Use of Digital Images to Predict Carcass Cut Yields in Cattle

T. Pabiou[a,c,e*] L. Kreuchwig[b], A.R. Cromie[a],* M.J. Drennan[d], M.G. Keane[d], W.F. Fikse[c], A. Näsholm[c] and D.P. Berry[e]

[a] The Irish Cattle Breeding Federation, Highfield House, Bandon, Co. Cork, Ireland ; [b] E+V Technology GmbH, Oranienburg, Germany ; [c] Swedish University of Agricultural Sciences, Department of Animal Breeding and Genetics, Uppsala, Sweden ; [d] Grange Research Center, Teagasc, Dunsany, Co. Meath, Ireland ; [e] Moorepark Dairy Production Research Center, Teagasc, Fermoy, Co. Cork, Ireland

Abstract

The objective of this study was to assess the potential of video image analysis (VIA) in predicting various wholesale carcass cuts. Video image analysis and dissection data were available on 436 and 281 cross bred Belgian Blue, Charolais, Limousin, Angus, Holstein, and Simmental steers and heifers, respectively. Dissected meat cuts were grouped into four groups based on retail value: Low Value Cuts (LVC), Medium Value Cuts (MVC), High Value Cuts (HVC), and Very High Value Cuts (VHVC). Each of the datasets were divided into a calibration dataset (75% of data) and a validation dataset (25% of data) for each of the four wholesale cut traits. Stepwise multiple regression were applied to each calibration dataset to predict the cuts from carcass weight only, carcass weight plus EUROP carcass classification, and carcass weight plus VIA parameters. Prediction equations were applied to the validation dataset. The proportion of variation explained in the carcass traits investigated ranged from 0.33 (total fat weight) to 0.91 (total meat weight) using carcass weight as the sole predictor, and this increased to 0.65 (LVC) and 0.97 (total meat weight) when carcass weight plus VIA variables were used as predictors. The RMSE of prediction across traits decreased from a range of 1.28 to 11.78 kg using carcass weight as the sole predictor to a range of 1.24 to 8.00 using carcass weight plus VIA variables as predictors. Mean bias and residual correlations were generally not different from zero. Results from this study show that wholesale cuts in steers and heifers can be accurately predicted using VIA.

Keywords: prediction, carcass cut, video image analysis, beef

Introduction

The entire retail value of a beef carcass varies with the distribution of the individual meat cuts. Payment for beef carcasses in the European Union is generally based on a combination of cold carcass weight and classification for carcass conformation and fat. The conformation classification system uses the letter E (excellent), U, R, O, P+, P (poor) and P- to describe the conformation of the carcass with particular emphasis on the round, back, and shoulder. The carcass fat classification system uses the scale 1 (low), to 5 (very high) to measure the amount of fat on the outside of the carcass and in the thoracic cavity. Although, carcass classification in Ireland was originally based on subject assessment by trained personnel, carcass classification is now undertaken in Ireland using authorised classification machines. In 2003, the EU regulation 1215/2003 defined the conditions and minimum requirements for authorisation of automated grading techniques in a member country. Since 2005, a copy of the two carcass images taken by the VBS2000 mechanical grading machine (E+V GmbH, Germany) after slaughter to derive the EUROP conformation and fat grading have been stored in the Irish Cattle Breeding Federation database.

The objective, therefore, of this study was to investigate the potential of using Video Image Analysis (VIA) to predict carcass cut yields. Because carcass images are collected routinely on all cattle slaughtered in Irish abattoirs, results from this study will facilitate a payment system more reflective of carcass retail value. Predicted cut yields may also be used by animal breeders to identify germplasm with a more favourable distribution of higher value carcass cuts.

Materials and Methods

The raw output data of the VBS2000 carcass grading machine comprise of 428 variables describing linear measurements of carcass dimensions, carcass contour and carcass color measurements.

Experimental dataset

A total of 578 carcass dissections from animals slaughtered between 2005 and 2008 were made available from the Teagasc Beef Research Center in Dunsany, Co. Meath, Ireland. These data will hereon in be referred to as the "experimental data". Digital images taken at slaughter were recovered for 419 of the animals (346 steers and 73 bulls). Only data on the steers was retained for estimation of prediction equations. Of the 346 steers available, 92% were crossbred, and all the known sires (n = 239) were pure breed males (Belgian blue 26%, Angus 22%, Friesian 15%, Charolais 15%, Holstein 12%, Limousin 5% , and Simmental 5%). The average slaughter age of the steers was 750 days.

