hair was clipped from each area pre-scanning and vegetable oil was applied to obtain adequate acoustic contact. Cattle were restrained at the head and physical palpation was used to accurately ascertain the scanning sites. The probe was placed perpendicular to the rib eye length (longissimus dorsi muscle) at the third lumbar vertebra and 13th thoracic rib until bones appeared on the monitor, and when a satisfactory image was achieved it was frozen on the monitor. Eye muscle depth and fat depth were then measured using an internal calliper built into the software to give instant results. Fat depth was measured at three points at the third lumbar vertebra across the width (0.4, 0.6 and 0.8) of the muscle and at four points (0.2, 0.4, 0.6 and 0.8) at the 13th thoracic vertebra. Fat depth was calculated by taking the mean of the average values for the third lumbar and 13th thoracic rib. Muscle depth was obtained at the deepest point (0.25) of the muscle (from the bottom of the backfat to the top of the bone) at the third lumbar vertebra.

Carcass measurements

Carcass conformation and fat scores were obtained using the mechanical grading system (Allen, 2007) on a 15-point scale rather than a five-point scale (Commission of the European Communities, 1982). Hot carcass weight was recorded and cold carcass weight was taken as 0.98 of hot carcass weight. Weight of perinephric and retroperitoneal fat was also recorded at slaughter. Following a period of 24 h at 4°C, the right side of each carcass was quartered at the fifth rib into an eight-rib pistola and the remaining forequarter. After recording the weight, the pistola was dissected into 13 cuts (leg, heel, silverside, topside, knuckle, rump, tail of rump, cap of rump, fillet, strip loin, cube roll, cap of rib and eye of round) from which all visible fat and bone (where applicable) was removed. The weight of each meat cut and total fat from the pistola were recorded as was bone weight following removal of all adhering tissues. Lean trim was weighed separately and added to the meat cuts to give total pistola meat yield. A similar procedure was carried out with the fore-quarter, which was dissected into 11 cuts (front shin, neck, brisket, chuck, flat ribs (1 to 5), plate, leg of mutton cut, bladesteak, braising muscle, chuck tender and clod). Pistola and fore-quarter meat, fat and bone weights were combined to give the weight of each component in the half carcass. High-value cuts in the carcass were defined as the meat in the cube roll, striploin and fillet. Carcass value was estimated as the sum of the commercial value of each meat cut with a small deduction for bone expressed as a proportion of half carcass weight.

Statistical analysis

Data were analysed using Proc REG and CORR of the Statistical Analysis Systems Institute (SAS, 2007). Simple correlation coefficients of live animal scores/measurements and carcass conformation and fat scores with the various carcass traits were carried out using Pearson’s correlations. The relationships between muscular scores, ultrasound muscle and fat depths, and conformation and fat scores and the dependant variables (meat, fat and bone proportions, proportion of high-value cuts in the carcass and meat, and carcass value) were determined using multiple regression. The contribution made to the estimation of each dependent variable by each independent variable was determined by comparison of the coefficient of determination (R2) and the residual standard deviation (r.s.d.).

Results

The mean, range and standard deviations for live and carcass traits are summarised in Table 1. At slaughter, animals had a mean age of 745 days, live weight of 640 kg and cold carcass weight of 342 kg. Carcass conformation and fat scores ranged from 2.0 to 12.0 and from 2.8 to 13.3, respectively. Carcass meat, fat and bone proportions were 686, 119 and 195 g/kg, respectively. High-value cuts in the carcass and in meat were 70 and 103 g/kg, respectively.

Assessors

Correlations obtained between the four assessors (two using the ICBF system and two using the Signet system) for muscular scores at 8 to 12 months of age ranged from 0.74 to 0.87 and pre-slaughter ranged from 0.71 to 0.86 ($P<0.001$). Repeatability values using simple correlations, obtained from scanning 84 animals, on two consecutive days pre-slaughter were 0.92 for muscle depth and 0.84 for fat depth.

Correlations using live animal muscular scores

Correlations using live animal scores with the various carcass traits are shown in Tables 2 and 3. Based on the figures obtained by the ICBF assessor A, positive correla¬tions were obtained (Table 3) using the average muscular score pre-slaughter with carcass meat proportion (r= 0.60), value (r= 0.55), carcass conformation score (r= 0.86) and the proportion of high-value cuts in the carcass (r= 0.31). The corresponding correlations were negative with carcass bone (r= —0.81) and fat proportion (r= —0.13), whereas those with the proportion of high-value cuts in the meat, perinephric and retroperitoneal fat and carcass fat score were low, and generally non-significant, ranging from —0.04 to 0.14. Corresponding correlations between live animal muscular scores at 8 to 12 months of age (Table 2) with the various carcass traits generally showed lower values and similar trends when compared to those using pre- slaughter figures. Correlations using muscular scores by assessors B, C and D were similar to those obtained by assessor A. Correlations between ICBF hind-quarter development alone and the various carcass traits resulted in similar correlations to the ICBF average of all six individual locations.

Correlations using skeletal scores

Correlation coefficients (Table 4), using skeletal scores (three locations combined) recorded pre-slaughter by Assessor A, showed positive correlations with carcass weight (r= 0.40), carcass fat proportion (r= 0.30), carcass bone proportion (r= 0.13), perinephric and retroperitoneal fat (r= 0.52) and carcass fat score (r= 0.31), whereas negative correlations ($P < 0.01$), ranging between -0.18 and -0.38, were obtained with carcass meat proportion, proportion of high-value cuts in the carcass and in meat, carcass value and carcass conformation score. Correlations between individual skeletal scores pre-slaughter generally had similar values to the average of the combined ICBF skeletal scores. Skeletal scores by assessor B had lower correlations with the various carcass traits than those obtained by assessor A. Correlations between skeletal scores taken at 8 to 12 months of age with the various carcass traits for both assessors A and B were poor, and generally not significant.

