Carcass video images in genetic evaluation and breeding program in Ireland

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Introduction

Most breeding objectives attempt to identify the most profitable animals by appropriately weighting well defined and accurately measured phenotypes into an overall breeding goal. Inclusion of all pertinent traits in the breeding objective is fundamental to its uptake and success in increasing genetic gain for profitability. The main source of revenue for beef farmers, either directly or indirectly, is carcass value. Traits included in European breeding objectives are, however, generally limited to carcass weight, carcass conformation score, and carcass fat score.

Harmonised carcass classification became a requirement of the member states of the European Union (EU) in the early 1980's as the Common Agricultural Policy entered a system of subsidies and border tariffs, demanding a price reporting process (European Council regulation 1358/80 of 5 June 1980). European Council regulations 1208/81 of 28 April 1981 and 2930/81 of 12 October 1981 determined the Community scales for the classification of bovine carcasses. Notably amended in 1991 (European Council regulation 1026/91) with the introduction of gender categories (i.e. young bull, bull, steer, cow, heifer) and the addition of a superior class of conformation (class "S"), the classification of carcasses is currently widely used across slaughter houses in the EU as a basis for payment to producers. The appraisal of carcasses in the EU is currently based on scores given for both conformation and fat; these scores are usually referred to as the 'EUROP gradings' for conformation and fat. The aim of EUROP conformation grading is to give an appreciation of the carcass shape, in particular the round, back, and shoulder, using the letters S (superior), E, U, R, O, and P (poor) to describe the conformation of the carcass. The carcass fat classification system uses the scale 1 (low), 2, 3, 4 and 5 (very high) to measure the quantity of fat on the outside of the carcass and in the thoracic cavity (Table 2).

EUROP gradings were based on subjective assessments by highly trained personnel. Boggaard et al. (1996) presented some limitations of European beef carcass grading operated by expert classifiers: bias can occur between groups of carcasses, classifiers' judgment can vary over time, and differences can be observed between classifiers. Objective carcass grading as operated by calibrated grading machines overcame these weaknesses. In Ireland, the accuracy (R^2) and fit (bias) of three classification machines (VIAscan, VBS2000, and BCC2) at predicting carcass classification in abattoir conditions for conformation and fat against a reference classification established by experts was documented by Allen et al. (2000).

Using digital imaging for carcass classification

The main technical challenges of mechanical grading systems are: i) to generate accurate predictions of carcass quality, and ii) to operate at line speed in slaughter houses. Allen (2005) detailed the technology available at the time to automatically predict the EUROP grades for conformation and fat. Three main steps exist in the mechanical grading process: 1) capture images of the carcass using camera(s), 2) estimate carcass measurements such as length, contour, angles, volumes, colour amongst others using image analysis, and 3) use an algorithm to predict the EUROP gradings from the collected data.

Three mechanical grading machines (VBS2000, VIAscan, BCC2) were evaluated using over 7,000 carcasses in Ireland and compared to three expert classifiers between 1999 and 2000. At the end of the trial, each of the three classification machines had the potential to be used for bovine classification purposes (Allen et al., 2000). A formal authorisation trial of the three systems was undertaken in Ireland in 2003 using 600 carcasses and each of the three mechanical grading systems exceeded the performance criteria laid down in the regulation 1215/03 of 7 July 2003 for authorisation. The use of the VBS2000 carcass grading machine was subsequently recommended by the Irish meat processing industry for EUROP mechanical grading in Irish slaughter houses. Since 2005, copies of the two pictures (tiff format) taken after slaughter by the VBS2000 mechanical grading machine (E+V GmbH, Germany) for each carcass to derive the EUROP conformation and fat grading have been stored in the Irish Cattle Breeding Federation (ICBF) database.

In practice, VBS200 mechanical grading machines use a one-angle colour camera, a holding frame, and a lighting system to create a two-dimensional (2D, in normal lighting) and a three-dimensional (3D, after changing the lighting to striped lighting) picture of the carcasses (Figure 1). Every day, before the slaughter line starts processing cattle, VBS2000 machines need to be calibrated to adjust primarily to the new light conditions and potential changes to the camera angle. To operate the calibration, the machine initialises itself by taking pictures of 2D and 3D template boards. After calibration, the slaughter line can start its daily work, and the right side of each carcass is photographed twice to create the 2D and 3D pictures. Both images are immediately broken down into 428 variables describing length, contour, angles, volumes, and colour of the carcasses. Using carcass weight, sex category (i.e. young bull, bull, steer, heifer, or cow) and the variables derived from the images, VBS2000 applies the relevant prediction equations to derive the EUROP gradings for conformation and fat.