Cold carcass weight as well as carcass conformation and carcass fat grade, scored using the EUROP classification system, is recorded for each animal slaughtered in Ireland. In the present study the EUROP classification grades were transformed to a 15-point linear scale as outlined by Hickey *et al.* (2007). The kidney and channel fat and the kidney knobs were removed prior to carcass weighing. Details of the carcass dissection describing 11 forequarter cuts and 12 hindquarter cuts were described previously (Pabiou *et al.*, 2009). Four groups of wholesale cut weights, hereon in referred to as wholesale cuts, were created according to their retail values: Lower Value Cut group (**LVC**) including fore- and hind shins, flank, ribs, brisket, neck, and lean trimmings; Medium Value Cut group (**MVC**) comprising of the shoulder and the chuck cuts; High Value Cut group (**HVC**) including the sirloin and the round cut weights; Very High Value Cut group (**VHVC**) comprising of the weights of the rib roast, strip-loin, and fillet cuts. Total carcass meat weight, total carcass fat weight and total bone weight were calculated by respectively summing the meat, fat and bone weight of the carcass. For total carcass meat weight this was equivalent to the sum of all four wholesale cuts.

Commercial dataset

A total of 3,501 carcass dissections from pure and cross bred animals slaughtered between 1999 and 2005 were made available by an Irish supermarket chain. These data will be hereon in referred to as the "commercial data". All the animals were processed through the same meat processing plant. The VIA images taken at slaughter were recovered for 281 heifers. Of the 281 heifers, 96% were crossbred and all known sires (n = 88) were pure breed males (Limousin 50%, Belgian blue 22%, Charolais 16%, Simmental 9%, and other breeds 3%). The average slaughter age of the heifers was 574 days.

Cold carcass weight, carcass conformation and carcass fat grade were also recorded for each animal slaughtered as described previously. Each carcass was dissected into 14 different cuts, seven in the forequarter, five in the hindquarter, and two cuts across both locations (Pabiou *et al.*, 2009). Four groups of wholesale cuts were created which differed from definitions in the experimental dataset due to different cutting procedures: Lower Value Cut group (**LVC**) include lean trimmings, ribs, and brisket; Medium Value Cut group (**MVC**) include the weights of the shoulder and the chuck cuts; High Value Cut group (**HVC**) include the sirloin and the round cut weights; and Very High Value Cut group (**VHVC**) include the weights of the rib roast, strip-loin, and fillet cuts. Additionally, total meat weight was calculated as the sum of all four wholesale cut group weights; total carcass fat weight and total bone weight were not available in this dataset.

Statistical Analysis

For each of the carcass traits analysed, the two datasets were individually split into a calibration and a validation sub-datasets, based on an equal distribution (i.e., similar mean and standard deviation) of the trait under investigation. In the experimental dataset, 232 steers (67% of the steer population) were included in the calibration dataset and 114 steers were included in the validation dataset; in the commercial dataset, the respective numbers were 189 (67% of the heifer population) and 92 heifers.

Three alternative prediction models were evaluated within the experimental and commercial dataset separately: 1) model including carcass weight only, 2) model including carcass weight plus EUROP classification for conformation and fat, and 3) model including carcass weight plus VIA parameters. Stepwise regression was used to chose which VIA variables best described the calibration dataset. The regression models developed from the calibration datasets were then applied to a validation dataset and the fit assessed. Statistics used to quantity the goodness of fit included the mean bias, the RMSE, the coefficient of multiple determination of the model (R^2), and the correlation between the predicted values and the residuals (r_e). A standardised RMSE (RMSE*std*) defined as the RMSE of the trait divided by its phenotypic standard deviation was also calculated.

Results

In the experimental dataset, the average cold carcass weight was 334 kg consisting of 227 kg meat, 41 kg fat, and 64 kg bones (Table 1). Average weight of the four groups of wholesale cuts was 98 kg, 43 kg, 60 kg, and 26 kg for the LVC, MVC, HVC, and VHVC groups, respectively. In the commercial dataset, the average cold carcass weight was 238 kg (Table 2); the average meat yield was 183 kg. The average weights for the four groups of meat cuts were 94 kg, 20 kg, 47 kg, and 22 kg for the LVC, MVC, HVC, and VHVC groups, respectively.