Correlations using ultrasonically scanned measurements

Positive correlations ($P < 0.001$) were obtained (Table 5) between scanned muscle depth pre-slaughter and carcass weight (r= 0.72), carcass meat proportion (r= 0.52), proportion of high-value cuts in the carcass (r= 0.31), carcass conformation score (r= 0.80) and carcass value (r= 0.47), whereas a high negative correlation ($P < 0.001$) was obtained with carcass bone proportion (r= -0.75). Low correlations, ranging from -0.08 to 0.21, were obtained between scanned muscle depth taken pre-slaughter and carcass fat proportion, proportion of high-value cuts in the meat, perinephric and retroperitoneal fat and carcass fat score. Corresponding correlations for scanned muscle depth at 8 to 12 months of age showed similar trends but were generally lower. Significant positive correlations were obtained between scanned fat depth taken pre-slaughter and carcass weight (r= 0.58), carcass fat proportion (r= 0.59), perinephric and retroperitoneal fat (r= 0.45), carcass conformation (r= 0.33) and fat score (r= 0.63), whereas significant negative correlations were obtained with carcass meat (r= -0.23) and bone (r= -0.50) proportions, proportion of high-value cuts in the carcass (r= -0.34) and in meat (r= -0.27) and carcass value (r= -0.32). Correlation coefficients between scanned fat depths at 8 to 12 months of age were in the same direction of those obtained pre-slaughter with carcass meat and fat proportions, proportion of high-value cuts in carcass and in meat and carcass value. Corresponding correlations with carcass weight, perinephric and retroperitoneal fat, carcass bone proportion and carcass conformation score were not significant.

Correlations using carcass conformation and fat scores

Positive correlations ($P < 0.001$), ranging between 0.60 and 0.71, were obtained (Table 6) for carcass conformation score with carcass weight, carcass meat proportion and carcass value, and a lower value obtained for the proportion of high-value cuts in the carcass (r= 0.29), whereas significant negative correlations were obtained with carcass bone (r= -0.84) and fat (r= -0.19) proportions and the proportion of high-value cuts in the meat (r= -0.11). Correlations of conformation score with perinephric and retroperitoneal fat and fat score were not significant. Positive correlations ($P < 0.001$) were obtained for carcass fat score with carcass weight (r= 0.42), carcass fat proportion (r= 0.69), proportion of high-value cuts in the meat (r= 0.24) and perinephric and retroperitoneal fat (r= 0.47), whereas negative correlations ($P < 0.001$), ranging between -0.31 and -0.43, were obtained with carcass meat and bone proportions, proportion of high- value cuts in the carcass and carcass value.

Regressions using live animal scores and measurements

Regression equations using live animal muscular scores (based on the figures recorded by ICBF assessor A) and ultrasound muscle and fat depth measurements alone to predict carcass meat, fat and bone proportions are shown in Table 7. Both muscular score (average of the six locations) and scanned muscle and fat depth alone taken pre-slaughter explained 0.36 and 0.51, respectively, of the total variation in carcass meat proportion. Muscular score alone was a poor predictor of carcass fat proportion (R2 = 0.02), whereas scanned muscle and fat depth alone explained 0.48 of the total variation in fat proportion. Muscular score alone and scanned muscle and fat depth measurements explained 0.66 and 0.59, respectively, of total variation in carcass bone proportion. The corresponding R2 values involving muscular score alone and scanned measurements at 8 to 12 months of age were lower but generally followed a similar trend to values obtained using those taken pre-slaughter.

Multiple regression equations using the combined live animal muscular scores and ultrasound muscle and fat depth measurements to predict the various carcass traits and carcass value are shown in Table 8. Using pre-slaughter measurements, the combined muscular and scanned measurements explained between 0.53 and 0.68 of the total variation in carcass meat and bone proportions and carcass value, with a lower proportion of total variation explained for carcass fat proportion (R2 = 0.48), the proportion of high-value cuts in the carcass (R2 = 0.37) and in meat (R1 = 0.10) and perinephric and retroperitoneal fat (R2 = 0.20). Again, corresponding R2 using muscular score and scanned measurements taken at 8 to 12 months of age were considerably lower than those obtained using pre- slaughter figures.

Regressions using carcass conformation and fat scores

Regression analysis (Table 9) showed that carcass conformation and fat scores explained between 0.60 and 0.76 of the total variation in carcass meat and bone proportions and carcass value, whereas the variation explained with carcass fat proportion (R^2 = 0.54), proportion of high- value cuts in the carcass (R^2 = 0.28) and perinephric and retroperitoneal fat (R^2 = 0.23) was lower. Little variation was explained (R^2 = 0.06) in using carcass conformation and fat scores to predict the proportion of high-value cuts in meat.

Conclusion

It can be concluded that pre-slaughter live animal scores and measurements were good predictors of carcass meat proportion and carcass value (R^2 5 0.53 to 0.58), and are therefore potentially useful in breed improvement programmes, particularly with breeding animals, where carcass data would not be available. However, the poorer relationships using data obtained at 8 to 12 months of age rather than pre-slaughter indicates the need to have animals at an advanced stage of finish when assessment is carried out. Muscular scoring systems can be simplified to three locations with emphasis on the hind-quarter and loin area. The EU beef carcass classification for conformation and fatness carried out mechanically was shown to be a good predictor of carcass meat proportion and value and thus, in addition to placing commercial value on carcasses, would be useful in progeny testing programmes.

Implications

In breed improvement programmes, repeatable live animal scores and measurements can be used in the identification of animals with superior genetic merit for carcass composition and value. This study also showed the potential of EU carcass conformation and fat scores to predict carcass meat proportion and thus, facilitate the operation of a payment system based on meat yield, which would reward farmers more equitably.

Table 1: Mean, standard deviation and range for live animal and carcass scores and measurements of steers

