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 the animal-level factors with primal cut yields in cattle and to understand the extent of the variability in primal cut yields independent of other primal cuts or as carcass weight itself. 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 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 level to increase performance.

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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 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 non-genetic) terms, also include the relevant systematic environmental effects (Henderson, 1949). Fourthly, in extension services when benchmarking 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 (mortality - Ring et al., 2018; feed efficiency - Hurley et al., 2017; milk quality - McDermott et al., 2016; animal health - Twomey et al., 2016). 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, although Moore et al. (2017) estimated correlations between primal cuts using VIA information on 17,765 carcasses. While 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 if 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 impacted 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 represented 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 inter-location movements was also available.

Data edits

Animals had to be between 13 and 36 months 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 animals that resided <70 days or >1,095 days 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 from is in Appendix 1. 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 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 days. 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 were estimated for the entire dataset 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 if 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 month 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 month 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 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 correlations among the forequarter cuts was 0.17 while the average of the 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 correlations between all primal cuts was, nonetheless, very similar in steers and heifers (0.19 versus 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 all other cuts varied by sex, the correlations were not consistently stronger or weaker for any one sex. The correlations between the primal cuts and the roasting cuts were all very 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), while 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 cut. Both the LMC/forequarter miscellaneous, as well as the chuck-and-neck cuts, were weakly correlated with carcass conformation (<0.14), and this was true regardless of sex. Primal cuts located in the hindquarter of the carcass were the most strongly correlated (all >0.33) with carcass conformation for 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 while the mean correlation between the forequarter cuts with carcass conformation was 0.29. 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 correlation 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, 5+ was 338 kg, 340 kg, 341 kg, 344 kg 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 8 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 inter-breed 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) while the difference between the mincing cuts was the largest (20.69 kg heavier 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. There was no difference between the weights of the 14 primal cuts or the grouped cuts between the two sets of animals.

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 4 cuts increased as age at slaughter increased from 16 to 32 months, after 32 months there was no clear relationship between age at slaughter and the weight of the 4 primal retail cuts. The mean weight of the 4 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, while the weight of the rump, striploin and cuberoll varied for the young (i.e., <18 months at slaughter) and older (>33 months at slaughter) animals.

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 (Connolly et al., 2016; Pabiou et al., 2011a); similar success stories have been documented in sheep (Simm et al., 2002; Conington et al., 1998). 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 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) 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. While genetic merit undoubtedly contributes to some of this variability (Pabiou et al., 2011a), understanding better the underlying non-genetic 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 while 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

While 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 themselves can by useful input parameters for decision support systems both on-farm but also at the level of the processor. While intra-breed genetic variability is known to exist for primal carcass cuts in cattle (Pabiou et al., 2011a; Sarti et al., 2013), clear inter-breed differences also exist (Table 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 to 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. While 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 is (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 (ie., 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.

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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[1]	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[2]	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

[1]Silverside flat, [2]LMC/forequarter miscellaneous

Table 2 Correlations[1] among primal cuts with (above diagonal) and without (below diagonal) including carcass weight as a covariate.

	Topside	SS flat[2]	Eye of round	Knuckle	Rump	Striploin	Fillet	Cuberoll	Bavette	Brisket	Chuck-tender	LMC Misc[3]	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[2]	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	0.1	-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[3]	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	

[1]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)
[2]Silverside flat, [3]LMC/Fore-quarter 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[1]	Eye of round	Knuckle	Rump	Striploin	Fillet	Cuberoll	Bavette	Brisket	Chuck-tender	LMC Misc[2]	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[1]	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[2]	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[†]	

[†]Correlations were not different (i.e., P > 0.05) from 0
[¤]Correlation in steers was not different (i.e., P > 0.05) from the corresponding correlation in heifers
[1]Silverside flat, [2]LMC/Fore-quarter miscellaneous

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/ FQ-Misc[1]	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

[1]LMC/Forequarter miscellaneous

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

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/FQ-Misc[1]	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

[1]LMC/Forequarter miscellaneous

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

Table 6 Dam parity least square means[1] (kg; standard error in parenthesis) 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-value	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

[1]The reference animal was a 27 month old Limousin steer born on a beef farm.
[a-d] Values with a different superscript within a row are statistically different from each other.

Table 7 Least square means[1] (kg; standard error in parenthesis) 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), 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}	13.2 (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 (0.2)^{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}

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

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

Table 8 Least square means[1] (kg; standard error in parenthesis) 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), 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}

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

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

Table 9 The difference (standard error of the difference in parenthesis) 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[1]	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[2]	5.32 (0.19)***	0.06 (0.19)
	Chuck-and-Neck	8.39 (0.29)***	0.9 (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)

[1]Silverside flat
[2]LMC/forequarter miscellaneous
*P < 0.05
**P < 0.01
***P < 0.001

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.

Appendix 1

Common Name	**Latin name**
Bavette	*Abdominal Oblique*
Striploin	*Longissimus thoracis*
Fillet	*Psoas Major/Psoas Minor*
Topside	*Semimembranosus*
Rump	*Gluteus Medius*
Chuck-and-Neck	*Longissimus dorsi (chuck)*
Heel/Shank	Group of extensor muscles and *Gastrocnemius*
Knuckle	*Vastus lateralis (side)/ Rectus femoris (centre)*
Brisket	*Deep/superficial pectoral*
Chuck-Tender/Blade	*Supraspinatus* (CT)
Eye of round	*Semitendinosus*
SS Flat	*Biceps Femoris*
LMC/ FQ Misc.	*Whoop's Triceps Brachii*
Cube roll	*Longissimus dorsi* (Thoracic end) 85% of the cube-roll; *Spinalis dorsi* 10% of cuberoll; and 5% other muscles depending on cutting variations.

Figure 1A

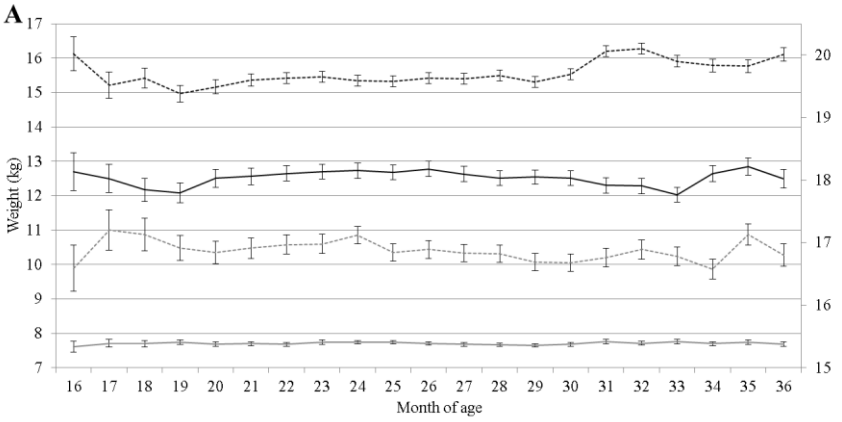

Figure 1B