RELATIVE TISSUE GROWTH PATTERNS AND CARCASS COMPOSITION IN BEEF CATTLE

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Summary

The main objective of the beef breed evaluation programme carried out at Grange Beef Research Centre was to compare the productive characteristics of different beef breed crosses out of Holstein-Friesian cows. In the course of this work much additional information was acquired, particularly on growth patterns of body organs and tissues, and how these affect kill-out proportion and carcass composition. The data were also used to examine relationships between carcass classification variables and carcass composition. Cattle used for beef production in Ireland can be classified into three main biological types: (i) early maturing, (ii) dairy, and (iii) late maturing. Results from an experiment that compared Friesians (dairy), Hereford × Friesians (early maturing) and Charolais × Friesians (late maturing) are used to represent these biological types. The material is organized under the following headings: (i) non carcass parts and kill-out proportion, (ii) carcass composition, (iii) carcass tissue distribution, (iv) muscle chemical composition, (v) gender, (vi) dairy breeds, and (vii) carcass classification and composition.

Kill-out proportion increased by about 10 g/kg from Friesians to Hereford × Friesians to Charolais × Friesians. It also increased by about 10 g/kg per 100 kg increase in slaughter weight. Friesians had higher proportions of gastrointestinal tract plus contents than the two beef crosses and also had higher proportions of metabolic organs. Hereford crosses had a higher proportion of hide and offal fats than Charolais crosses. At any carcass weight, early maturing animals had more fat and less bone and muscle than late maturing animals. As carcass weight increased, the proportions of bone and muscle in the carcass decreased, and the proportion of fat increased, but the rates of these changes differed with biological type. Carcass muscle distribution also differed with biological type. Late maturing cattle had a higher proportion of hind quarter and higher value muscle than Friesians and early maturing animals, while Friesians had higher proportions than early maturing animals. Muscle lipid content (marbling) differed with biological type (early maturing > dairy > late maturing) and with carcass joint (highest for flank and ribs, lowest for *m. longissimus*).

Early maturing steers and heifers had similar carcass fat proportions when the heifers were about 60 kg carcass lighter than the steers. Despite having poorer carcass conformation, heifers had a slightly higher proportion of muscle and a considerably higher proportion of higher value muscle than steers. Carcass classification grade was not a reliable indicator of carcass muscle proportion. Carcass fat class was related to both carcass fat and muscle proportions but accounted for less than half the variance in these. Carcass conformation class was not related to carcass fat proportion, carcass muscle proportion or higher value muscle proportion, but it was negatively related to carcass bone proportion.

Introduction

Growth is a complex process. Every animal starts from the fusion of two single cells and grows and develops through cell division and differentiation into a highly organized unit capable of doing everything necessary to sustain its own life and to reproduce the species. Beef cattle must survive and be productive under a range of environmental and management conditions. This is facilitated by the wide variety of breed types that exist each with its own unique characteristics. Many of the common breed types prosper and are productive in a wide range of environmental and management conditions but their ranking for various production traits may vary with environment (genotype x environment interaction).

The main objective to the beef breed evaluation programme carried out at Grange Beef Research Centre was to evaluate the common breed types under Irish conditions. The programme was designed primarily to provide information on the productive characteristics of different beef crosses out of Holstein-Friesian cows. The main findings of this research have been widely published and disseminated but in the course of the work much additional information was acquired, particularly on growth patterns of body organs and tissues and how these determine kill-out proportion and carcass composition.

Cattle used for beef production in Ireland can be categorised into three main biological types: (i) early maturing breed types such as Angus and Hereford and their crosses, (ii) dairy breeds such as Holstein-Friesian, Norwegian Red, Jersey and Meuse-Rhine Issel (MRI), and (iii) late maturing or continental breed types such as Limousin, Blonde D'Aquitaine, Charolais, Belgian Blue and their crosses. Throughout this report the results from an experiment that compared Friesians (dairy), Hereford × Friesians (early maturing) and Charolais × Friesians (late maturing) will be used to represent these three biological categories. The subject matter is considered under the following headings: (i) non carcass parts and kill-out proportion, (ii) carcass composition, (iii) carcass tissue distribution, (iv) muscle chemical composition, (v) gender, (vi) dairy breeds, and (vii) carcass classification and composition.