	Mean	Standard Deviation	Minimum	Maximum
At 8-12 months of age				
Muscular scores (scale 1 to 15)				
Width between withers (ICBF assessor A)	6.5	2.00	2.0	10.0
Width behind withers (ICBF assessor A)	5.8	1.95	1.0	9.0
Loin development (ICBF assessor A)	6.5	1.57	2.0	9.0
Hindquarter development (ICBF assessor A)	6.8	1.88	3.0	10.0
Hindquarter width (ICBF assessor A)	6.8	1.46	4.0	10.0
Inner-thigh development (ICBF assessor A)	6.4	1.75	2.0	10.0
ICBF average muscular score (assessor A)	6.5	1.69	2.5	9.5
ICBF muscular score at 5 locations (assessor A)	6.5	1.69	2.6	9.4
ICBF muscular score at 2 locations (assessor A)	6.8	1.62	3.5	10.0
ICBF average muscular score (assessor B)	5.8	1.52	2.5	9.3
Signet muscular score (assessor C)	6.2	1.54	3.0	9.3
Signet muscular score (assessor D)	6.1	2.23	1.0	9.7
Scanned eye muscle depth (mm)	55.0	7.34	39.0	75.2
Scanned fat depth (mm)	0.95	0.269	0.25	1.45
Pre-slaughter				
Muscular scores (scale 1 to 15)				
Width between withers (ICBF assessor A)	7.8	2.29	1.0	12.0
Width behind withers (ICBF assessor A)	7.1	2.25	1.0	11.0
Loin development (ICBF assessor A)	8.1	1.90	1.0	11.0
Hindquarter development (ICBF assessor A)	7.6	2.15	2.0	12.0
Hindquarter width (ICBF assessor A)	8.3	1.47	3.0	12.0
Inner-thigh development (ICBF assessor A)	7.4	1.90	1.0	10.0
ICBF average muscular score (assessor A)	7.7	1.87	1.83	10.8
ICBF muscular score at 5 locations (assessor A)	7.8	1.89	1.8	11.0
ICBF muscular score at 2 locations (assessor A)	7.9	1.76	2.5	11.5
ICBF average muscular score (ICBF assessor B)	7.0	2.03	2.3	13.2
Signet muscular score (assessor C)	6.2	2.33	1.0	11.0
Signet muscular score (assessor D)	5.6	2.30	1.0	11.0
Scanned eye muscle depth (mm)	71.5	9.08	52.6	91.2
Scanned fat depth (mm)	3.5	1.78	0.3	9.1
Pre-slaughter weight (kg)	640	82.6	435	884
Post-slaughter				
Cold carcass wt (kg)	342	53.6	234	501
Kill-out (g/kg)	533	29.2	470	621
Slaughter age (kg)	745	55	437	915
Perinephric plus retroperitioneal fat (kg)	9.2	3.22	2.9	20.6
[1]Conformation score (scale 1 to 15)	7.1	2.27	2.0	12.0
[2]Fat score (scale 1 to 15)	8.5	1.92	2.8	13.3
Meat (g/kg)	686	36.0	593	785
Fat (g/kg)	119	29.1	54	211
Bone (g/kg)	195	21.8	150	262
High-value cuts in carcass (g/kg)	70	6.4	52	87
High-value cuts in meat (g/kg)	103	7.3	77	112
Carcass value (c/kg)	293	19.8	244	347

[1]15 = best conformation; [2]15 = fattest.

Table 2: Correlations of live animal muscular scores at 8 to 12 months of age with carcass weight, carcass meat, fat and bone proportions, proportion of high-value cuts in the carcass and meat, perinephic and retroperitoneal fat, carcass conformation and fat scores and carcass value

		Proportion in carcass						Carcass		
	Carcass weight	Meat	Fat	Bone	[1]HVC	[1]HVC in Meat	Perinephic + Retroperitoneal fat	Conformation Score	Fat Score	Value
Width between withers (A)	0.53***	0.33**	-0.11	-0.60***	0.29**	0.20	0.29**	0.61***	0.10	0.36***
Width behind withers (A)	0.48***	0.30**	-0.10	-0.58***	0.25**	0.16	0.25*	0.59***	0.14	0.34**
Loin development (A)	0.56***	0.27*	-0.07	-0.55***	0.26*	0.19	0.25*	0.54***	0.10	0.32**
Hind-quarter development (A)	0.56***	0.32**	-0.12	-0.58***	0.29**	0.19	0.29**	0.59***	0.13	0.35**
Hind-quarter width (A)	0.60***	0.22**	-0.03	-0.53***	0.11	0.03	0.11	0.44***	0.19	0.22*
Inner-thigh development (A)	0.54***	0.27*	-0.07	-0.55***	0.21	0.13	0.21	0.55***	0.14	0.30**
ICBF average muscular score (A)	0.57***	0.30**	-0.09	-0.60***	0.25*	0.16	0.25*	0.59***	0.14	0.33**
ICBF muscular score -5 locations (A)	0.57***	0.31**	-0.09	-0.60***	0.26*	0.17	0.26*	0.59***	0.13	0.34**
ICBF muscular score - 2 locations (A)	0.59***	0.29**	-0.09	-0.58***	0.22*	0.13	0.22*	0.54***	0.16	0.30**
ICBF average muscular score (B)	0.43***	0.45***	-0.25*	-0.62***	0.39**	0.22	-0.19	0.62***	0.05	0.47***
Signet muscular score (C)	0.49***	0.46***	-0.23	-0.68***	0.40***	0.23	-0.09	0.61***	-0.003	0.50***
Signet muscular score (D)	0.66***	0.50***	-0.27*	-0.70***	0.47***	0.29*	-0.21	0.77***	0.009	0.54***

[1]High-value cuts. Assessors A and B: ICBF linear muscular scoring system. Assessors C and D: Signet muscular scoring system.

Table 3: Correlations of live animal muscular scores pre-slaughter with carcass weight, killing-out rate, carcass meat, fat and bone proportions, proportion of high-value cuts in the carcass and meat, perinephic and retroperitoneal fat, carcass conformation and fat scores and carcass value

		Proportion in carcass						Carcass		
	Carcass weight	Meat	Fat	Bone	[1]HVC	[1]HVC in Meat	Perinephic + Retroperitoneal fat	Conformation Score	Fat Score	Value
Width between withers (A)	0.57***	0.57***	-0.14*	-0.76***	0.32***	-0.02	0.01	0.80***	0.14*	0.53***
Width behind withers (A)	0.58***	0.58***	-0.11*	-0.82***	0.30***	-0.05	0.01	0.84***	0.17**	0.53***
Loin development (A)	0.59***	0.49***	-0.03	-0.77***	0.20***	-0.11	0.08	0.79***	0.18***	0.43***
Hind-quarter development (A)	0.51***	0.64***	-0.23***	-0.75***	0.37***	-0.01	-0.11	0.82***	-0.03	0.60***
Hind-quarter width (A)	0.63***	0.52***	-0.07	-0.77***	0.22***	-0.11*	0.04	0.81***	0.14**	0.47***
Inner-thigh development (A)	0.48***	0.55***	-0.14**	-0.72***	0.32***	-0.01	-0.06	0.76***	0.11	0.52***
Average muscular score (A)	0.59***	0.60***	-0.13*	-0.81***	0.31***	-0.04	0.007	0.86***	0.14*	0.55***
ICBF muscular score - 5 locations (A)	0.61***	0.60***	-0.13*	-0.82***	0.30***	-0.05	0.003	0.86***	0.14*	0.55***
ICBF muscular score - 2 locations (A)	0.58***	0.61***	-0.17**	-0.82***	0.32***	-0.04	-0.05	0.85***	0.08	0.57***
ICBF average muscular score (B)	0.58***	0.56***	-0.15*	-0.78***	0.44***	0.14*	0.14*	0.79***	0.20**	0.56***
Signet muscular score (C)	0.58***	0.63***	-0.17**	-0.81***	0.30***	-0.08	-0.09	0.88***	0.08	0.59***
Signet muscular score (D)	0.46***	0.62***	-0.24***	-0.70***	0.37***	-0.02	0.12*	0.79***	0.02	0.60***

[1]High-value cuts. Assessors A and B: ICBF linear muscular scoring system. Assessors C and D: Signet muscular scoring system.

