# Factors associated with the weight of individual primal cuts and their inter-relationship in cattle

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**ABSTRACT:** Input parameters for decision support tools are comprised of, amongst others, knowledge of the associated factors and the extent of those associations with the animal-level feature of interest. The objective of the present study was to quantify the association between animal-level factors with primal cut yields in cattle and to understand the extent of the variability in primal cut yields independent carcass weight. The data used consisted of the weight of 14 primal carcass cuts (as well as carcass weight, conformation, and fat score) on up to 54,250 young cattle slaughtered between the years 2013 and 2017. Linear mixed models, with contemporary group of herd-sex-season of slaughter as a random effect, were used to quantify the associations between a range of model fixed effects with each primal cut separately. Fixed effects in the model were dam parity, heterosis coefficient, recombination loss, a covariate per breed representing the proportion of Angus, Belgian Blue, Charolais, Jersey, Hereford, Limousin, Simmental, and Holstein–Friesian and a three-way interaction between whether the animal was born in a dairy or beef herd, sex, and age at slaughter, with or without carcass weight as a covariate in the mixed model. The raw correlations among all cuts were all positive varying from 0.33 (between the bavette and the striploin) to 0.93 (between the topside and knuckle). The partial correlation among cuts, following adjustment for differences in carcass weight, varied from −0.36 to 0.74. Age at slaughter, sex, dam parity, and breed were all associated ($P < 0.05$) with the primal cut weight. Knowledge of the relationship between the individual primal cuts, and the solutions from the models developed in the study, could prove useful inputs for decision support systems to increase performance.

**Key words:** beef, cattle, primal cuts, retail

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Transl. Anim. Sci. 2019.3:1593–1605
doi: 10.1093/tas/txz134

## INTRODUCTION

Knowledge of the factors associated with a given performance trait, and the actual magnitude of that association from the underlying statistical model, has many uses. Firstly, the model solutions can be used to populate bioeconomic models to

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Received April 15, 2019.
Accepted August 12, 2019.

understand the likely impact of a change in, for example, herd age structure (i.e., due to changes in reproductive performance) on herd performance (Shalloo et al., 2014). Secondly, the model solutions can be used to parameterize decision support tools such as those which aid in identifying cows for culling (Kelleher et al., 2015); the expected impact on progeny performance from culling an older cow or a cow calving in a particular season can be weighed up against the progeny performance from a replacement heifer possibly calving in a different season, while taking cognizance of the expected longer remaining productivity of the heifer. Thirdly, accurate genetic evaluation systems are based on a statistical model which, as well as comprising of the relevant random effects relating to the genetic (and nongenetic) terms, also include the relevant systematic environmental effects (Henderson, 1949). Fourthly, in extension services that benchmark herds on performance against contemporaries (Dunne et al., 2018), it is important to know the contributions of different factors to the performance variable being benchmarked. Knowledge of these factor contributions is also valuable when tailoring advice to the farmer; for example, should higher cut yields be associated with the progeny from older cows (Connolly et al., 2016), then poor cow survival on one farm could be costing the producer primal yield, the extent of which can be modeled from the fixed effects solutions from the statistical model.

Many studies exist in cattle populations in which statistical models have been developed from cross-sectional data and associations between animal- and herd-level factors have been reported (milk quality—McDermott et al., 2016; animal health—Twomey et al., 2016; feed efficiency—Hurley et al., 2017; mortality—Ring et al., 2018). Such studies also exist for carcass traits although they have generally been confined to the macro-carcass traits of carcass weight, conformation, and fat score in cattle (Conroy et al., 2009; Pabiou et al., 2011a; Englishby et al., 2016).

Fewer studies, in cattle at least, have explored the inter-relationships among primal carcass cuts (Pabiou et al., 2009; Sarti et al., 2013; Moore et al., 2017) and some of these studies have been limited in sample population size. Pabiou et al. (2009) and Sarti et al. (2013) estimated correlations among primal cuts from 578 and 842 carcasses, respectively, while Moore et al. (2017) estimated correlations between primal cuts using VIA information on 17,765 carcasses. Although the studies investigated contained more than one sex (Pabiou et al., 2009; Sarti et al., 2013; Moore et al., 2017), Pabiou et al. (2009) was the only study to determine whether the correlations among predicted wholesale cut weights (grouped by primal value) differed by sex; however, it was reported that a confounding effect between sex and cutting method may have affected their results.

The objective of the present study was to firstly understand the inter-relationships among a range of different carcass primal cuts in cattle and how these relationships differed by sex, and secondly to identify the animal-level factors associated with primal cut yields and to quantify the extent of these associations.

## MATERIALS AND METHODS

### Animal and Carcass Information

Carcass data including slaughter date as well as the carcass characteristics weight, conformation, and fat score were available on 191,847 steers and heifers slaughtered in a single abattoir between the years 2013 and 2017, inclusive. Carcass conformation and fat score were measured on a 15-point scale using video image analysis (Pabiou et al., 2011b), where score 1 for conformation and fat represented poor and lean, respectively, and score 15 represent very well conformed and excessively fat, respectively. The classification system for conformation score focuses mainly on the round, back, and shoulder of the animal. The classification system for fat describes the fat cover on the outside of the carcass as well as in the thoracic cavity. The weights of several different carcass primal cuts for each carcass side were also available. The actual cut specification available was dependent on the customer demands on the day of slaughter. Ancillary information such as the date of birth of each animal, sex and breed composition, as well as all interlocation movements was also available.

### Data Edits

Animals had to be between 13 and 36 mo of age when slaughtered and had to have information on carcass weight, carcass conformation, and carcass fat score to be considered further. Animals that moved herds >3 times in their lifetime as well as animals that resided <70 or >1,095 d on the farm from which they were slaughtered were not considered further. Animals were also categorized depending on whether they were born in a dairy or in a beef herd and will be referred to as dairy-herd or beef-herd animals hereon. This was based on the breed composition of their dams (Ring et al., 2018).

For the purposes of the present study, the 14 primal cuts considered were the topside, silverside flat, eye of round, knuckle, rump, striploin, fillet, cuberoll, bavette, brisket, chuck-tender/blade, leg-of-mutton cut (LMC) and fore-quarter miscellaneous, chuck-and-neck, and heel/shank. The list of muscles from which each primal cut was derived is in Supplementary Material. Considerably fewer records were available for the cuberoll cut because of specific cutting regimes in the abattoir when the data were being collected. A set of data edits were then applied to ensure integrity of the primal carcass cut weights. Only animals where both sides of the carcass were cut to the same cut profile were retained so that an animal had exactly two weights for the same primal cut. Primal cut records were only retained if the recorded cut weight from both sides of the carcass had a within-animal coefficient of variation of <0.1, and the total weight of each cut was within 4 standard deviations of the mean weight of the cut within the relevant sex (i.e., steers or heifers). Only animals with a weight record, after all edits, for at least 5 of the 14 primal cuts were retained. Three "grouped" cuts were calculated from the individual cuts primarily based on cooking method and included: 1) frying/grilling meat (hereon in referred to as frying meat)—striploin, fillet, and rump cuts, 2) roasting meat—topside, knuckle, silverside flat, and eye of round cuts, and 3) dicing/mincing meat (hereon in referred to as mincing meat)—bavette, brisket, chuck-and- neck, heel/shank, chuck-tender/blade, and the LMC/fore-quarter miscellaneous cuts. To be considered for the "grouped" cuts, every animal had to have a weight for all cuts contributing to that group.