Non-carcass parts and kill-out proportion

The non-carcass parts of beef cattle are sources of food and industrial raw materials but their main relevance to beef producers is their influence on kill-out proportion which determines carcass weight and hence carcass value. The mean weights and proportions of non-carcass parts for Friesian, Hereford × Friesian and Charolais × Friesian steers are shown in Table 1. Taken together, transport weight loss and weight of rumen contents ranged from 99 g/kg for Charolais crosses to 110 g/kg for Friesians. The higher value for Friesians was due to their greater feed intake and consequently their greater weight of rumen and intestinal contents. As a proportion of full live weight, empty body weight ranged from 890 g/kg for Friesians to 901 g/kg for Charolais crosses. Gastrointestinal tract weight (rumen plus reticulum plus abomasum empty, plus the omasum and intestines with contents) as a proportion of empty body weight, ranged from 99 g/kg for Hereford crosses to 110 g/kg for Friesians, the higher value for Friesians again being a function of their higher intake capacity. Hide, head and feet combined, ranged from 124 g/kg for Friesians to 139 g/kg for Hereford crosses, the higher value for Hereford crosses being due to their greater hide proportion. Red offal (lungs, heart, liver, kidneys, blood and trim) amounted to 99 g/kg for Friesians, 94 g/kg for Hereford crosses and 95 g/kg for Charolais crosses. The higher value for the Friesians probably reflects the higher metabolic potential of pure dairy breeds. Offal fats (kidney, channel, caul, cod and topside) amounted to 68 g/kg for Friesians, 62 g/kg for Hereford crosses and 55 g/kg for Charolais crosses. The higher value for Friesians is in agreement with the known greater deposition of internal fats in dairy than in beef breeds, while the higher value for Hereford than the Charolais crosses is in line with the generally greater fatness of the Hereford than the Charolais breed.

As proportions of empty body weight, all the non-carcass parts (plus chill weight loss) totaled 412 g/kg for Friesians, 406 g/kg for Hereford crosses and 398 g/kg for Charolais crosses. This resulted in carcass weight (cold) proportions of 588, 594 and 602 g/kg empty body weight for the three breed types, respectively. Based on full live weight, the kill-out proportions were 533, 543 and 553 g/kg for Friesians, Hereford crosses and Charolais crosses, respectively. Thus, at a fixed slaughter weight of 570 kg, the cold carcass weight of Friesian, Hereford crosses and Charolais crosses would be 304, 310 and 315 kg, respectively.

The comparison of the three breed types shown in Table 1 is based on similar slaughter weights. In practice however, these breed types would have different slaughter weights. As slaughter weight affects the proportions of non-carcass parts, it follows that at slaughter weights other than those shown kill-out proportions would be different. Accordingly, carcass weights and kill-out proportions were calculated for three different slaughter weights for each of the breed types (Table 2). The three weights chosen were 500, 600 and 700 kg empty body weight. Over the range 500 to 700 kg empty body weight, kill-out proportion increased by about 20 g/kg for all three breed types. At empty body weight 600 kg (slaughter weight ~ 670 kg), carcass weights were 359, 368 and 373 kg for the Friesians, Hereford crosses and Charolais crosses, respectively. Corresponding carcass weights at 700 kg empty body weight (slaughter weight ~ 770 kg) were 420, 430 and 435 kg, respectively. In brief, the kill-out proportion of Hereford crosses was about 10 g/kg higher than that of Friesians and the kill-out proportion of Charolais crosses was about 10 g/kg higher than that of Hereford crosses. Kill-out proportion increased by about 10 g/kg for each 100 kg increase in slaughter weight and this was reasonably constant for the different breed types.

Carcass composition

Carcass composition is defined as the proportions of fat, muscle, bone and other tissue in the carcass. Other tissue includes tendons, ligaments, fascia, glands and large blood vessels and is generally included with bone in the presentation of compositional data. Fat is partitioned into the subcutaneous and intermuscular depots. Subcutaneous fat is that which is visible and overlies the muscle on the surface of the carcass. Intermuscular fat comprises the seams of separable fat lying beneath and between the muscles. It should not be confused with intramuscular or marbling fat which is the fat between the muscle fibres. This can only be quantified by chemical analysis and is often defined as lipid.

Carcass composition changes with increasing carcass weight. Thus, a single point estimate of composition is of little value because it gives no indication of what it would be at different carcass weights. In order to estimate carcass composition at different carcass weights, measurement of the growth rates of the different tissues is required. Based on such tissue growth measurements, the proportions of subcutaneous fat, intermuscular fat, bone (including other tissue) and muscle were estimated for various breed types at 280, 340 and 400 kg carcass weight. The results are shown in Table 3. At 280 kg carcass weight, Friesians had about 180 g/kg fat, 200 g/kg bone and 620 g/kg muscle. Corresponding proportions were 200 g/kg, 190 g/kg and 610 g/kg for Hereford crosses, 150 g/kg, 190 g/kg and 660 g/kg for Limousin crosses, 140 g/kg, 190 g/kg and 670 g/kg for Charolais crosses, and 130 g/kg, 190 g/kg and 680 g/kg for Belgian Blue crosses. Thus, at 280 kg carcass weight, muscle proportion ranged from 610 g/kg for Hereford crosses to 680 g/kg for Belgian Blue crosses. As carcass weight increased, proportion of fat increased and proportions of muscle and bone decreased. From 280 kg to 400 kg carcass weight, fat proportion increased by 90 g/kg and bone and muscle proportions decreased by 30 and 60 g/kg, respectively for Friesians. Corresponding changes were 110, 30 and 80 g/kg for Hereford crosses, 70, 30 and 40 g/kg Charolais crosses, and 70, 40 and 30 g/kg for Belgian Blue crosses.