Table 4: Correlation of live animal skeletal scores with carcass weight, carcass meat, fat and bone proportions, proportion of high-value cuts in the carcass and meat, perinephric and retropertitoneal fat, carcass conformation and fat scores and carcass value

		Proportion in carcass						Carcass		
At 8-12 months of age	Carcass weight	Meat	Fat	Bone	[1]HVC	[1]HVC in Meat	Perinephic + Retroperitoneal fat	Conformation Score	Fat Score	Value
Height at withers (A)	0.44***	-0.26*	0.28**	0.02	-0.36***	-0.32**	0.27*	-0.20	0.28**	-0.30**
Length of back (A)	0.40***	-0.13	0.16	-0.02	-0.18	-0.16	0.09	-0.12	0.24*	-0.15
Length of pelvis (A)	0.41***	-0.96	0.14	-0.07	-0.19	-0.19	0.13	-0.04	0.21	-0.12
ICBF average skeletal (A)	0.44***	-0.17	0.20	-0.02	-0.26*	-0.24*	0.17	-0.12	0.26*	-0.20
Height at withers (B)	0.51***	-0.15	0.18	-0.007	-0.16	-0.10	0.33**	0.04	0.22	-0.13
Length of back (B)	0.41***	-0.15	-0.04	-0.30*	0.16	0.14	-0.10	0.26*	0.20	0.16
Length of pelvis (B)	0.33**	-0.03	0.06	-0.06	-0.02	0.003	0.17	0.11	0.06	0.002
ICBF average skeletal (B)	0.50***	-0.02	0.09	-0.14	-0.01	0.14	0.17	0.16	0.20	0.01
Pre-slaughter										
Height at withers (A)	0.36***	-0.31***	0.28***	0.15**	-0.38***	-0.26***	0.51***	-0.22***	0.30***	-0.38***
Length of back (A)	0.43***	-0.24***	0.25***	0.07	-0.29***	-0.19***	0.46***	-0.08	0.26***	-0.29***
Length of pelvis (A)	0.35***	-0.32***	0.29***	0.14*	-0.37***	-0.24***	0.47***	-0.19***	0.30***	-0.37***
ICBF average skeletal (A)	0.40***	-0.32***	0.30***	0.13*	-0.38***	-0.25***	0.52***	-0.18**	0.31***	-0.38***
Height at withers (B)	0.27***	-0.34***	0.20**	0.30***	-0.32***	-0.17**	0.38***	-0.41***	0.24***	-0.34***
Length of back (B)	0.33***	-0.13*	-0.13*	0.05	0.11	-0.05	0.27***	-0.08	0.24***	-0.12
Length of pelvis (B)	0.30***	-0.22***	0.20**	0.09	-0.16*	-0.05	0.32***	-0.23***	0.34***	-0.22***
ICBF average skeletal (B)	0.37***	-0.29***	0.22***	0.19**	-0.25***	-0.11	0.40***	-0.31***	0.33***	-0.29***

[1]High-value cuts. A= ICBF assessor A B= ICBF assessor B.

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Table 5: Correlation of ultrasonically scanned measurements with carcass weight, carcass meat, fat and bone proportions, proportion of high-value cuts in the carcass, and in meat, perinephric and retroperitoneal fat, carcass conformation and fat scores and carcass value

		Proportion in carcass						Carcass		
	Carcass weight	Meat	Fat	Bone	[1]HVC	[1]HVC in Meat	Perinephic + Retroperitoneal fat	Conformation Score	Fat Score	Value
At 8-12 months of age										
Muscle depth	0.64***	0.31**	-0.08	-0.62***	0.23*	0.12	-0.03	0.60***	0.13	0.31**
Fat depth	0.15	-0.32**	0.37***	-0.01	-0.46***	-0.41***	0.14	-0.21	0.35**	-0.39***
Pre-slaughter										
Muscle depth	0.72***	0.52***	-0.08	-0.75***	0.31***	0.07	0.11	0.80***	0.21*	0.47***
Fat depth	0.58***	-0.23**	0.59***	-0.50***	-0.34**	-0.27***	0.45***	0.33***	0.63***	-0.32***

[1]High-value cuts.

Table 6: Correlation of carcass conformation and fat scores with carcass weight, carcass meat, fat and bone proportions, proportion of high-value cuts in the carcass and meat, carcass conformation and fat scores, perinephric and retroperitoneal fat and carcass value

		Proportion in carcass						Carcass		
	Carcass weight	Meat	Fat	Bone	[1]HVC	[1]HVC in Meat	Perinephic + Retroperitoneal fat	Conformation Score	Fat Score	Value
Conformation Score	0.71***	0.66***	-0.19***	-0.84***	0.29***	-0.11*	-0.01	1	0.10	0.60***
Fat Score	0.42***	-0.37***	0.69***	-0.31***	-0.41***	0.24***	0.47***	0.10	1	-0.43***

[1]High-value cuts.

Table 7: Regression equations using live animal muscular and ultrasound scanned measurements at 8 to 12 months of age and pre-slaughter for predicting carcass meat, fat and bone proportions

	Intercept	Muscular score	Scanned muscle depth	Scanned fat depth	R^2	Residual standard deviation
At 8-12 months of age						
Meat proportion						
Muscular score	662	6.4(2.20)**			0.08	34.0
Scanned muscle and fat	655		1.7(0.48)***	-49.0(13.00)***	0.21	31.7
Fat proportion						
Muscular score	133	-1.7(2.03)			0.01	31.4
Scanned muscle and fat	111		-0.6(0.44)	45.4(12.10)***	0.13	29.3
Bone proportion						
Muscular score	205	-4.7(0.70)***			0.35	10.8
Scanned muscle and fat	234		-1.1(0.16)***	3.4(4.36)	0.37	10.6
Pre-slaughter						
Meat proportion						
Muscular score	596	11.6(0.84)***			0.36	28.9
Scanned muscle and fat	531		2.8(0.24)***	-10.3(1.21)***	0.51	23.3
Fat proportion						
Muscular score	135	-2.1(0.84)*			0.02	28.9
Scanned muscle and fat	173		-1.33(0.217)***	12.9(1.11)***	0.48	21.4
Bone proportion						
Muscular score	268	-9.4(0.37)***			0.66	12.7
Scanned muscle and fat	296		-1.43(0.129)***	-2.57(0.661)	0.59	12.8