Contemporary groups were formed to represent herd by sex by period of the year of slaughter. The definition of herd-sex-period of slaughter was based on the algorithm described in detail by Crump et al. (1997). The algorithm is based on maximizing the size of the herd-sex-period of slaughter group while simultaneously ensuring the time between the start and end of the periods of slaughter is minimal. For the present study, animals (within sex) slaughtered from the same herd within 10 d of each other were placed in the same contemporary group. If the number of records within a contemporary group was less than 10, then the records in that contemporary group were merged with a contemporary group from that herd adjacent in time if the start date and end date of the adjacent contemporary groups was less than 30 d. Only records from animals in contemporary groups of ≥5 animals were retained. The number of records used in the analysis of each trait is in Table 1.

### *Data Analysis*

***Correlation analyses.*** The raw correlation among all primal cuts weights as well as with carcass weight, conformation, and fat score was estimated for the entire data set but also within each sex separately; the partial correlations were also estimated where all variables were adjusted for carcass weight. The Fishers $r$-to-$Z$ transformation was used to determine whether the pairwise correlations among the same pair of traits but in different sexes differed ($P < 0.05$) from each other.

***Mixed model analyses.*** A linear mixed model was used to estimate the association between a range of fixed effects and the different primal cut yields and groups of cuts using SAS 9.4 (SAS, 2012). Contemporary group was included in all models as a random effect. Factors considered for inclusion in the model were dam parity (1, 2, 3, 4, 5+), heterosis coefficient (0%, ≤10%, ≤20%, ≤30%, ≤40%, ≤50%, ≤60%, ≤70%, ≤80%, ≤90, ≤99%, or 100%), recombination loss (0, ≤0.10, ≤0.20, ≤0.30, ≤0.40, ≤0.50, or >0.50), a covariate per breed representing the proportion of Angus, Belgian Blue, Charolais, Jersey, Hereford, Limousin, Simmental, and Holstein-Friesian and a three-way interaction between whether the animal was born in a dairy or beef herd, sex, and age at slaughter, with or without carcass weight included as a covariate in the mixed model. The reference animal for the derivation of least square means was a 27-mo-old (the average of the dataset) Limousin steer, born from a parity 3 dam into a beef herd with no recombination or heterosis. The exception was when estimating the breed least squares means for Holstein-Friesian and Jersey cattle in which case the reference was still a 27-mo-old steer born from a third parity dam with no recombination or heterosis, but born in a dairy herd. When carcass weight was included as a covariate in the model, the least square means were for an animal with a carcass weight of 350 kg (the average of the dataset).

## RESULTS

The number of records and summary statistics for all traits are in Table 1. The coefficient of variation for carcass weight was 0.14. The coefficient of variation for the individual primal cuts varied from 0.14 (heel/shank) to 0.20 (bavette) but, when

**Table 1.** Number of records (N) and summary statistics (i.e., mean, raw standard deviation [SD] and the standard deviation when adjusted to a common carcass weight [adjusted SD]) for the carcass traits, individual primal cuts, and groups of cuts

| | | N | Mean | Raw SD | Adjusted SD |
|---|---|---|---|---|---|
| Macro carcass traits | Weight, kg | 54,250 | 341.87 | 48.09 | |
| | Conformation (scale 1 to 15) | 54,250 | 7.46 | 1.64 | 1.85 |
| | Fat (scale 1 to 15) | 54,250 | 6.44 | 2.00 | 1.63 |
| Primal cut traits, kg | Topside | 50,935 | 22.83 | 3.69 | 1.88 |
| | SS flat[†] | 39,938 | 16.09 | 2.84 | 1.52 |
| | Eye of round | 38,066 | 6.43 | 1.24 | 0.77 |
| | Knuckle | 45,630 | 14.07 | 2.11 | 0.99 |
| | Rump | 48,744 | 18.92 | 2.92 | 1.79 |
| | Striploin | 23,853 | 16.02 | 2.74 | 1.96 |
| | Fillet | 34,546 | 7.02 | 1.17 | 0.78 |
| | Cuberoll | 16,767 | 12.39 | 2.29 | 1.92 |
| | Bavette | 27,191 | 13.59 | 2.67 | 2.11 |
| | Brisket | 34,540 | 16.10 | 3.03 | 1.62 |
| | Chuck-tender/blade | 29,973 | 13.25 | 2.09 | 0.90 |
| | LMC/Misc[‡] | 47,356 | 26.53 | 4.22 | 2.01 |
| | Chuck-and-Neck | 49,516 | 36.49 | 6.74 | 2.86 |
| | Heel/Shank | 48,317 | 11.91 | 1.72 | 0.85 |
| Grouped cuts, kg | Frying | 17,323 | 42.47 | 6.12 | 3.36 |
| | Roasting | 31,914 | 59.00 | 9.51 | 4.32 |
| | Mincing | 12,286 | 102.04 | 15.23 | 4.23 |

[†] Silverside flat.

[‡] LMC/forequarter miscellaneous.

adjusted to a common carcass weight, the coefficient of variation for the individual primal cuts all reduced by 0.07, on average, and varied from 0.07 (chuck-tender/blade) to 0.16 (bavette).

### *Correlation Analyses*

The correlations among the primal cuts with or without adjusting for differences in carcass weight are in Table 2. The raw correlations among all cuts were all positive varying from 0.33 (between the bavette and the striploin) to 0.93 (between the topside and knuckle); the average correlation among all cuts was 0.71. The average of the correlations among the cuts in the forequarter (i.e., chuck-and-neck, LMC/forequarter miscellaneous, chuck-tender/blade, brisket, and bavette) was 0.71 while the average of the correlations among the cuts in the hindquarter (i.e., cuberoll, fillet, striploin, rump, knuckle, eye of round, silverside flat, and topside) was 0.77; the average of the correlations between cuts in the hindquarter and cuts in the forequarter was 0.66.

The partial correlation among cuts, following adjustment for differences in carcass weight, varied from −0.36 (between the cuberoll and the LMC/forequarter miscellaneous) to 0.74 (between the topside and the eye of round); the average of the absolute correlations (i.e., non-negative value without regard to its sign) among all primal cuts was 0.20. The average of the partial correlations among the forequarter cuts was 0.17 while the average of the partial correlations among the hindquarter cuts was 0.30.

Table 3 summarizes the partial correlations between the cuts within steers and heifers separately (carcass weight was included as a covariate for all correlations). The pairwise correlations between primal cuts differed between steers and heifers 75% of the time. The average absolute difference for the same correlation in steers and heifers was 0.07, with the maximum difference being 0.24 (the correlation was between the heel/shank and the rump). The average of the absolute partial correlations between all primal cuts was, nonetheless, very similar in steers and heifers (0.19 vs. 0.17).

Table 4 summarizes the correlations between each of the individual primal cuts with the groups of cuts. The strength of the correlations between the 14 primal cuts and the grouped cuts differed ($P < 0.05$) by sex and cut group for the majority of the primal cuts. With the exception of the bavette and chuck-and-neck cuts, correlations between the primal cuts and frying group of cuts were either equal or stronger in steers than in heifers. The correlations between the roasting cuts and