The changes in fat and muscle proportions per 10 kg change in carcass weight are shown in Table 4. Rates of fat change varied from 8.2 g per 10 kg carcass weight for Hereford crosses to 5.5 g per 10 kg carcass weight for Belgian Blue crosses. Rates of muscle change were lower and varied from -6.3 for Hereford crosses to -2.4 for Belgian Blue crosses. Carcass weights at similar total carcass fatness (210 g/kg) ranged from 286 kg for Hereford crosses to 427 kg for Belgian Blue crosses. Compared with Friesians, Hereford crosses were about 30 kg carcass lighter, and MRI, Limousin, Simmental, Charolais, Blonde d'Aquitaine and Belgian Blue crosses were about 10, 40, 60, 90, 100 and 110 kg carcass heavier, respectively at the same carcass fat proportion. Muscle proportion at constant fatness was similar for Friesians, Hereford and MRI crosses, and was approximately 20, 30, 30, 40 and 50 g/kg higher for Simmental, Limousin, Blonde d'Aquitaine, Charolais and Belgian Blue crosses, respectively. Thus, even at constant carcass fatness there were differences in carcass muscle proportion with higher values for the continental crosses.

Carcass tissue distribution

As well as differing in the proportions of carcass tissues, breeds also differ in the distribution of tissues across the carcass, and this distribution changes with changes in carcass weight. The distribution of muscle in the main carcass joints for Friesian, Hereford × Friesian and Charolais × Friesian steers at three carcass muscle weights is shown in Table 5. The carcass weights at which these muscle weights occurred are also shown. At any muscle weight, Hereford crosses had a lower proportion of muscle in the hind limb and higher proportions in the flank and ribs than Friesians. Charolais crosses had a higher proportion of muscle in the hind limb and thorax and lower proportions in the flank and fore limb than both Friesians and Hereford crosses. Overall, the breeds did not differ greatly in the proportions of muscle in the fore- and hind-quarters. There were some differences in the proportions of muscle in the higher value joints with Charolais crosses having more than Friesians which in turn had more than Hereford crosses. This latter observation is of interest in the context of differences between the breed types in carcass conformation, a frequently presumed indicator of the proportion of carcass weight in the hind quarter and the proportion of total muscle in the higher value joints. Friesians which had poorer conformation than Hereford × Friesians had a higher proportion of higher value muscle. Across the breed types the proportion of higher value muscle decreased by 2.67 g per 10 kg increase in side muscle weight. While carcass conformation improved with increasing (muscle) weight, the proportion of higher value muscle declined, again indicating that conformation was not a reliable indicator of muscle distribution. In brief, while there were differences between the breeds in muscle distribution such differences were small. Late maturing cattle had a greater proportion of higher value muscle than Friesians, which in turn had a greater proportion than early maturing cattle. The proportion of muscle in the hind quarter and higher value joints decreased with increasing carcass and muscle weight.

Chemical composition of muscle

The chemical constituents of muscle are moisture, protein, lipid (intramuscular fat) and ash. As ash content is reasonably constant and usually accounts for only about 10 g/kg, it is generally not measured but assumed at 10 g/kg. The mean composition of muscle is about 720 g/kg moisture, 220 g/kg protein, 50 g/kg lipid and 10 g/kg ash. However, as shown in Table 6, the chemical composition of muscle varied between joints across the carcass. In general, protein proportion remained reasonably constant but lipid and moisture proportions varied inversely with each other. The hind limb and *m. longissimus* had the lowest lipid concentrations followed by the fore limb and loin. The flank and thorax had lipid values almost double those in the hind limb and *m. longissimus* and the ribs had the highest lipid concentration. This high value may reflect the practical difficulty of obtaining a complete separation of muscle and intermuscular fat in the ribs.