Table 8: Regression equations using live animal muscle scores and ultrasound muscle and fat measurements at 8 to 12 months of age and pre-slaughter for predicting the proportions of meat, fat, bone and high-value meat cuts in the carcass and carcass value

	Intercept	Muscular score	Muscle depth	Fat depth	R^2	Residual Standard Deviation
At 8-12 months of age						
Meat proportion (g/kg)	660	4.3(2.55)	1.1(0.59)	-49.1(12.87)***	0.23	31.3
Fat proportion (g/kg)	109	-1.5(2.41)	-0.4(0.55)	45.5(12.10)***	0.13	29.4
Bone proportion (g/kg)	231	-2.9(0.81)***	-0.8(0.19)***	3.6(4.08)	0.45	9.9
Proportion of high-value cuts (g/kg)	66	0.9(0.52)	0.18(0.120)	14.2(2.62)***	0.30	6.4
High-value cuts as proportion of meat (g/kg)	100	0.77(0.609)	0.09(0.141)	-13.3(3.07)***	0.18	7.5
Perinephric plus retroperitoneal fat (kg)	10.1	-0.2(0.27)	0.008(0.0617)	1.8(1.34)	0.03	3.3
Carcass value (c/kg)	276	3.3(1.45)*	0.59(0.335)	-34.9(7.30)***	0.30	17.8
Pre-slaughter						
Meat proportion (g/kg)	535	5.4(1.84)**	-2.1(0.33)***	-10.5(1.18)***	0.53	22.7
Fat proportion (g/kg)	173	0.34(1.74)	-1.4(0.31)***	12.9(1.11)***	0.48	21.5
Bone proportion (g/kg)	292	-5.8(0.92)***	-0.7(0.16)***	-2.4(0.59)	0.68	11.3
Proportion of high-value cuts (g/kg)	48	0.7(0.42)	0.31(0.073)***	-2.1(0.27)***	0.37	5.1
High-value cuts as proportion of meat (g/kg)	91	0.2(0.58)	0.16(0.102)	-1.6(0.37)***	0.10	7.1
Perinephric plus retroperitoneal fat (kg)	9.5	0.08(0.231)	-0.05(0.041)	0.9(0.15)***	0.20	2.9
Carcass value (c/kg)	211	3.2(0.97)**	1.1(0.17)***	-6.7(0.62)***	0.58	12.0

Table 9: Regression on carcass conformation and fat scores of carcass meat, fat and bone proportions, proportion of high-value cuts in the carcass and in meat and carcass value

	Intercept	Conformation Score	Fat Score	R^2	Residual standard deviation
Meat proportion (g/kg)	675***	11.2(0.53)***	-8.2(0.629)***	0.63	22.2
Fat proportion (g/kg)	51***	-3.3(0.47)***	10.9(0.56)***	0.54	19.7
Bone proportion (g/kg)	273***	-7.9(0.26)***	-2.7(0.30)***	0.76	10.6
Proportion of high-value cuts (g/kg)	76***	0.96(0.131)***	-1.5(0.16)***	0.28	5.4
High-value cuts as proportion of meat (g/kg)	112***	-0.27(0.169)	-0.9(0.20)***	0.06	7.0
Perinephric plus retroperitoneal fat (kg)	2.9***	-0.08(0.068)	0.8(0.08)***	0.23	2.8
Carcass value (c/kg)	296***	5.6(0.30)***	-5.1(0.36)***	0.60	12.6

EXPERIMENT 4: Predicting beef carcass meat, fat and bone proportions from carcass conformation and fat scores or hind-quarter dissection

Introduction

In the European Union (EU), beef carcasses are classified according to their conformation and fatness (ECIR0811981) (Allen, 2007). In 2004, Ireland replaced visual assessment with mechanical classification using a video image analysis (VIA) system. Automated classification simply mimics the human assessor by analysing an image of the carcass (Fisher *et al.,* 2007). Machine classification is deemed preferable to visual assessment because of greater consistency and producers can have more confidence in the objectivity of the results (Allen *et al.,* 2007). Several studies quantified the associations of ultrasound (Faulkner *et al.,* 1990; Herring *et al.,* 1994; Hamlin *et al.,* 1995) and live animal scores (Perry *et al.,* 1993a and 1993b) with carcass traits. However, few studies have examined the relationship between EU carcass classification scores and carcass composition (Drennan *et al.,* 2008; Conroy *et al.,* 2009a, b). Muldowney *et al.* (1997) reported that although conformation (EUROP coded 1 to 5) and fat scores (1 to 5) are routinely measured on beef carcasses their value as indicators of carcass characteristics and commercial value is not well established. Carcass conformation and fat scores have explained moderate to high proportions of the variation (R^2 ranged from 0.47 to 0.70) in carcass meat yield (Perry *et al.,* 1993b; Drennan *et al.,* 2008; Conroy *et al.,* 2009a, b). According to Gardner *et al.* (1997), the evaluation technique used to predict meat yield must be able to function on-line in a commercial setting without disrupting the normal product flow. Johnson and Chant (1998) noted that research has used very expensive technologies to improve the accuracy of carcass composition prediction, while Shackelford *et al*. (1995) reported that, to their knowledge, equations to predict boneless and totally trimmed retail cut yields have not been published.

Considering that payment for carcasses in the EU is based on carcass conformation and fat scores, and that these data are routinely available on carcasses, it seems logical to develop equations that predict carcass meat, fat and bone proportions using these scores. Accurate equations to predict carcass characteristics from routinely collected data would facilitate payment systems based on carcass meat proportion which, in addition to the specific market, is the main determinant of carcass value. Due to the differences in the value of different meat cuts, both meat yield and distribution are the primary determinants of carcass value (Drennan, 2006). Purchas *et al.* (1999) concluded that improvements in accuracy of predicting saleable meat yield proportion would provide an opportunity to increase the premiums paid on carcasses that excel in this characteristic. Payment based on meat yield would also send a stronger market signal to the producer since in a value-based marketing system the viability of the beef industry is dependent on the production of high quality, consistent carcasses (Hassan *et al.,* 1998).

In an industry that is seeking increasingly detailed data on carcass composition, an accurate and rapid technique to estimate carcass composition would be invaluable. A long-term objective of carcass dissection studies should be the development of accurate part to whole carcass composition relationships that would reduce the resource requirement that is now an integral part of detailed carcass dissection (Johnson and Charles, 1981). Zgur *et al.* (2006) reported that various individual cuts from the carcass explained moderate to high amounts of variation (0.58 to 0.80) in the percentage of carcass meat, fat and bone.