**Table 2.** Correlations[†] among primal cuts with (above diagonal) and without (below diagonal) including carcass weight as a covariate

| | Topside | SS flat[‡] | Eye of round | Knuckle | Rump | Striploin | Fillet | Cuberoll | Bavette | Brisket | Chuck- tender | LMC Misc[‖] | Chuck- and-Neck | Heel/ Shank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Topside | | 0.61 | 0.74 | 0.73 | 0.33 | 0.35 | 0.36 | −0.02 | −0.26 | 0.12 | −0.16 | 0.10 | 0.04 | 0.60 |
| SS flat[‡] | 0.90 | | 0.55 | 0.55 | −0.03 | 0.27 | 0.18 | −0.04 | −0.13 | 0.07 | −0.10 | 0.13 | 0.06 | 0.46 |
| Eye of round | 0.91 | 0.85 | | 0.52 | 0.36 | 0.34 | 0.30 | 0.11 | −0.16 | 0.15 | −0.18 | −0.01 | 0.00 | 0.48 |
| Knuckle | 0.93 | 0.89 | 0.84 | | 0.22 | 0.20 | 0.29 | −0.11 | −0.26 | 0.02 | −0.02 | 0.18 | 0.05 | 0.62 |
| Rump | 0.79 | 0.67 | 0.77 | 0.78 | | 0.34 | 0.16 | 0.08 | −0.09 | 0.10 | −0.12 | −0.10 | −0.19 | 0.23 |
| Striploin | 0.72 | 0.70 | 0.69 | 0.69 | 0.71 | | 0.36 | −0.04 | −0.17 | 0.24 | −0.21 | 0.08 | −0.07 | 0.24 |
| Fillet | 0.76 | 0.69 | 0.70 | 0.75 | 0.65 | 0.70 | | 0.25 | −0.11 | 0.05 | −0.08 | −0.10 | 0.06 | 0.15 |
| Cuberoll | 0.46 | 0.46 | 0.52 | 0.45 | 0.48 | 0.40 | 0.57 | | 0.36 | −0.04 | −0.10 | −0.36 | −0.11 | −0.11 |
| Bavette | 0.42 | 0.47 | 0.41 | 0.44 | 0.43 | 0.33 | 0.39 | 0.57 | | −0.05 | 0.06 | −0.29 | −0.07 | −0.26 |
| Brisket | 0.76 | 0.74 | 0.72 | 0.75 | 0.70 | 0.67 | 0.64 | 0.40 | 0.50 | | 0.01 | 0.24 | 0.03 | 0.05 |
| Chuck-tender | 0.75 | 0.77 | 0.68 | 0.80 | 0.71 | 0.56 | 0.66 | 0.50 | 0.57 | 0.78 | | 0.27 | 0.35 | −0.06 |
| LMC/Misc[‖] | 0.78 | 0.77 | 0.68 | 0.82 | 0.66 | 0.64 | 0.62 | 0.41 | 0.44 | 0.80 | 0.85 | | 0.30 | 0.25 |
| Chuck-and-Neck | 0.79 | 0.78 | 0.71 | 0.81 | 0.67 | 0.61 | 0.69 | 0.46 | 0.53 | 0.78 | 0.89 | 0.86 | | −0.03 |
| Heel/Shank | 0.90 | 0.86 | 0.83 | 0.91 | 0.76 | 0.68 | 0.69 | 0.42 | 0.43 | 0.74 | 0.78 | 0.82 | 0.78 | |

[†] Correlations that were ≤|0.01| were not different (i.e., $P > 0.05$) from 0. All pairwise raw correlations between traits were different ($P < 0.05$) from the corresponding partial pairwise correlations (adjusted for carcass weight).

[‡] Silverside flat.

[‖] LMC/Forequarter miscellaneous.

**Table 3.** Correlations among primal cuts for steers (above diagonal) and heifers (below diagonal) when carcass weight was included as a covariate

| | Topside | SS_flat[†] | Eye of round | Knuckle | Rump | Striploin | Fillet | Cuberoll | Bavette | Brisket | Chuck- tender | LMC Misc[‡] | Chuck-and-Neck | Heel/ Shank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Topside | | 0.59 | 0.71 | 0.72 | 0.28 | 0.29 | 0.30 | −0.08 | −0.28 | 0.11 | −0.10 | 0.19 | 0.11 | 0.61 |
| SS_flat[†] | 0.55 | | 0.52 | 0.55 | −0.13 | 0.20 | 0.12 | −0.08 | −0.13 | 0.05 | −0.04 | 0.21 | 0.12 | 0.47 |
| Eye of round | 0.67 | 0.46 | | 0.50 | 0.28 | 0.27 | 0.23 | 0.04 | −0.18 | 0.14 | −0.12 | 0.11 | 0.08 | 0.51 |
| Knuckle | 0.73 | 0.49 | 0.51[‖] | | 0.21 | 0.17 | 0.25 | −0.13 | −0.27 | 0.01 | 0.01[$] | 0.22 | 0.06 | 0.61 |
| Rump | 0.07 | −0.27 | 0.11 | 0.05 | | 0.23 | 0.10 | 0.00[$] | −0.12 | 0.06 | −0.05 | −0.01[$] | −0.12 | 0.26 |
| Striploin | 0.09 | 0.11 | 0.04 | 0.08 | 0.17 | | 0.31 | −0.12 | −0.19 | 0.24 | −0.15 | 0.16 | 0.01 | 0.23 |
| Fillet | 0.37 | 0.17 | 0.30 | 0.33 | 0.07 | 0.25 | | 0.20 | −0.12 | 0.04 | −0.04 | −0.07 | 0.09 | 0.13 |
| Cuberoll | −0.06[‖] | −0.12[‖] | 0.04[‖] | −0.15[‖] | 0.05 | −0.12[‖] | 0.26 | | 0.36 | −0.04 | −0.07 | −0.32 | −0.09 | −0.12 |
| Bavette | −0.25 | −0.14[‖] | −0.12 | −0.28[‖] | −0.03 | −0.11 | −0.11 | 0.41 | | −0.04 | 0.06 | −0.29 | −0.06 | −0.27 |
| Brisket | 0.02 | 0.01[$] | 0.04 | −0.04 | 0.03 | 0.13 | −0.01[$] | −0.13[‖] | −0.07 | | 0.04 | 0.27 | 0.06 | 0.06 |
| Chuck- tender | −0.05 | −0.02[‖,$] | −0.05 | 0.05 | −0.01[$] | −0.07 | −0.05[‖] | −0.07[‖] | 0.04[‖] | 0.08 | | 0.23 | 0.31 | −0.05[$] |
| LMC/Misc[‡] | 0.17[‖] | 0.19[‖] | 0.02 | 0.23[‖] | −0.06 | 0.15[‖] | −0.03 | −0.38 | −0.34 | 0.25 | 0.26 | | 0.27 | 0.28 |
| Chuck-and-Neck | 0.17 | 0.15 | 0.11 | 0.15 | −0.12[‖] | 0.02[‖,$] | 0.17 | −0.02[$] | −0.09 | 0.07[‖] | 0.30[‖] | 0.25[‖] | | −0.01 |
| Heel/Shank | 0.53 | 0.41 | 0.34 | 0.61[‖] | 0.02 | 0.06 | 0.15 | −0.20 | −0.25[‖] | −0.06 | 0.03 | 0.29[‖] | 0.02[$] | |

[†] Silverside flat.

[‡] LMC/Forequarter miscellaneous.

[‖] Correlation in steers was not different (i.e., $P > 0.05$) from the corresponding correlation in heifers.

[$] Correlations were not different (i.e., $P > 0.05$) from 0.

all other cuts varied by sex and the correlations were not consistently stronger or weaker for any one sex. The correlations between the primal cuts and the roasting cuts were all strong (≥0.38) with the weakest correlation existing with the bavette in both sexes. For the mincing cuts, the correlations with the primal cuts were either the same or stronger in heifers than they were in steers. The mean correlation between the primal cuts with the mincing cuts was 0.80 in heifers and 0.78 in steers. For the frying cuts, the rump cut explained most of the variability (there was no difference in the weight of this cut between sexes), whereas the topside cut explained most of the variability in the roasting cuts regardless of sex.