Figure1. Digital images collected on carcass 3800 mechanically graded on 29/09/2010.

Predicting meat cuts from digital images

Defining meat cuts

Carcass muscle dissections collated from experimental designs on bull and steers collected between 2005 and 2008 (hereon in referred to as 'experimental' data) were made available from Teagasc Grange beef research center, located in Dunsany, Co. Meath, Ireland. Carcasses (right side) were dissected into 23 different muscle cuts (11 taken in the forequarter and 12 in the hindquarter) using a controlled cutting procedure based on the Beef Cuts Code (Pabiou et al, 2009).

Also available were carcass muscle dissections collected from 1999 to 2005 by a commercial industry partner (hereon in referred to as 'commercial' data ; Pabiou et al, 2009). Cutting procedures in the hindquarter were very similar to those used in the experimental dataset. However, in the forequarter dissections, the commercial cutting procedure applied more severe cutting procedures on the individual muscle cuts with the objective of neat presentation of the cut on the supermarket shelves. As a result, the number of muscle cuts available in the forequarter was lower in the commercial dataset compared to the experimental dataset, but also included heavier lean trimming weights. In both the experimental (340 steers and 73 bulls) and the commercial (575 heifers, 26 bulls, and 34 steers).datasets, 14 primal cuts were identified according to their location on the carcass (Figure 2a).

The primal cut weights were then assembled into four wholesale cut weights (Pabiou et al, 2010 ; Figure 2b).based on retail value: lower value cuts (LVC), medium value cuts (MVC), high value cuts (HVC), and very high value cuts (VHVC). This step was done with the support of meat experts (researchers and industry representatives).

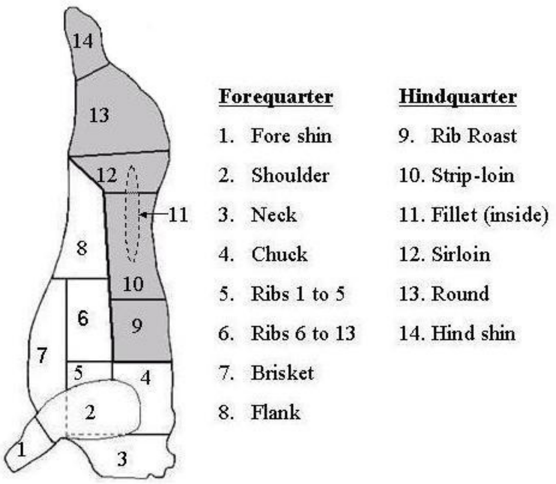

Figure2a: Location of primal cuts

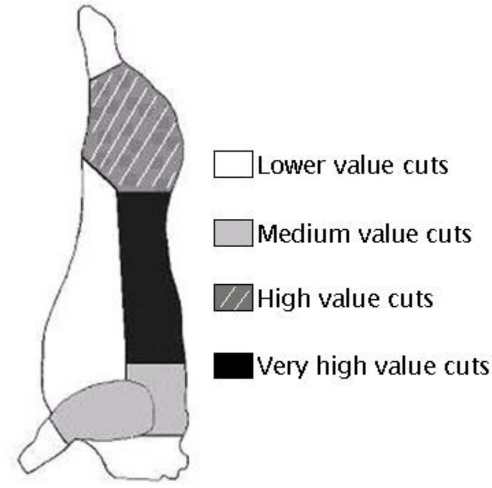

Figure2b: Location of wholesale cuts

Predicting meat cuts from digital images

Multivariate analyses based on 281 heifers, 346 steers, and 74 bulls were used to predicted meat cut weights from digital images(Pabiou et al., 2010). Images have been collected by ICBF across 25 slaughter houses and stored on hard drives since July 2005.

Across the five multivariate methods tested by Pabiou et al. (2010), stepwise regression methods gave the best results in terms of maximising R^2 and minimising bias. Across the three models tested (i.e. carcass weight; carcass weight + EUROP gradings, carcass weight + VIA variables), the model that included VIA variables was superior to the other models in terms of accuracy of prediction across traits (lowest RMSE, highest R^2); mean bias and correlations between the residuals and predicted values were generally not different from zero (Table 1).