Therefore, the objectives were (1) to develop and test the accuracy of prediction equations for carcass meat, fat and bone proportions, derived from carcass conformation and fat scores, and (2) to develop prediction equations for total carcass composition from hind-quarter composition.

Materials and Methods

Animals and Management

A total of 662 animals, which included 115 bulls, 40 heifers and 507 steers, were available for the analysis. The animals were partitioned into the following genotype groups: (i) Holstein-Friesian; (ii) Early-maturing × Holstein Friesian and early-maturing × early-maturing; (iii) Late-maturing × Holstein Friesian and late-maturing × early-maturing and (iv) genotypes with 0.75 or greater late-maturing ancestry.

Bulls were slaughtered at 13 to 17 months of age on 3 different dates. The heifers were slaughtered at approximately 20 months of age on one day, whereas the steers were slaughtered at approximately 24 months of age on 12 different dates. Prior to slaughter, the bulls were offered *ad-libitum* access to a barley-based concentrate plus 1 kg of grass silage dry matter per head daily or, grass silage plus approximately 4 kg of a barley-based concentrate per head daily. The heifers were offered grass silage *ad-libitum* and approximately 4 kg of a barley-based concentrate per head daily. The diets offered to the steers prior to slaughter comprised either, grass silage only, grass or maize silage plus supplementary concentrates, or concentrates offered ad-*libitum* plus 1 kg of roughage dry matter per head daily.

Treatment for endo- and ecto-parasites and vaccination against clostridial and respiratory diseases was carried out as deemed necessary.

Carcass evaluations and measurements

Carcass conformation and fat scores were obtained using the mechanical grading system on a 15 point scale (Hickey *et al.*, 2007) rather than a 5 point scale (Commission of the European Communities, 1982). Hot weight of both sides of each carcass was recorded and cold carcass weight was taken as 0.98 of hot carcass weight. Following a period of 24 hours at 4°C, the right side of each carcass was quartered at the 5th rib into an 8-rib hind-quarter (pistola) and the remaining fore-quarter. After recording the weight, the hind-quarter was dissected into thirteen cuts (leg, heel, silverside, topside, knuckle, rump, tail of rump, cap of rump, fillet, strip loin, cube roll, cap of rib and eye of the round) from which all visible fat and bone (where applicable) were removed (Conroy *et al.*, 2009a). The weight of each individual meat cut and total fat from the hind-quarter was recorded, as was bone weight following removal of all adhering lean tissues. Lean trim was weighed separately and included with the meat cuts to give total hind-quarter meat yield. A similar procedure was carried out with the fore-quarter, which was dissected into eleven cuts (front shin, neck, brisket, chuck, flat ribs (1-5), plate, *M. triceps brachii*, bladesteak, braising muscle, chuck tender and clod) (Conroy *et al.*, 2009a). Hind-quarter and fore-quarter meat, fat and bone weights were combined to give the weight of each component in the half carcass. Recovered weights were calculated and expressed as a proportion of side weight to check for errors in weighing (Perry *et al.*, 1993a).

Statistical Analysis

Two series of analyses were undertaken (SAS, 2008), where in all cases, the dependent variable was carcass meat, fat or bone proportion. In the first series of analyses carcass conformation and fat score were included as continuous independent variables, while in the second series of analyses the continuous independent variable was the hind-quarter proportion of the dependent variable under investigation (i.e., when the dependent variable was carcass meat proportion the independent variable was hind-quarter meat proportion). In both series of analyses the same procedures were used. Preliminary analyses were undertaken on all data to develop the most parsimonious multiple regression prediction model using backward elimination. Gender, linear and non-linear associations with the regressors, as well as two way interactions between gender and the continuous independent variables, were initially included in the model; gender was included as a class effect with 3 levels (bulls, steers and heifers). Terms that didn't make a significant contribution (P>0.05) to the regression equation were removed. The proportion of variation in the dependent variable explained by the model was quantified. The ability of the developed equation at predicting meat, fat and bone yield was undertaken using cross-validation. This involved omitting each of the 662 animals individually from the development of the prediction equation and then applying the equation to the omitted animal to predict its meat, fat and bone yield. Residuals were calculated as the difference between true total carcass composition and predicted carcass composition. Parameters used to quantify the predictive ability of the equations were: 1) the normality of the residuals, 2) the average bias, computed as the mean of the residuals, 3) the root mean square error (RMSE), computed as the standard deviation of the residuals, 4) accuracy of the fit defined as the variance of the dependent variable divided by the sum of the variance of the dependent variable and the variance of the residuals, 5) the 25% and 75% quartiles of the residuals, and 6) the correlation between the predicted proportions and the residuals. Additional analyses were undertaken using a fixed effects linear model to determine if there was any systematic bias in the estimation of total carcass composition across genotype. Genotypes were (1) Holstein-Friesian (2) Early-maturing × Holstein-Friesian and early-maturing × early-maturing (3) Late-maturing × Holstein-Friesian and late-maturing × early-maturing and (4) genotypes with 0.75 or greater late-maturing ancestry. Following the completion of the analysis, prediction equations using carcass conformation and fat scores or hind-quarter composition were developed on the entire dataset and these are presented in this study.

Results

The mean, range and standard deviation for live animal, carcass traits and carcass yield components for bulls, heifers and steers are summarised in Table 1. At slaughter, the bulls, heifers and steers had a mean age of 454, 606 and 751 days, a live weight of 583, 535 and 625 kg, and a cold carcass weight of 332, 293 and 333 kg, respectively. Carcass conformation scores ranged from 4.7 to 14.4 for bulls, 5.4 to 10.9 for heifers and 2.0 to 12.0 for steers. Corresponding fat scores ranged from 2.7 to 11.5, 3.2 to 11.3, and 2.8 to 13.3.

Prediction equations using carcass conformation and fat scores

Prediction equations developed from the entire dataset for carcass meat, fat and bone proportions using carcass conformation and fat scores are summarised in Table 2. Gender was associated (P<0.001) with carcass composition although the relationship between either carcass conformation or fat score and carcass composition did not differ by gender. Furthermore, no non-linear associations (P > 0.05) between carcass conformation or fat score and carcass composition were evident. The correlation between carcass conformation and fat score (r = -0.07) was not different from zero.