Regardless of sex, carcass weight was strongly positively correlated (all correlations ≥ 0.53) with all primal cuts (Table 5). The correlations between carcass weight and each of the primal cuts were consistently stronger in heifers than in steers (with the exception of the cuberoll cut where the correlation was 0.55 which did not differ between sexes). The maximum difference between sexes in the correlation between carcass weight and any cut was 0.12 (bavette). The correlation between carcass conformation and the primal cuts was dependent on the individual

**Table 4.** Correlations between the different primal cuts with each of the grouped cuts by animal sex

| | Steers | | | Heifers | | |
|---|---|---|---|---|---|---|
| Primal cut | Frying | Roasting | Mincing | Frying | Roasting | Mincing |
| Topside | 0.86 | 0.98 | 0.83 | 0.81 | 0.98 | 0.87 |
| Silverside-flat | 0.80 | 0.95 | 0.85 | 0.75 | 0.95 | 0.88 |
| Eye of round | 0.82 | 0.92 | 0.78 | 0.77 | 0.93 | 0.82 |
| Knuckle | 0.84 | 0.96 | 0.84 | 0.80 | 0.96 | 0.86 |
| Rump | 0.92† | 0.80 | 0.77 | 0.92 | 0.77 | 0.80 |
| Striploin | 0.91 | 0.75 | 0.68† | 0.90 | 0.71 | 0.70 |
| Fillet | 0.84 | 0.74 | 0.68† | 0.82 | 0.76 | 0.70 |
| Cuberoll | 0.50† | 0.55 | 0.52 | 0.52 | 0.49 | 0.46 |
| Bavette | 0.38 | 0.38 | 0.57 | 0.54 | 0.48 | 0.66 |
| Brisket | 0.78 | 0.75† | 0.80 | 0.76 | 0.76 | 0.82 |
| Chuck-tender/Blade | 0.75† | 0.78 | 0.90 | 0.73 | 0.80 | 0.91 |
| LMC/Misc‡ | 0.76† | 0.81† | 0.88† | 0.76 | 0.81 | 0.88 |
| Chuck-and-Neck | 0.77 | 0.81 | 0.95 | 0.78 | 0.85 | 0.96 |
| Heel/Shank | 0.83 | 0.91† | 0.83 | 0.77 | 0.91 | 0.86 |

†Correlation in steers was not different (*P* > 0.05) from the corresponding correlation in heifers.

‡LMC/Forequarter miscellaneous.

**Table 5.** Correlations between the different primal cuts with carcass weight, carcass conformation, and carcass fat in steers and heifers separately

| | Steers | | | Heifers | | |
|---|---|---|---|---|---|---|
| Primal cut | Weight | Conformation | Fat | Weight | Conformation | Fat |
| Topside | 0.86 | 0.71 | −0.01 | 0.89 | 0.75 | −0.08 |
| Silverside-flat | 0.84 | 0.64 | 0.07 | 0.85 | 0.68 | 0.04 |
| Eye of round | 0.80 | 0.76 | 0.04 | 0.84 | 0.73 | −0.03 |
| Knuckle | 0.86 | 0.63 | 0.02 | 0.87 | 0.70 | −0.05 |
| Rump | 0.82 | 0.57† | 0.24† | 0.83 | 0.57† | 0.24† |
| Striploin | 0.74 | 0.64 | 0.24† | 0.75 | 0.54 | 0.22† |
| Fillet | 0.73 | 0.48 | −0.02 | 0.76 | 0.62 | −0.09 |
| Cuberoll | 0.55† | 0.33 | 0.21 | 0.55† | 0.37 | 0.11 |
| Bavette | 0.53 | 0.20 | 0.28† | 0.65 | 0.38 | 0.26† |
| Brisket | 0.81 | 0.59 | 0.26 | 0.85 | 0.62 | 0.20 |
| Chuck-tender/blade | 0.87† | 0.44 | 0.18 | 0.88† | 0.54 | 0.12 |
| LMC/Misc‡ | 0.84 | 0.53 | 0.14 | 0.85 | 0.57 | 0.08 |
| Chuck-and-Neck | 0.87 | 0.52 | 0.09 | 0.90 | 0.64 | 0.05 |
| Heel/Shank | 0.84 | 0.66 | 0.06 | 0.87 | 0.65 | −0.05 |

†Correlation in steers was not different (*P* > 0.05) from the corresponding correlation in heifers.

‡LMC/Forequarter miscellaneous.

**Table 6.** Dam parity least square means[†] (kg; standard error in parentheses) for the yield of carcass primal cuts with and without adjustment to a common carcass weight

| | No adjustment for carcass weight | | | | | | Adjustment for carcass weight | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dam parity | | | | | | Dam parity | | | | | |
| Cut | 1 | 2 | 3 | 4 | 5 | *P* | 1 | 2 | 3 | 4 | 5 | p-value |
| Topside | $26.41^{a}$ (0.06) | $26.53^{b}$ (0.06) | $26.59^{c}$ (0.06) | $26.61^{c}$ (0.07) | $26.43^{a}$ (0.06) | <0.001 | $25.91^{a}$ (0.04) | $25.90^{a}$ (0.04) | $25.91^{a}$ (0.04) | $25.90^{a}$ (0.04) | $25.82^{b}$ (0.03) | <0.001 |
| SS flat[‡] | $16.93^{a}$ (0.06) | $17.02^{b}$ (0.06) | $17.09^{c}$ (0.06) | $17.10^{c}$ (0.06) | $16.96^{a,b}$ (0.06) | <0.001 | $18.03^{a}$ (0.04) | $17.99^{b}$ (0.04) | $18.02^{a,c}$ (0.04) | $18.01^{a,b}$ (0.04) | $17.96^{b}$ (0.04) | 0.012 |
| Eye of round | $7.37^{a}$ (0.02) | $7.41^{b}$ (0.02) | $7.43^{b,c}$ (0.03) | $7.45^{c}$ (0.03) | $7.39^{a}$ (0.02) | <0.001 | 7.63 (0.02) | 7.63 (0.02) | 7.63 (0.02) | 7.63 (0.02) | 7.61 (0.02) | 0.797 |
| Knuckle | $14.49^{a}$ (0.04) | $14.57^{b}$ (0.04) | $14.62^{b,c}$ (0.04) | $14.63^{c}$ (0.04) | $14.51^{a}$ (0.04) | <0.001 | $15.61^{a}$ (0.02) | $15.60^{a}$ (0.02) | $15.62^{a}$ (0.02) | $15.62^{a}$ (0.02) | $15.55^{b}$ (0.02) | <0.001 |
| Rump | $19.57^{a}$ (0.06) | $19.74^{b,d}$ (0.06) | $19.76^{b,c}$ (0.07) | $19.83^{c}$ (0.07) | $19.74^{d}$ (0.06) | <0.001 | $19.61^{a}$ (0.04) | $19.65^{b}$ (0.04) | $19.62^{a,b}$ (0.04) | $19.66^{a,b}$ (0.04) | $19.67^{b}$ (0.04) | <0.001 |
| Striploin | 16.35 (0.08) | 16.41 (0.08) | 16.46 (0.08) | 16.45 (0.08) | 16.41 (0.08) | 0.058 | 16.86 (0.05) | 16.83 (0.05) | 16.82 (0.06) | 16.85 (0.06) | 16.59 (0.05) | 0.301 |
| Fillet | $7.27^{a}$ (0.03) | $7.34^{b}$ (0.03) | $7.37^{c}$ (0.03) | $7.36^{b,c}$ (0.03) | $7.31^{d}$ (0.03) | <0.001 | $7.63^{a}$ (0.02) | $7.67^{b,c}$ (0.02) | $7.68^{b}$ (0.02) | $7.66^{a,c,d}$ (0.02) | $7.64^{a,d}$ (0.02) | <0.001 |
| Cuberoll | 12.64 (0.09) | 12.70 (0.09) | 12.70 (0.09) | 12.70 (0.09) | 12.66 (0.09) | 0.462 | 12.67 (0.07) | 12.64 (0.07) | 12.63 (0.07) | 12.58 (0.07) | 12.62 (0.06) | 0.379 |
| Bavette | $12.09^{a}$ (0.08) | $12.21^{b}$ (0.08) | $12.25^{a,b}$ (0.08) | $12.25^{b}$ (0.08) | $12.23^{b}$ (0.08) | 0.001 | 13.13 (0.07) | 13.15 (0.07) | 13.15 (0.07) | 13.13 (0.07) | 13.20 (0.06) | 0.281 |
| Brisket | $15.11^{a}$ (0.07) | $15.36^{b,c}$ (0.07) | $15.36^{b}$ (0.07) | $15.42^{b}$ (0.08) | $15.43^{c}$ (0.07) | <0.001 | $16.70^{a}$ (0.05) | $16.79^{b}$ (0.04) | $16.79^{b}$ (0.05) | $16.77^{b}$ (0.05) | $16.80^{b}$ (0.04) | <0.001 |
| Chuck- tender | $11.97^{a}$ (0.08) | $12.00^{a,b}$ (0.08) | $12.03^{b}$ (0.08) | $12.05^{b}$ (0.08) | $11.96^{a}$ (0.08) | 0.001 | $13.42^{a}$ (0.04) | $13.40^{b}$ (0.04) | $13.40^{b}$ (0.04) | $13.40^{b}$ (0.04) | $13.39^{b}$ (0.04) | <0.001 |
| LMC/Misc[‖] | $25.04^{a}$ (0.08) | $25.15^{b}$ (0.08) | $25.25^{c}$ (0.08) | $25.23^{c}$ (0.08) | $25.03^{a}$ (0.08) | <0.001 | $27.81^{a,b}$ (0.05) | $27.82^{a}$ (0.05) | $27.78^{b}$ (0.05) | $27.72^{a,b}$ (0.05) | $28.03^{c}$ (0.05) | <0.001 |
| Chuck-and- neck | $33.22^{a}$ (0.12) | $33.41^{b,c}$ (0.12) | $33.50^{b}$ (0.12) | $33.58^{b}$ (0.12) | $33.39^{c}$ (0.11) | <0.001 | $38.81^{a}$ (0.07) | $38.73^{a,b}$ (0.07) | $38.68^{b}$ (0.07) | $38.72^{a,b}$ (0.07) | $38.73^{a,b}$ (0.06) | 0.038 |
| Heel/Shank | $11.96^{a}$ (0.03) | $12.07^{b}$ (0.03) | $12.11^{c}$ (0.03) | $12.12^{c}$ (0.03) | $12.01^{d}$ (0.03) | <0.001 | $12.90^{a}$ (0.02) | $12.93^{b}$ (0.02) | $12.94^{b}$ (0.02) | $12.94^{b}$ (0.02) | $12.89^{a}$ (0.02) | <0.001 |