1) Predictions using carcass weight

In the experimental dataset (Table1), the RMSE*std* was 0.30, 0.82, and 0.58 for total meat weight, total fat weight, and total bone weight, respectively; the RMSE*std* for the four wholesale cuts ranged from 0.52 (VHVC and MVC) to 0.37 (LVC). In the commercial dataset (Table 2), RMSE*std* ranged from 0.52 (total meat weight) to 0.69 (LVC). Accuracy of prediction in the experimental dataset, as defined by the R^2, ranged from 0.33 (total fat weight) to 0.91 (total meat weight); accuracy of prediction of the wholesale cuts were all greater than 0.73. The accuracy of prediction in the commercial dataset were 0.46 (LVC), 0.62 (MVC), and 0.68 (HVC and VHVC). Across all traits, the absolute correlation between residuals and predicted traits were less than 0.12 and not different from zero in the experimental dataset and only the correlation between the residuals and VHVC differed ($P<0.01$) from zero in the commercial dataset.

2) Predictions using carcass weight plus EUROP gradings

In the experimental dataset (Table 1), bias of prediction across the different carcass cut traits were generally not different from zero with the exception of the prediction of HVC, implying, on average, an underestimation of 1.10 kg of predicted HVC. RMSE*std* ranged from 0.33 (HVC) to 0.51 (total fat weight). Accuracy of prediction was 0.97, 0.74, and 0.79 for total meat weight, total fat weight, and total bone weight, respectively. Accuracy of prediction for the wholesale cuts ranged from 0.79 (MVC) to 0.89 (LVC and HVC). The correlation between residuals and predicted weights was different ($P < 0.05$) from zero for total meat weight ($r_e = 0.16$) implying an underestimation of predicted total meat weight for steers with large meat yield, and vice versa for steers with low meat yield. In the commercial dataset, RMSE*std* ranged from 0.41 (HVC) to 0.61 (LVC) (Table 4). R^2 was 0.80 for total meat weight, and ranged from 0.57 (LVC) to 0.81 (HVC) across the four groups of meat cuts. The correlation between residuals and predicted weights differed ($P < 0.001$) from zero for VHVC (r_e=-0.37) indicating overestimation of the predicted weight for the heifers with heavy VHVC weight.

3) *Predictions using carcass weight and VIA variables*

In the experimental dataset (Table 1), HVC were, on average, underestimated by 1.18 kg. RMSE*std* was 0.17, 0.49, and 0.43 for total meat weight, total fat weight, and total bone weight, respectively. RMSE*std* ranged from 0.28 (HVC) to 0.40 (VHVC) for the four groups of meat cuts. Accuracy for total meat weight, total fat weight, and total bone weight were 0.97, 0.77, and 0.81, respectively. Accuracy ranged from 0.84

(VHVC) to 0.93 (HVC) across the four groups of meat cuts. In the commercial dataset, (Table 2) RMSE*std* was 0.37 for total meat weight, and ranged from 0.36 (HVC) to 0.55 (LVC) across the four wholesale cuts. The accuracy of the regression model for total meat weight was 0.84, and varied from 0.65 (LVC) to 0.85 (HVC) across the four groups of meat cuts. The correlation between residuals and predicted trait differed ($P<0.01$) from zero (-0.44) for only VHVC.

Discussion

The difference in average carcass weight between the experimental and the commercial dataset in the present study is most likely due to gender differences between the two datasets. Four carcass conformation classes were represented in the dataset with 80% of the animals graded as class "R". This misrepresentation of EUROP classes of carcass conformation was reflected in smaller coefficient of variation: 15% *vs.* 29% in the experimental dataset where EUROP conformation classes distribution was more balanced.

The total meat weight as a proportion of total carcass weight was similar across both datasets (68% in the experimental dataset, and 64% in the commercial dataset), and similar to the meat yields observed in other studies of various crossbred populations (e.g., Koch *et al.*, 1982).

Despite showing similar weights, the yields of LVC as a percentage of the total meat weight was lower (43%) in the experimental dataset compared to the commercial dataset (51%); the corresponding values for MVC were 19% and 11%, respectively. These differences can be attributed to i) the gender differences between the two datasets, and ii) the different cutting procedures used in the experimental and the commercial datasets.

Prediction of total meat, total fat, and total bone weights

Inclusion of VIA variables in the prediction model improved the fit to the data, as evidenced by lower RMSE and greater coefficient of multiple determination, compared to just fitting carcass weight or carcass plus EUROP classification. With the exception of VHVC, the lack of a residual correlation when predictions were undertaken using the VIA variables implies no systematic bias in predictive ability.