Across genders, and at a constant carcass fat score, a one unit increase in carcass conformation score on a 15 point scale was associated with an increase in carcass meat proportion of 11.8 g/kg, whereas a one unit increase in carcass fat score was associated with a 9.6 g/kg decrease in carcass meat proportion. For carcass fat proportion a one unit increase in conformation score was associated with a reduction in fat proportion of 4.4 g/kg, whereas a one unit increase in carcass fat score was associated with an increase of 12.0 g/kg in carcass fat proportion. Both regression coefficients in the model showed a negative association with carcass bone proportion, with decreases of 7.4 g/kg and 2.4 g/kg per unit increase in carcass conformation and fat score, respectively.

The prediction of carcass composition from carcass conformation and fat scores across genders accounted for 73%, 67% and 71% of total variation in carcass meat, fat and bone proportions, respectively.

There was no significant bias in estimating carcass composition across all animals nor was there any trend in the bias across different values for each carcass composition trait as evidenced by the lack of a correlation between the residuals and the predicted dependent variable. The root mean square error of prediction varied from 11.2 g/kg (carcass bone proportion) to 22.3 g/kg (carcass meat proportion); the accuracy of predicting carcass composition across genders ranged from 0.75 (carcass fat proportion) to 0.79 (carcass meat proportion). In the prediction of carcass meat proportion, 50% of the predicted values were within -14.07 to 15.00 g/kg of the true value. The interquartile range was lower, for the prediction of carcass fat proportion and lower still for the prediction of carcass bone proportion than for carcass meat proportion.

Using the equations developed with carcass conformation and fat scores there was no bias in prediction for carcass meat proportion across the different genotypes (Table 3), except for genotype 2 (Early-maturing × Holstein-Friesian and early-maturing × early-maturing) which was significantly overestimated (7.54 g/kg). Carcass fat proportion was found to be significantly under-estimated (-14.18 g/kg) and over-estimated (3.29 g/kg) in genotypes 2 (Early-maturing × Holstein-Friesian and early-maturing × early-maturing) and 3 (Late-maturing × Holstein-Friesian and late-maturing × early-maturing), respectively. Furthermore, carcass bone proportion in genotype 1 (Holstein-Friesian) and 2 was significantly under- and over-estimated by -2.92 g/kg and 6.60, respectively.

Prediction equations using hind-quarter composition

The prediction equations for estimating carcass meat, fat and bone proportions from dissected hind-quarter meat, fat and bone proportions are summarised in Table 4.

Although animal gender was associated ($P<0.001$) with carcass meat, fat and bone proportions, the association between total carcass composition and hind-quarter composition did not differ by gender nor was the association with hind-quarter composition non-linear.

Regression coefficients for hind-quarter meat, fat and bone proportions relative to the corresponding proportion in the carcass were 1.03, 1.17 and 0.89, respectively; the respective R^2 were 0.93, 0.87 and 0.89. The corresponding root mean squared error values were 11.43, 12.56 and 6.69; accuracy of predicting carcass meat, fat and bone proportions from carcass hind-quarter meat, fat and bone was 0.94, 0.91 and 0.77, respectively.

The lack of a significant bias across the entire data set signifies that carcass meat, fat and bone proportions were not under- or over-estimated from hind-quarter composition. Predictions of carcass meat, fat and bone proportions were under-estimated by at least 6.89 g/kg, 8.56 g/kg and 3.62 g/kg, respectively, in 25% of the dataset (i.e., 1st quartile) and over-estimated by at least 7.49 g/kg, 8.00 g/kg and 4.09 g/kg, respectively, in 75% of the dataset (i.e., 3rd quartile). Correlations between the residuals and predicted meat, fat and bone proportions were not different from zero.

Using the equation developed from hind-quarter composition across genotypes for the entire dataset (Table 5), carcass meat proportion was significantly over-estimated for genotype 2 (6.65 g/kg). Carcass fat proportion was significantly under-estimated in genotypes 1 (-2.88 g/kg) and 2 (-8.18 g/kg) and over-estimated (2.79 g/kg) in genotype 4. Hind-quarter bone over- and under-estimated carcass bone proportion for genotypes 2 (3.90 g/kg) and 3 (-2.13 g/kg), respectively.

Conclusion

These results show that equations developed using carcass conformation and fat scores were accurate predictors (i.e. high R^2 and low RMSE) of carcass meat, fat and bone proportions and are applicable across gender and genotype. These equations could have a useful role in rewarding farmers for producing animals with better carcass traits by implementing a payment system based on predicted meat yield. As carcass classification in Ireland is carried out using video imaging analysis machines, the implementation of a payment system based on carcass composition would be quick and practical with little or no additional expense to the abattoir.

Equations developed using hind-quarter composition were also shown to accurately predict carcass meat, fat and bone proportions. These equations would reduce the huge cost associated with whole carcass dissection and make it more beneficial and appealing to those carrying out carcass studies.

Implications

This study shows the potential of EU carcass conformation and fat scores to predict carcass meat proportion and thus, facilitate the operation of a payment system based on meat yield, which would reward farmers more equitably. Also, prediction equations developed from hind-quarter composition would reduce the huge cost associated with whole carcass dissection and make it more beneficial and appealing to those carrying out carcass studies.

Table 1. Mean, standard deviation (SD) and range for live and carcass measurements and yield components of bulls, heifers and steers.

Trait	Mean	SD	Minimum	Maximum
Bulls (n =115)				
Pre-slaughter weight (kg)	583	81.89	408	857
Cold carcass wt (kg)	332	56.0	207	475
Kill-out (g/kg)	567	34.0	484	669
Slaughter age (days)	454	38	386	569
Conformation score[1]	9.8	2.23	4.7	14.4
Fat score[1]	7.8	1.35	2.7	11.5
Carcass meat proportion (g/kg)	727	41.4	627	840
Carcass fat proportion (g/kg)	85	27.4	31	163
Carcass bone proportion (g/kg)	188	21.2	129	251
Heifers (n = 40)				
Pre-slaughter weight (kg)	535	55.1	441	642
Cold carcass wt (kg)	293	30.1	242	359
Kill-out (g/kg)	548	22.8	497	585
Slaughter age (days)	606	27	554	647
Conformation score[1]	8.4	1.48	5.4	10.9
Fat score[1]	7.6	2.22	3.2	11.3
Carcass meat proportion (g/kg)	722	39.3	637	798
Carcass fat proportion (g/kg)	93	34.1	37	171
Carcass bone proportion (g/kg)	185	13.6	158	210
Steers (n = 507)				
Pre-slaughter weight (kg)	625	77.8	435	884
Cold carcass wt (kg)	333	49.8	234	501
Kill-out (g/kg)	532	27.3	469	621
Slaughter age (days)	751	52	437	915
Conformation score[1]	6.8	2.20	2.0	12.0
Fat score[1]	8.5	1.89	2.8	13.3
Carcass meat proportion (g/kg)	679	13.3	564	785
Carcass fat proportion (g/kg)	123	31.8	47	260
Carcass bone proportion (g/kg)	197	20.2	150	262

[1]Scale 1 to 15

Table 2. Prediction equations for meat, fat and bone proportion estimated using a linear model on the entire dataset (662 animals) using carcass conformation and fat score. The table contains the intercept and regression coefficient of the regression model estimated from the entire dataset including the r-square of the model fit using the entire dataset. Also included are the bias, root mean square error (RMSE), and accuracy of prediction as well as the 25% (Q1) and 75% (Q3) quartiles of the residuals and the correlation between the predicted compositions and residuals (r_e).