[†] The reference animal was a 27-mo-old Limousin steer born on a beef farm.

[‡] Silverside flat.

[‖] LMC/forequarter miscellaneous.

$^{a–d}$Values with a different superscript within a row are statistically different from each other.

cut. Primal cuts located in the hindquarter of the carcass were the most strongly correlated (all >0.33) with carcass conformation in both heifers and steers. The strongest correlations with carcass conformation existed between the topside cut in heifers (0.75) and the eye-of-round cut in steers (0.76). The mean correlation between the hindquarter cuts of the carcass with carcass conformation was 0.60, whereas the mean correlation between the forequarter cuts with carcass conformation was 0.46. The direction and strength of the correlations between carcass fat and the primal cuts was dependent on both the individual primal cuts and sex. The correlations between the individual primal cuts and carcass fat were all positive or close to zero (i.e., >−0.10). Regardless of sex, the strongest correlation between any of the primal cuts with carcass fat was the bavette cut (0.26 in heifers and 0.28 in steers).

### *Mixed Model Analyses*

The least square means for the individual primal cuts for each dam parity, with and without adjustment for differences in carcass weight, are in Table 6. Dam parity was associated ($P < 0.05$) with all primal cuts except striploin, cuberoll, eye-of-round, and bavette; the latter two primal cuts were not associated with dam parity only when animals were adjusted to a common carcass weight. Mean carcass weight of progeny for parity 1, 2, 3, 4, and 5+ was 338, 340, 341, 344, and 344 kg, respectively. The heavier carcass weight of animals born from older parity dams was generally reflected in heavier cut weights, although the difference per primal cut was small. The difference was even smaller once adjusted to a common carcass weight.

The least square means for the yields of the 14 primal cuts from animals of eight different breeds, without adjustment to a common carcass weight, are in Table 7. Breed differences existed for all cuts ($P < 0.05$). With the exception of the fillet, the primal cuts from Jersey animals were the lightest (an average of 2.5 kg lighter across cuts than the next lightest breed). Differences in primal cut weights also existed even when interbreed differences in carcass weight were adjusted for in the statistical model (Table 8); primal cuts from the Jersey breed were, however, no longer consistently the lightest across breeds.

The difference between steers and heifers as well as steers born on a beef-herd versus steers born a dairy-herd for all traits is in Table 9. Steers were, on average, heavier with a lower conformation and fat score than heifers. Steers had a heavier mean cut weight (2.60 kg on average) than heifers for all 14 primal cuts. The largest difference for the weights of cuts between steers and heifers existed for the chuck-and-neck cut; steers had an 8.39 kg heavier chuck-and-neck cut than heifers. The weight of the grouped cuts was very also heavier for steers than for heifers. The difference between the group of frying cuts was the smallest (3.83 kg heavier in steers than heifers), whereas the difference between the mincing cuts was the largest (20.69 kg heavier

**Table 7.** Least square means[†] (kg; standard error in parentheses) for the yield of carcass primal cuts without adjustment to a common carcass weight in Aberdeen Angus (AA), Belgium Blue (BB), Charolais (CH), Hereford (HE), Holstein-Friesian (HF), Jersey (JE), Limousin (LM), and Simmental (SI)