Table 1. Mean bias (kg), residual root mean square error (RMSE; kg), coefficient of determination (R^2), and correlation between residuals and predicted weights (r_e) in the validation dataset of wholesale cut weights and overall weights from 114 steers (experimental dataset) and 92 heifers (commercial dataset) using models including carcass weight and VIA variables developed in the calibration dataset of 232 steers (experimental dataset) and 189 heifers (commercial dataset), respectively

	Trait (kg)	Bias (s.e)	RMSE	R^2	r_e
STEERS	Total meat	-0.74 (0.63)	6.77	0.97	-0.02
	Total fat	-0.58 (0.60)	6.38	0.77	-0.13
	Total bone	0.32 (0.30)	3.22	0.81	-0.12
	LVC	0.15 (0.52)	5.60	0.92	-0.08
	MVC	0.13 (0.26)	2.73	0.86	-0.10
	HVC	1.18 (0.31)**	3.27	0.93	0.05
	VHVC	-0.11 (0.16)	1.75	0.84	-0.01
HEIFERS	Total meat	-0.24 (0.83)	8	0.84	0.06
	LVC	-0.01 (0.69)	6.62	0.65	0.07
	MVC	-0.12 (0.14)	1.37	0.70	-0.03
	HVC	0.01 (0.23)	2.16	0.85	-0.01
	VHVC	0.04 (0.13)	1.24	0.72	-0.44**

Bias / Correlation different from zero at P < 0.01 (**)

Using predicted meat cut in the Irish genetic evaluation

Beef breeding objective in Ireland

The breeding objective for beef cattle in Ireland was originally described by Amer et al. (2001), acknowledging the use of beef germplasm in both beef and dairy herds, as well as the different production systems (i.e. weanling and finishing cattle) found in Ireland.

Irish beef farming comprises of a small quantity of pedigree farms (approximately 3,300 in 2010; on average 4 pedigree cows per farm) and a large number of commercial (i.e. non-pedigree) farms (approximately 56,000 farms in 2010 with, on average, 17 cows per farm). Pedigree farms produce the next generation of superior bulls and commercial farmers source the best of these animals from the pedigree farms.

Of the 2.0 million calves born in 2009 in Ireland, 62% were from crossbreeding matings across dairy and beef breeds (DAFF, 2009). The most popular breed(s) is Holstein in dairy herds, and Charolais, Limousine, Angus, Simmental, Hereford, and Belgian Blue in beef herds. There is a seasonal aspect to calving in both dairy and beef production systems with 76% of calves born between January and May (DAFF, 2009). Of the calves born in Ireland, 69% were destined to be slaughtered, 16% were exported live, and the remaining 15% were used as replacements. Steers and heifers represented 70% of cattle slaughtered in Ireland in 2009 (DAFF, 2010).

The beef breeding goal is defined by 4 groups of economically weighted indexes:

- Calving index, by reflecting the cost of calving, gestation length, and calf mortality;
- Weanling production and live exports, by reflecting the value of weanlings (weight, price);
- Finished animals, by reflecting the value of slaughtered cattle (weight for age, carcass weight, carcass conformation, carcass fat, feed efficiency);
- Replacement animals, by reflecting the value of milk and fertility in females.

The Suckler Beef Value combines all 4 indexes to reflect the overall profit value of animals. Currently, calving index, weanling export index, carcass index, and replacement index represent 44%, 9%, 35%, and 13%, respectively of the Suckler Beef Value.

The genetic of carcass images

The first step prior to further genetic analysis was to convert the stored digital images into predicted cut weights thus recreating the mechanical grading conditions (light, camera angle) for each day of slaughter. This was achievable by recovering the calibration files used daily within slaughter house from 2005 to 2010 (Pabiou et al.,2011a ; Pabiou et al.,2011b).

The conversion of historical images into cut weights can be broken down into 2 major editing steps: 1) creating the carcass file (animal tag, carcass weight, sex) by linking carcass tags attached to each double image with animal tags present in the ICBF genetic database, 2) matching calibration files recovered from slaughter house to their corresponding slaughter house and date of slaughter. The edited datasets were converted into wholesale cut weights by applying the relevant regression equations.

The heritability for predicted carcass cut weights were estimated using a large dataset of converted images (n = 52,722 observations, Pabiou et al.,2011a). Heritability estimates for predicted carcass cut weights ranged from 0.17 (VHVC) to 0.40 (HVC). Genetic correlations between predicted carcass cut weights were estimated by Pabiou et al. (2011a) and as expected were strong and positive (Table 2).