When expressed as a proportion of the phenotypic standard deviation, the developed models predicted total meat yield better than total fat or total bones. However, the prediction of meat yield in the experimental dataset was superior to that in the commercial dataset. Greiner *et al.* (2003) found comparable results of accuracy for predicting total meat weight: R^2 ranging from 0.78 to 0.84 when using live ultrasonic measurements, and R^2 ranging from 0.83 to 0.87 when fitting hot carcass weight and three other carcass measurements in the models. Using image analysis of the 12^{th} rib section on 703 carcasses, Chen *et al.* (2007) reported high accuracy of the total retail cut prediction observing an overall R^2 equal of 0.97. Also using a carcass weight and EUROP grading model, Conroy *et al.* (2009) observed similar accuracy of prediction for fat and bone weight using (R^2 = 0.67 for fat weight, and R^2 = 0.71 for bone weight).

Prediction of wholesale cuts weight

Across both the experimental and the commercial datasets, the best predictions as measured by a high accuracy and low RMSE were obtained when VIA variables were included in the model along with carcass weight. In both the experimental and the commercial dataset, the inclusion of EUROP classification in the model only slightly improved the fit to the data for the MVC and LVC groups. However, there was a considerable improvement in the prediction of HVC by including EUROP classification in the model. This is consistent with the objective of the EUROP grading system for carcass conformation where the aim is to appreciate carcass conformation. The main component of the HVC group is the hind thigh which represent a volume easily appreciated on the two and three dimensional pictures taken after slaughter. In both the experimental and the commercial dataset, the accuracy of prediction was greatest for the HVC cuts (R^2 = 0.93 and 0.85 in the experimental commercial datasets, respectively).

Between the four groups of meat cuts defined in the experimental dataset, the VHVC group of meat cuts gave the lowest accuracy result (R^2 = 0.84); this is consistent with the fact that in the VHVC group of meat cuts, the fillet is included in the calculation of VHVC but is hidden from the camera pictures due to its positioning inside the carcass, and due to its shape, the volume of the full loin can also be difficult to appreciate from a side view image. The negative residual correlation observed for VHVC in the commercial dataset was largely influenced by 8 animals; when removed from the analysis, the residual correlation improved (r_e = -0.23; P = 0.03). Using the analysis of 12th rib sections on a large population of Chinese cattle (n=703), Chen *et al.* (2007) created a group of Top Grade Retail Cuts (i.e., fillet, strip-loin and rib-eye) similar to the VHVC group of meat cuts and found a lower overall accuracy of prediction (R^2 = 0.67). These results showed that VIA technology can predict the different wholesale weight cuts more accurately than the carcass weight and carcass weight plus EUROP grading models, and that the accuracy improved where the meat yields contours and volumes are easily picked up on images.

Conclusion

The objective of this study was to quantify the potential of VIA technology to predict groups of selected beef meat cuts using two separate datasets of steers and heifers. Inclusion of VIA variables in prediction models improved the fit to the data compared to including only carcass weight or carcass weight and EUROP classification. More dissection data is needed to fully validate the developed prediction equations on bulls. VIA technology is fast and non and VIA classification machines are in all Irish cattle abattoirs with the images routinely stored thus providing a powerful tool for improving beef breeding programs.

The regression equations validated on steers and heifers will be used on the image database of the Irish Cattle Breeding Federation, and variance component estimation for the predicted groups of cuts and production of breeding values will take place thereafter.

References

Chen, Y., Li, C., Liu, L., Zhou, G., Xu, X. & Gao, F. 2007. Prediction of yield of retail cuts for native and crossbred Chinese Yellow cattle. *Anim. Sci. 78,* 440-444.

Conroy, S.B., Drennan, M.J., McGee, D.A., Keane, M.G., Kenny, D.A. & Berry, D.P. 2008. Predicting carcass meat, fat and bone proportions from carcass conformation and fat scores or hindquarter dissection of beef carcasses. *Animal* (Submitted).

Hickey, J.M., Keane, M.G., Kenny, D.A., Cromie, A.R. & Veerkamp, R.F. 2007. Genetic parameters for EUROP carcass traits within different groups of cattle in Ireland. *J. Anim. Sci. 85,* 314-321.

Greiner, S.P., Rouse, G.H., Wilson, D.E., Cundiff, L.V. & Wheeler, T.L. 2003. Prediction of retail product weight and percentage using ultrasound and carcass measurements in beef cattle. *J. Anim. Sci. 81,* 1736-1742.

Koch, R.M., Cundiff, L.V. & Gregory, K.E. 1982. Heritability and genetic, environmental and phenotypic correlations of carcass traits in a population of diverse biological types and their implications in selection programs. *J. Anim. Sci. 55,* 1319-1329.

Pabiou, T., Fikse, W.F., Näsholm, A., Cromie, A.R., Drennan, M.J., Keane, M.G. & Berry, D.P. 2009. Genetic Parameters for Carcass Cuts Weight in Irish Beef Cattle. *J. Anim. Sci.* (submitted).