| Cut | AA | BB | CH | HE | HF | JE | LM | SI |
|---|---|---|---|---|---|---|---|---|
| Topside | 21.50 (0.14)$^{a}$ | 27.95 (0.15)$^{b}$ | 25.73 (0.10)$^{c}$ | 20.86 (0.10)$^{e}$ | 21.68 (0.10)$^{a}$ | 17.00 (0.45)$^{d}$ | 26.59 (0.10)$^{f}$ | 24.65 (0.13)$^{g}$ |
| SS flat[‡] | 14.12 (0.12)$^{a}$ | 17.85 (0.14) $^{b}$ | 16.97 (0.10) $^{c}$ | 13.15 (0.09) $^{e}$ | 13.92 (0.09)$^{a}$ | 10.31 (0.41) $^{d}$ | 17.09 (0.09)$^{c}$ | 15.99 (0.12)$^{f}$ |
| Eye of round | 5.98 (0.05)$^{a}$ | 8.24 (0.06)$^{b}$ | 6.91 (0.04)$^{c}$ | 5.59 (0.04)$^{e}$ | 5.35 (0.04)$^{f}$ | 4.05 (0.18)$^{d}$ | 7.43 (0.04)$^{g}$ | 6.72 (0.05)$^{h}$ |
| Knuckle | 11.92 (0.08)$^{a}$ | 15.29 (0.09)$^{b}$ | 14.56 (0.07)$^{c}$ | 11.61 (0.06)$^{e}$ | 12.12 (0.06)$^{f}$ | 8.91 (0.27)$^{d}$ | 14.62 (0.06)$^{c}$ | 13.47 (0.08)$^{g}$ |
| Rump | 17.87 (0.13)$^{a}$ | 19.90 (0.15)$^{b}$ | 19.51 (0.10)$^{c}$ | 18.32 (0.10)$^{e}$ | 16.55 (0.09)$^{f}$ | 13.49 (0.43)$^{d}$ | 19.76 (0.09)$^{g}$ | 18.31 (0.13)$^{h}$ |
| Striploin | 14.40 (0.16)$^{a}$ | 15.83 (0.17)$^{b,c}$ | 15.95 (0.12)$^{b}$ | 13.66 (0.20)$^{a}$ | 13.42 (0.12)$^{e}$ | 12.37 (0.54)$^{d}$ | 16.46 (0.11)$^{f}$ | 15.79 (0.15)$^{c}$ |
| Fillet | 6.26 (0.06)$^{a}$ | 7.70 (0.07)$^{b}$ | 7.36 (0.05)$^{c}$ | 5.41 (0.04)$^{d}$ | 6.30 (0.04)$^{a}$ | 5.42 (0.19)$^{d}$ | 7.37 (0.04)$^{c}$ | 6.97 (0.06)$^{e}$ |
| Cuberoll | 12.10 (0.17)$^{a}$ | 12.91 (0.19)$^{b}$ | 12.42 (0.14)$^{c}$ | 13.01 (0.22)$^{a,e}$ | 11.56 (0.13)$^{f}$ | 10.52 (0.59)$^{d}$ | 12.70 (0.13)$^{g}$ | 12.22 (0.17)$^{e}$ |
| Bavette | 12.63 (0.18)$^{a}$ | 12.26 (0.19)$^{b,c}$ | 12.45 (0.13)$^{b}$ | 11.49 (0.13)$^{d}$ | 12.22 (0.13)$^{e}$ | 11.33 (0.62)$^{d}$ | 12.25 (0.12)$^{e}$ | 12.57 (0.17)$^{c}$ |
| Brisket | 15.10 (0.15)$^{a}$ | 16.87 (0.17)$^{b}$ | 15.52 (0.12)$^{c}$ | 12.90 (0.12)$^{e}$ | 12.82 (0.11)$^{f}$ | 11.21 (0.52)$^{d}$ | 15.42 (0.11)$^{c}$ | 15.09 (0.15)$^{g}$ |
| Chuck-tender | 11.31 (0.11)$^{a}$ | 13.20 (0.12)$^{b}$ | 12.51 (0.08)$^{c}$ | 10.93 (0.08)$^{a}$ | 11.21 (0.08)$^{e}$ | 8.25 (0.37)$^{d}$ | 12.03 (0.08)$^{f}$ | 11.63 (0.10)$^{g}$ |
| LMC[‖] | 22.85 (0.17)$^{a}$ | 27.51 (0.19)$^{b}$ | 25.79 (0.13)$^{c}$ | 23.12 (0.13)$^{e}$ | 22.06 (0.12)$^{f}$ | 16.92 (0.58)$^{d}$ | 25.25 (0.12)$^{g}$ | 24.30 (0.17)$^{h}$ |
| Chuck-and-neck | 30.79 (0.26)$^{a}$ | 35.46 (0.28)$^{b}$ | 34.00 (0.20)$^{c}$ | 26.93 (0.19)$^{e}$ | 28.81 (0.18)$^{f}$ | 24.20 (0.85)$^{d}$ | 33.50 (0.18)$^{g}$ | 31.98 (0.25)$^{h}$ |
| Heel shank | 10.48 (0.07)$^{a}$ | 12.50 (0.07)$^{b}$ | 12.71 (0.05)$^{c}$ | 10.56 (0.05)$^{e}$ | 9.89 (0.05)$^{f}$ | 7.13 (0.23)$^{d}$ | 12.11 (0.05)$^{g}$ | 11.25 (0.07)$^{h}$ |

[†] The reference animal was a 27-mo-old steer from a third parity dam that was born on either a dairy (Holstein and Jersey) or beef (remaining breeds) farm.

[‡] Silverside flat.

[‖] LMC/forequarter miscellaneous.

$^{a-h}$Values with a different superscript within a row are statistically different from each other ($P < 0.05$).

in steers than heifers). Beef-herd steers were marginally heavier (5.00 kg) than dairy-herd steers and they had similar conformation and fat scores. The difference between the weights of the primal cuts in beef-herd steers and dairy-herd steers was minimal and, with the exception of the chuck and neck cut, was restricted to hind-quarter cuts.

Figure 1 illustrates the least square means for the weight of the rump, striploin, fillet, and cuberoll cuts from animals slaughtered at different ages (in months). On average, without adjustment for carcass weight, the weight of all four cuts increased as age at slaughter increased from 16 to 32 mo; after 32 mo there was no clear relationship between age at slaughter and the weight of the four primal retail cuts. The mean weight of the four primal cuts was more constant across month of age of slaughter when adjusted for carcass weight. Age at slaughter had the least effect on the weight of the fillet, whereas the weight of the rump, striploin, and cuberoll varied for the young (i.e., <18 mo at slaughter) and older (>33 mo at slaughter) animals.

**Table 8.** Least square means[†] (kg; standard error in parentheses) for the yield of carcass primal cuts with adjustment to a common carcass weight in Aberdeen Angus (AA), Belgium Blue (BB), Charolais (CH), Hereford (HE), Holstein-Friesian (HF), Jersey (JE), Limousin (LM), and Simmental (SI)

| Cut | AA | BB | CH | HE | HF | JE | LM | SI |
|---|---|---|---|---|---|---|---|---|
| Topside | 22.18 (0.14)$^{a}$ | 26.40 (0.15)$^{b}$ | 24.65 (0.10)$^{c}$ | 22.17 (0.10)$^{a}$ | 22.57 (0.10)$^{d}$ | 21.49 (0.45)$^{e}$ | 25.91 (0.10)$^{f}$ | 24.37 (0.13)$^{g}$ |
| SS flat[‡] | 16.27 (0.12) | 18.15 (0.14) | 17.53 (0.10) | 15.86 (0.09) | 16.51 (0.09) | 15.71 (0.41) | 18.02 (0.09) | 17.36 (0.12) |
| Eye of round | 6.69 (0.05)$^{a}$ | 8.18 (0.06)$^{b}$ | 6.95 (0.04)$^{c}$ | 6.51 (0.04)$^{d}$ | 6.20 (0.04)$^{e}$ | 6.02 (0.18)$^{f}$ | 7.63 (0.04)$^{g}$ | 7.10 (0.05)$^{h}$ |
| Knuckle | 13.82 (0.08)$^{a}$ | 15.75 (0.09)$^{b}$ | 15.27 (0.07)$^{c}$ | 13.97 (0.06)$^{d}$ | 14.38 (0.06)$^{e}$ | 13.05 (0.27)$^{f}$ | 15.62 (0.06)$^{g}$ | 14.78 (0.08)$^{h}$ |
| Rump | 18.93 (0.13)$^{a}$ | 19.05 (0.15)$^{a,b}$ | 18.97 (0.10)$^{b}$ | 20.10 (0.10)$^{c}$ | 18.10 (0.09)$^{d}$ | 17.95 (0.43)$^{d}$ | 19.62 (0.09)$^{e}$ | 18.62 (0.13)$^{f}$ |
| Striploin | 15.60 (0.16)$^{a,b}$ | 15.52 (0.17)$^{a}$ | 16.03 (0.12)$^{c}$ | 15.36 (0.20)$^{a}$ | 15.06 (0.12)$^{d}$ | 16.56 (0.54)$^{e}$ | 16.83 (0.11)$^{e}$ | 16.45 (0.15)$^{b,d}$ |
| Fillet | 6.92 (0.06)$^{a}$ | 7.74 (0.07)$^{b}$ | 7.56 (0.05)$^{c}$ | 6.30 (0.04)$^{d}$ | 7.13 (0.04)$^{e}$ | 7.19 (0.19)$^{c,e,f}$ | 7.68 (0.04)$^{g}$ | 7.42 (0.06)$^{f}$ |
| Cuberoll | 12.57 (0.17)$^{a}$ | 12.39 (0.19)$^{a,b}$ | 12.14 (0.14)$^{c}$ | 13.73 (0.22)$^{d}$ | 12.31 (0.13)$^{b,e}$ | 12.87 (0.59)$^{a,d,e}$ | 12.63 (0.13)$^{a}$ | 12.34 (0.17)$^{c,e}$ |
| Bavette | 14.41 (0.18)$^{a}$ | 12.56 (0.19)$^{b}$ | 13.11 (0.13)$^{b}$ | 13.68 (0.13)$^{c}$ | 14.37 (0.13)$^{d}$ | 15.44 (0.62)$^{d}$ | 13.15 (0.12)$^{e}$ | 13.77 (0.17)$^{a}$ |
| Brisket | 17.81 (0.15)$^{a}$ | 17.41 (0.17)$^{b}$ | 16.41 (0.12)$^{c}$ | 16.18 (0.12)$^{d}$ | 15.88 (0.11)$^{e}$ | 17.25 (0.52)$^{a,b,f}$ | 16.79 (0.11)$^{g}$ | 16.80 (0.15)$^{f,g}$ |
| Chuck-tender/blade | 13.60 (0.11)$^{a}$ | 14.11 (0.12)$^{b}$ | 13.60 (0.08)$^{a}$ | 13.72 (0.08)$^{c}$ | 13.87 (0.08)$^{d}$ | 12.98 (0.37)$^{e}$ | 13.40 (0.08)$^{f}$ | 13.39 (0.10)$^{f}$ |
| LMC[‖] | 27.04 (0.17)$^{a}$ | 29.08 (0.19)$^{b}$ | 27.83 (0.13)$^{c}$ | 28.31 (0.13)$^{d}$ | 27.02 (0.12)$^{a}$ | 26.07 (0.58)$^{e}$ | 27.82 (0.12)$^{c}$ | 27.43 (0.17)$^{f}$ |
| Chuck- and-neck | 38.79 (0.26)$^{a}$ | 38.90 (0.28)$^{a}$ | 38.30 (0.20)$^{b}$ | 36.18 (0.19)$^{c}$ | 37.82 (0.18)$^{d}$ | 39.64 (0.85)$^{e}$ | 38.68 (0.18)$^{a}$ | 38.14 (0.25)$^{b}$ |
| Heel shank | 12.06 (0.07)$^{a}$ | 12.89 (0.07)$^{b}$ | 13.33 (0.05)$^{c}$ | 12.59 (0.05)$^{d}$ | 11.74 (0.05)$^{e}$ | 10.75 (0.23)$^{f}$ | 12.94 (0.05)$^{b}$ | 12.31 (0.07)$^{g}$ |