Table 2. Heritability in a combined population of steers and heifers (on diagonal), genetic correlations in steers (above diagonal) and heifers (below diagonal)

	Total meat	Total fat	Total bone	LVC	MVC	HVC	VHVC
Total meat	**0.44**	-0.61	-0.24	0.71	0.78	0.93	0.80
Total fat	*n/a*	**0.14**	0.13	-0.50	-0.56	-0.58	-0.54
Total bone	*n/a*	*n/a*	**0.49**	-0.22	-0.23	-0.35	-0.62
LVC	0.87	*n/a*	*n/a*	**0.18**	0.45	0.66	0.57
MVC	0.75	*n/a*	*n/a*	0.47	**0.27**	0.79	0.86
HVC	0.89	*n/a*	*n/a*	0.80	0.82	**0.40**	0.89
VHVC	0.82	*n/a*	*n/a*	0.69	0.82	0.82	**0.17**

n/a : estimates not available for heifers.

Associated traits investigated by Pabiou et al. (2011b) comprised of live weights, auction prices, linear scores assessed by trained classifiers, farmer scores, and slaughter traits. Live weight was recorded on pedigree farms as well as in live-auction sales around Ireland. Price per animal was collected from live-auction sales on calves, weanlings, and post-weanling animals. Linear scores for muscle (4 traits) and skeletal (7 traits) traits were collected on pedigree farms, whereas farmer scores of weanling quality (score from 1 (poor quality) to 5 (good quality)) were collected mainly on commercial farms. Slaughter records included carcass value (price per kilo x carcass weight).

Estimated genetic and phenotypic parameters from Pabiou et al. (2011a, 2011b) were used in a genetic gain study designed to quantify the impact of including the four predicted cut weights (i.e. LVC, MVC, HVC, & VHVC) in the overall Irish beef breeding program (Pabiou, 2012). Heritability, phenotypic and genetic correlations from McHugh et al. (2011a, 2011b) and Crowley et al. (2010) were also used in the genetic gain predictions.

Benefit for the Irish industry

Pabiou et al. (2012) analysed the impact of using predicted wholesale cut weights as a selection tool by testing 5 different scenarios to a common breeding objective. Scenario 1 was a selection index based on live recordings (i.e. no slaughter predictors), scenario 2 added carcass weight to scenario 1, scenario 3 added EUROP grades to scenario 2, and scenario 4 added the predicted carcass cut weights to scenario 3. Additionally, a scenario 5, based on scenario 4, mimicked the use of better accuracy of carcass cut prediction. In order to analyse the financial impact between scenarios, Pabiou et al. (2012) conducted a cost-benefit analysis to quantify differences in average Suckler Beef Value per annum while accounting for time delay in genetic improvement due to different generation intervals across bull candidates. Cumulating the yearly differential benefits of adding predicted cut weights (scenario 4) to the current Irish selection index (scenario 3) over 10 years will bring an extra €2.4 million to the Irish beef industry (Pabiou et al., 2012 ;Table 3). No extra costs were associated with the upgrade of the selection criteria to predicted carcass cut weights (scenario 4) as a process of collecting and converting images is already active.

Table 3. Expected benefit for including wholesale carcass cut weights in the selection index (million of Euros)

Scenari tested	Adding carcass weight	Adding EUROP grades	Adding predicted carcass cuts	Using more accurate prediction of carcass cuts
Comparison of	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*
with	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario5*
10 years	+ € 7.3	+ € 0.6	+ € 2.4	+ € 0.6
20 years	+ € 17.5	+ € 1.5	+ € 5.7	+ € 1.8
30 years	+ € 27.4	+ € 2.3	+ € 8.9	+ € 2.9

Using more accurate prediction equations to derive predicted cut weights (scenario 5) has the potential to add €0.6 million over a 10 year horizon to the industry in Ireland. An initial cost of €224,000 associated with the upgrade of the accuracy of prediction of carcass cut weight was taken out of the cumulative benefits.

Conclusion

Using video image analysis of digital carcass images to predict wholesale cut weights is feasible and the inclusion of predicted carcass cuts as selection tool in the breeding program is beneficial for the Irish industry.

The Irish industry could investigate the feasibility of collecting more carcass and meat quality phenotypes to further improve the efficiency of the beef breeding scheme and its return to farmers, retailers, and consumers.

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