Ruis-Vilarrasa, E., Bunger, L., Maltin, C., Matthews, K.R. & Roehe, R. 2009. Evaluation of Video Image Analysis (VIA) technology to predict meat yield of sheep carcasses on-line under UK abattoir conditions. *Meat Sci. 82,* 94-100.

Table 1. Mean and phenotypic standard deviation (σ_p) for the carcass traits in the entire population as well as the mean bias, residual root mean square error (RMSE), coefficient of determination (R^2), and correlation between residuals and predicted weights (r_e) in the validation dataset of 114 steers from the experimental dataset using models containing carcass weight (CCW), carcass weight and EUROP grading for conformation and fat (CCW plus EUROP), and carcass weight and VIA variables (CCW plus VIA) developed in the calibration dataset of 232 steers.

	Overall Statistics		Predictions results for steers on validation dataset											
			CCW				CCW plus EUROP				CCW plus VIA			
	Mean (kg)	σ_p (kg)	Bias (s.e)	RMSE	R^2	r_e	Bias (s.e)	RMSE	R^2	r_e	Bias (s.e)	RMSE	R^2	r_e
Total meat	227	39.4	-1.02 (1.10)	11.78	0.91	0.07	-1.06 (0.70)	7.43	0.97	-0.16*	-0.74 (0.63)	6.77	0.97	-0.02
Total fat	41	13.0	-0.36 (1.00)	10.71	0.33	-0.03	-0.76 (0.62)	6.67	0.74	-0.01	-0.58 (0.60)	6.38	0.77	-0.13
Total bone	64	7.4	0.00 (0.40)	4.31	0.66	-0.03	0.18 (0.32)	3.38	0.79	-0.09	0.32 (0.30)	3.22	0.81	-0.12
Lower value cuts	98	18.6	-0.59 (0.65)	6.92	0.87	-0.10	-0.34 (0.61)	6.54	0.89	-0.07	0.15 (0.52)	5.60	0.92	-0.08
Medium value cuts	43	7.2	0.03 (0.35)	3.73	0.74	-0.02	-0.01 (0.31)	3.36	0.79	-0.00	0.13 (0.26)	2.73	0.86	-0.10
High value cuts	60	11.8	0.76 (0.56)	6.03	0.75	-0.04	1.10 (0.37)**	3.91	0.89	-0.01	1.18 (0.31)**	3.27	0.93	0.05
Very high value cuts	26	4.4	-0.01 (0.21)	2.28	0.74	-0.11	-0.09 (0.16)	1.74	0.85	0.01	-0.11 (0.16)	1.75	0.84	-0.01

Correlation different from zero at P < 0.01 (**) or P < 0.05 (*).

Table 2. Mean and phenotypic standard deviation (σ_p) for the carcass traits in the entire population as well as the mean bias, residual root mean square error (RMSE), coefficient of determination (R^2), and correlation between residuals and predicted weights (r_e) in the validation dataset of 92 heifers from the commercial dataset using models containing carcass weight (CCW), carcass weight and EUROP grading for conformation and fat (CCW plus EUROP), and carcass weight and VIA variables (CCW plus VIA) developed in the calibration dataset of 189 heifers.

	Overall Statistics		Predictions results for heifers on validation datasets											
			CCW				CCW plus EUROP				CCW plus VIA			
	Mean (kg)	σ_p (kg)	Bias (s.e)	RMSE	R^2	r_e	Bias (s.e)	RMSE	R^2	r_e	Bias (s.e)	RMSE	R^2	r_e
Total meat	183	21.6	-1.25 (1.18)	11.31	0.68	-0.07	-0.36 (0.95)	9.07	0.80	0.15	-0.24 (0.83)	8.00	0.84	0.06
Lower value cuts	94	12.0	-0.87 (0.87)	8.32	0.46	-0.15	-1.08 (0.77)	7.35	0.57	-0.04	-0.01 (0.69)	6.62	0.65	0.07
Medium value cuts	20	2.6	-0.11 (0.16)	1.53	0.62	-0.05	-0.10 (0.15)	1.43	0.67	0.01	-0.12 (0.14)	1.37	0.70	-0.03
High value cuts	47	6.0	-0.31 (0.33)	3.16	0.68	-0.04	-0.19 (0.26)	2.47	0.81	0.07	0.01 (0.23)	2.16	0.85	-0.01
Very high value cuts	22	2.3	0.09 (0.13)	1.28	0.68	-0.40**	0.14 (0.13)	1.20	0.71	-0.37**	0.04 (0.13)	1.24	0.72	-0.44**

**Correlation different from zero at P < 0.0