[†] The reference animal was a 27-mo-old steer from a third parity dam that was born on either a dairy (Holstein and Jersey) or beef (remaining breeds) farm.

[‡] Silverside flat.

[‖] LMC/forequarter miscellaneous.

$^{a-h}$Values with a different superscript within a row are statistically different from each other ($P < 0.05$).

## DISCUSSION

The relatively crude approaches of carcass assessment in cattle, operational now for many decades (Borggaard et al., 1996), have been successfully exploited by geneticists in the pursuit of better conformed carcasses (Pabiou et al., 2011a; Connolly et al., 2016); similar success stories have been documented in sheep (Conington et al., 1998; Simm et al., 2002). The rapid development in technologies (e.g., Jones et al., 2004; Pabiou et al., 2011a) for generating higher granularity carcass-related characteristics presents new opportunities to more precisely focus on individual primal carcass cuts. Such technologies are rapidly being deployed, contributing to the generation of vast quantities of potentially more informative, more detailed information. The logical progression is in depth evaluation of the possibilities of further exploiting such data sources.

### *Correlation Analyses*

A correlation is a measure of co-dependence and, by extension, therefore provides an assessment of the ability to alter one feature (e.g., a primal cut) independent of a second feature (e.g., carcass weight or another primal cut). A correlation of 0.5 between two traits, for example, implies that 25% (i.e., $0.5^2$) of the variation in one trait is explained by variability in the other trait, and thus considerable

**Table 9.** The difference (standard error of the difference in parentheses) between steers versus heifers and steers born on a beef farm versus steers born on a dairy farm for the least square mean values of the macro-carcass traits and the primal and grouped cut traits

| | | Difference (SED) | |
|---|---|---|---|
| | | Steers versus heifers | Beef bred steers versus dairy bred steers |
| Macro carcass traits | Weight, kg | 57.66 (2.10)*** | 5.00 (2.10)* |
| | Conformation (1–15 scale) | −0.21 (0.08)** | 0.63 (0.08)*** |
| | Fat (1–15 scale) | −0.65 (0.08)*** | 0.17 (0.08)* |
| Primal cut traits, kg | Topside | 3.15 (0.16)*** | 0.62 (0.16)*** |
| | SS flat[†] | 2.63 (0.14)*** | 0.65 (0.14)*** |
| | Eye of round | 0.99 (0.06)*** | 0.28 (0.06)*** |
| | Knuckle | 2.18 (0.10)*** | 0.31 (0.10)** |
| | Rump | 1.68 (0.15)*** | 0.27 (0.15) |
| | Striploin | 1.36 (0.23)*** | 0.53 (0.23)* |
| | Fillet | 0.75 (0.08)*** | 0.09 (0.08) |
| | Cuberoll | 0.96 (0.28)*** | 0.18 (0.28) |
| | Bavette | 1.75 (0.19)*** | 0.28 (0.20) |
| | Brisket | 2.96 (0.18)*** | 0.23 (0.18) |
| | Chuck-tender/blade | 2.56 (0.15)*** | 0.18 (0.15) |
| | LMC/Misc[‡] | 5.32 (0.19)*** | 0.06 (0.19) |
| | Chuck-and-Neck | 8.39 (0.29)*** | 0.90 (0.30)** |
| | Heel/Shank | 1.91 (0.08)*** | 0.12 (0.08) |
| Grouped cuts, kg | Frying | 3.83 (0.64)*** | 0.89 (0.64) |
| | Roasting | 9.31 (0.49)*** | 2.09 (0.49)*** |
| | Mincing | 20.69 (1.63)*** | 1.20 (1.64) |

[†] Silverside flat.

[‡] LMC/forequarter miscellaneous.

*$P < 0.05$.

**$P < 0.01$.

***$P < 0.001$.

potential exists to alter the first trait independent of the other, and vice versa. The strong raw correlations amongst all the primal cuts in the present study are not unexpected and are consistent with the limited reports from cattle populations (Sarti et al., 2013). This is because all the primal cuts have an underlying common trait in carcass weight, and the strong correlations between all primal cuts and carcass weight observed in the present study are again consistent with previous estimates (Sarti et al., 2013). However, for several reasons, not least the impact of increasing carcass weight on the feed intake of an animal (Crowley et al., 2010), there is often a desire to increase, not simply the weight of primal cuts, but instead increase their weight relative to the overall carcass weight. On average, 62% (steers) to 67% (heifers) of the variability in the primal cut yields could be explained by differences in carcass weight. Importantly, however, 31% to 47% (i.e., almost half) of the variability in the high value rump, striploin, and fillet cut weights was independent of carcass weight signifying considerable variability amongst animals, even for the same carcass weight. Although genetic merit undoubtedly contributes to some of this variability (Pabiou et al., 2011a), understanding better the underlying nongenetic contributing factors could be valuable. Interestingly, the correlation between the mean weight of each of the 14 primal cuts and the correlation of that cut trait with carcass weight was just 0.37; this implies that although the heavier carcass cuts contribute more to the variability in carcass weight, this association was not very strong. Also of note was the relatively small variability in the strength of the correlations between each primal cut and carcass weight with a standard deviation in the correlations being between 0.10 (heifers) and 0.11 (steers) again indicating a relatively equal contribution of the variation in the different primal cuts to the variability in carcass weight.