	Entire dataset				Validation dataset					
Trait	Intercept (se)[1]	Conformation score (se)	Fat score (se)	R-square	Bias (se)	RMSE	Accuracy	Q1	Q3	r_e
Meat proportion (g/kg)	704 (2.20) [2] 713 (3.52) 698 (1.12)	11.82 (0.40)	-9.56 (0.47)	0.73	-0.004 (0.867)[3]	22.3	0.79	-14.07	15.00	0.004[4]
Fat proportion (g/kg)	96 (2.00) 100 (3.20) 113 (1.014)	-4.40 (0.36)	11.95 (0.43)	0.67	-0.003 (0.778) [3]	20.27	0.75	-12.60	13.50	0.005[4]
Bone proportion (g/kg)	200(1.10) 187 (1.76) 190 (0.56)	-7.41 (0.20)	-2.39 (0.24)	0.71	-0.002 (0.434) [3]	11.16	0.77	-6.89	7.49	0.004[4]

[1]Intercept chosen to represent conformation score of 8 and fat score of 8; intercepts presented from top to bottom represent bulls, heifers and steers, respectively
[2] Example: Meat yield (g/kg) of bulls = 704 + 11.82* (conformation score - 8) - 9.56* (fat score - 8)
[3] Bias not different from zero
[4] Correlation not different from zero

Table 3. Average bias in prediction across genotypes (662 animals) from prediction equation including carcass conformation and fat scores as well as 25% (Q1) and 75% (Q3) quartiles of the residuals

Trait	Genotype[1]	Bias (se)	Q1	Q3
	1	3.20 (1.79)	-10.94	17.43
Meat proportion (g/kg)	2	7.54 (2.58)**	-4.36	21.05
	3	-2.30 (1.67)	-15.24	8.59
	4	-2.41 (1.36)	-17.25	15.42
	1	-0.258 (1.59)	-13.24	13.52
Fat proportion (g/kg)	2	-14.17 (2.30)***	-27.73	0.859
	3	3.29 (1.49)*	-6.66	13.95
	4	1.90 (1.21)	-12.13	15.87
	1	-2.92 (0.881)**	-9.13	4.38
Bone proportion (g/kg)	2	6.60 (1.27)***	1.72	13.81
	3	-0.96 (0.823)	-7.58	6.50
	4	0.49 (0.670)	-6.51	7.12

*Value different (P<0.05) from zero
[1]Genotypes = 1) Holstein-Friesian (n = 152); 2) Early-maturing × Holstein-Friesian and early-maturing × early-maturing (n = 73); 3) Late-maturing × Holstein-Friesian and late-maturing × early-maturing (n = 174) and 4) genotypes with 0.75 or greater late-maturing ancestry (n = 263).

Table 5. Average bias in prediction across genotypes (662 animals) from prediction equation including carcass hindquarter meat fat and bone proportions as well as 25% (Q1) and 75% (Q3) quartiles of the residuals

Trait	Genotype[1]	Bias (se)	Q1	Q3
	1	0.44 (0.91)	-7.46	8.61
Meat proportion (g/kg)	2	6.65 (1.31)***	-0.41	13.70
	3	-0.32 (0.85)	-7.49	6.94
	4	-1.89 (0.69)	-9.12	4.49
	1	-2.88 (0.98)**	-11.36	4.87
Fat proportion (g/kg)	2	-8.18 (1.41)***	-15.50	0.91
	3	1.18 (0.91)	-6.48	8.92
	4	2.79 (0.74)***	-4.89	10.06
	1	0.47 (0.53)	-3.60	5.12
Bone proportion (g/kg)	2	3.90 (0.76)***	0.19	7.47
	3	-2.13 (0.49)***	-5.83	1.82
	4	0.05 (0.40)	-3.17	3.86

*Value different (P<0.05) from zero
[1]Genotypes = 1) Holstein-Friesian (n = 152); 2) Early-maturing × Holstein-Friesian and early-maturing × early-maturing (n = 73); 3) Late-maturing × Holstein-Friesian and late-maturing × early-maturing (n = 174) and 4) genotypes with 0.75 or greater late-maturing ancestry (n = 263).

Table 4. Prediction equations for meat, fat and bone proportion estimated using a linear model on the entire dataset (662 animals) using hindquarter weights. The table contains the intercept and regression coefficient of the regression model estimated from the entire dataset including the r-square of the model fit using the entire dataset. Also included are the bias, root mean square error (RMSE), and accuracy of prediction as well as the 25% (Q1) and 75% (Q3) quartiles of the residuals and the correlation between the predicted compositions and residuals (r_e).

	Entire dataset			Validation dataset					
Trait	Intercept (se)[1]	Hindquarter (se)	R-squared	Bias (se)	RMSE	Accuracy	Q1	Q3	r_e
Meat proportion (g/kg)	686.6 (1.17) 674.8 (1.89) 676.6 (0.51)	1.03 (0.013)	0.93	-0.001 (0.444)[2]	11.43	0.94	-6.89	7.49	0.0013[3]
Fat proportion (g/kg)	118.8 (1.30) 126.9 (2.06) 130.4 (0.57)	1.17 (0.020)	0.87	-0.001 (0.488)[2]	12.56	0.91	-8.56	8.00	0.002[3]
Bone proportion (g/kg)	197.2 (0.64) 199.9 (1.08) 194.3 (0.30)	0.89 (0.012)	0.89	-0.0004 (0.26)[2]	6.69	0.77	-3.62	4.09	0.002[3]

[1]Intercept chosen to represent conformation score of 8 and fat score of 8; intercepts presented from top to bottom represent bulls, heifers and steers, respectively
[2]Bias not different from zero
[3]Correlation not different from zero

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