### *Model Solutions and Their Use in Farm- and Processor-Level Decision Support Systems*

Although knowledge of the factors associated with a given trait, such as primal cut yield, can be useful to inform statistical models such as those used in genetic evaluations, the model solutions

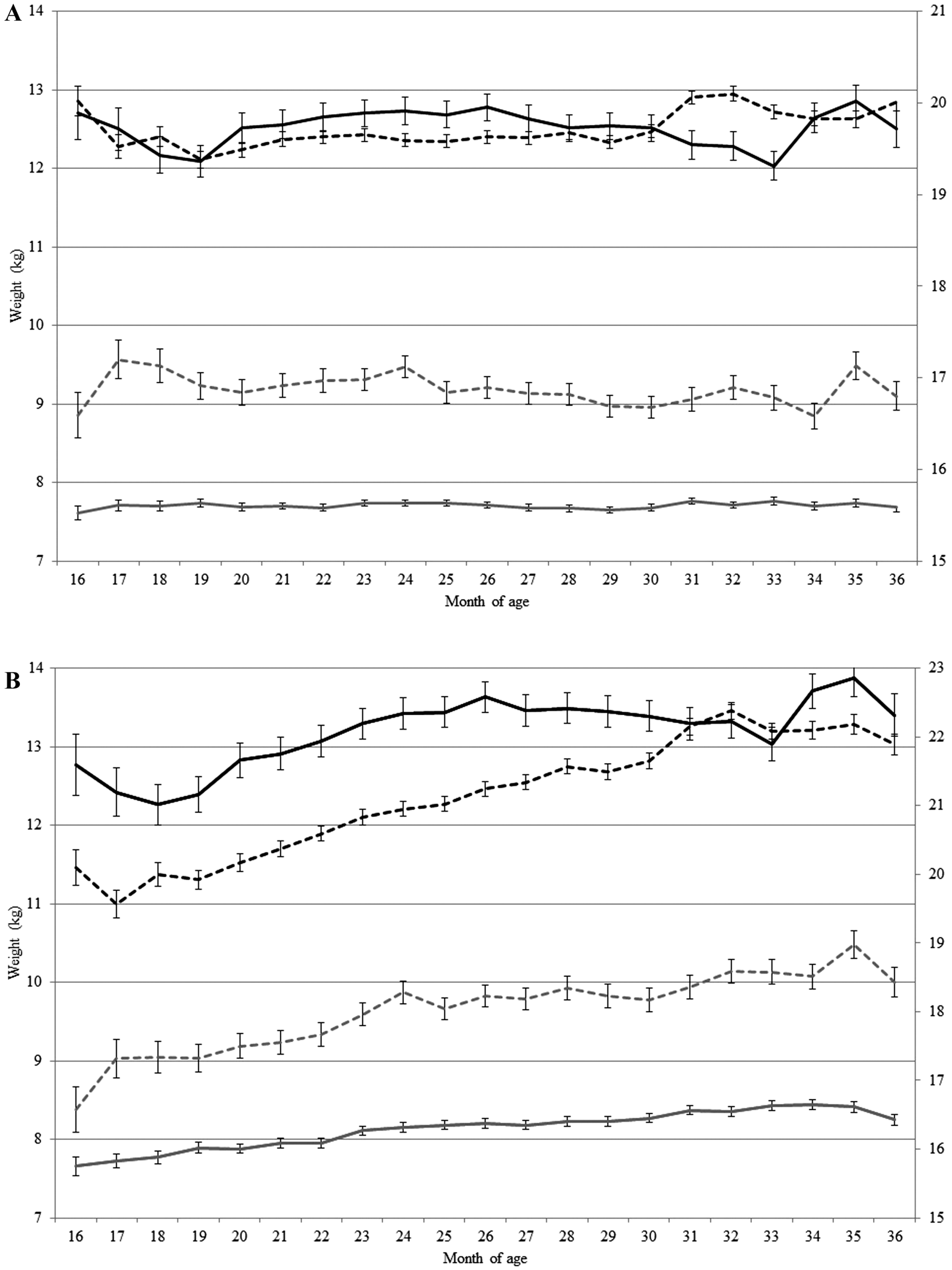

**Figure 1.** The least square means weight of the primal cuts across month of age (standard error represented by error bars), with (A) and without (B) adjustment for carcass weight (rump; dashed black line (secondary axis), striploin; dashed grey line (secondary axis), cuberoll; solid black line, fillet; solid grey line). The reference animal was a Limousin steer born from a parity 3 animal on a beef farm.

themselves can by useful input parameters for decision support systems both on-farm but also at the level of the processor. Although intrabreed genetic variability is known to exist for primal carcass cuts in cattle (Pabiou et al., 2011a; Sarti et al., 2013), clear interbreed differences also exist (Tables 7 and 8). There is a paucity of information in the scientific literature on the breed differences in the weight of different primal carcass cuts and, while is it expected that breeds with heavier carcasses produce, on average, heavier primal cuts, of real interest in the present study was the weight of the primal cuts at a constant carcass weight. Still breed differences existed and such knowledge can be used by producers when selecting the breed of sire to use in the pursuit of a stepwise change in carcass merit which may not be as rapidly achieved through within breed selection. Breed differences in primal cut yields may also be used by processors when firstly procuring animals based on the up-coming demand of retailers but also could be used to crudely stratify animals in lairage for the different market demands of that kill; ideally such breed differences in expected carcass credentials should be complemented with expected within -breed differences in the form of estimated breeding values for primal cut yields. The same could be true from the model solutions for sex effects and its use by processors in aligning (expected) animal supply with (anticipated) market demands.

Benchmarking is a useful psychological strategy to engage individuals in initiating change. Simply providing producers with raw means for the various carcass metrics of their most recent kill, and comparing this to contemporaries, can be irresponsible. As an example, kill statistics of a producer who focuses exclusively on finishing heifers should not be directly compared with kill statistics of a producer who focuses exclusively on finishing steers; based on the results from the present study, the mean carcass weight of the producer finishing steers is expected to be 57.66 kg heavier than the producer killing heifers, not because the former is a superior manager, but instead because each producer chose to operate a different system. The model solutions generated in the present study for animal sex (as with other fixed effects) can be used to adjust the statistics accordingly to a common reference. Once benchmarking metrics are provided, support should be provided on how best to improve performance. Although minimal difference in the weight of individual cuts existed among dam parities, the overall carcass weight of progeny from first parity dams was 6 kg lighter than the carcass weight of progeny from mature dams, a trend consistent with reported elsewhere in cattle (Connolly et al., 2016). Such information can be used to inform producers that, for example, their lighter carcass weights are (partly) due to their younger herd; if the herd is expanding through the retention of more heifers, then the producer can be put at ease that the differential will diminish as the herd enters a steady state. If however, the younger herd is a function of compromised cow longevity, then firstly the impact on carcass value can be included in any full economic appraisal of the ramifications of the shorter longevity, but also the impact of improving cow longevity on herd revenue can be quantified. Moreover, other than attempting to increase output, the trends in mean primal cut weight across ages could be used to advise on the change in carcass value per month of age and by extension the potential to reduce the costs of producing by slaughtering animals earlier.

In conclusion, with an average correlation between the 14 primal cuts of 0.71, a strong relationship between all cuts was evident. Taking cognizance of the underlying correlation of these traits with carcass weight, it was estimated that almost half the variability of high value cuts (i.e., rump, striploin, and fillet) was independent of carcass weight, thus highlighting the large variation in primal cut weight present in the population, even for animals of the same carcass weight. Furthermore, solutions from the models developed in the present study could prove as useful inputs for decision support systems at both the farmer and processor level to increase performance levels.

## SUPPLEMENTARY MATERIAL

Supplementary data are available at *Translational Animal Science* online.

## FUNDING

This publication has emanated from research supported in part by a research grant from Science Foundation Ireland and the Department of Agriculture, Food and Marine on behalf of the Government of Ireland under the Grant 16/RC/3835 (VistaMilk) as well as funding from the Research Stimulus Fund (BreedQuality).

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