As with physical composition, chemical composition also varied with breed type and slaughter weight. The estimated mean chemical composition of the *m. longissimus* at three carcass weights is shown in Table 7 for the common breed types. Mean lipid concentration varied from a low of 16 g/kg for Blonde d’Aquitaine, Belgian Blue and Charolais cross steers at 280 kg carcass weight, to a high of 77 g/kg for Hereford cross steers at 400 kg carcass weight. Some continental crosses at 340 kg carcass weight had a similar lipid concentration to Hereford crosses at 280 kg carcass weight. Similarly, Charolais crosses at 400 kg carcass weight had a similar lipid concentration to Friesians at 280 kg carcass weight, while Belgian Blue and Blonde d’Aquitaine crosses at 400 kg carcass weight had a similar lipid concentration to Limousin crosses at 340 kg carcass weight. When compared with data in Tables 3 and 4, it is clear that the differences in carcass weight between breeds at similar muscle lipid concentration are less than at similar carcass fat proportion. In brief, Hereford crosses had the highest lipid concentration at any slaughter weight followed by MRI crosses and then Friesians. Of the continental crosses, the Limousin crosses had the highest lipid concentration followed in order by Simmental, Charolais, Blonde d’Aquitaine and Belgian Blue crosses.

Gender (Steers v. Heifers)

There have been few direct comparisons of carcass composition of steers and heifers in the same production system. In the past, heifers were discounted in price per unit carcass weight. The reasons for this had little to do with the respective real carcass value of the two genders. The price of steers was often influenced by market supports and by the prices prevailing on export markets, whereas there were few or no market supports for heifers which were predominantly traded on the domestic market.

However, heifer carcasses do grade poorer (higher fat class and/or poorer conformation class) than steer carcasses of the same breed type and age.

The data in Table 8 are from a comparison of Hereford × Friesian steers and heifers which were reared together from calf-hood to slaughter. The heifers were serially slaughtered to ensure they covered the same range of fatness as the steers. Slaughter groups of heifers and steers which had approximately the same carcass composition were compared. At the same carcass composition, steers were about 60 kg carcass weight heavier than heifers, and the carcass conformation of heifers was about a half class poorer than for steers with little difference in carcass fat class. The heifers had a higher proportion of higher value muscle than the steers. In brief, early maturing heifers and steers had similar proportions of carcass fat when the heifers were about 60 kg carcass lighter than the steers. The poorer carcass conformation of heifers did not indicate a lower carcass value per unit weight as it was accompanied by a slightly higher muscle proportion and a considerably higher proportion of higher value muscle.

Dairy breeds

There has been much criticism from beef interests of the move to Holsteins by dairy farmers. This is mainly because the Holsteins have inferior carcass conformation. As an alternative to the Holstein-Friesian, the MRI has been proposed as a more suitable dairy breed because of its better carcass conformation. Both the Holstein (Holstein × (Holstein × Friesian) and the MRI (MRI × Friesian) have been evaluated at Grange (Table 9). In agreement with much published work worldwide, the Grange experiments showed that even though Holsteins had considerably poorer carcass conformation than Friesians, there was little difference in carcass composition between the two strains. However, Holsteins did have a slightly lower proportion of higher value muscle.

In the comparison between Friesians and MRIs, the MRIs had superior carcass conformation (0.4 class) but there were no differences in the proportions of muscle or higher value muscle. Clearly therefore, these dairy breeds differed little in carcass composition and real carcass value despite the relatively large difference in carcass conformation class.

Carcass classification and composition

The main purposes of carcass classification are (a) to serve as a common language for the visual description of carcasses, (b) to facilitate price reporting and the administration of various EU support schemes, and (c) to provide a basis for differential pricing of carcasses. Developers and proponents of carcass classification schemes do not claim that such schemes necessarily differentiate between carcasses on the basis of muscle proportion, muscle distribution or muscle value.

From research both by the UK Meat and Livestock Commission (MLC) and at Grange it is clear that the relationship between carcass conformation and carcass composition depends on the mix of breed types involved. Some breed types have both good conformation and high meat yields while others have both poor conformation and low meat yields. In cattle populations comprised predominantly of these two types, there is a good relationship between carcass conformation and carcass composition (meat yield). In practice however, cattle populations are comprised of a wide range of breed types including those with reasonably good conformation but rather low meat yields, and those with relatively poor conformation but relatively high meat yields. Thus, any relationship between carcass conformation and meat yield depends on the relative proportions of these different breed types in the population. This is evident from an experiment that compared Friesian, Belgian Blue × Friesian and MRI × Friesian steers.

The data in Table 10 show a comparison by conformation class and breed type. Belgian Blue crosses were predominantly R class while Friesians were predominantly O class. Muscle proportions for these two conformation classes were 648 and 593 g/kg, respectively, and higher value muscle proportions were 404 and 394 g/kg, respectively. Thus, on the basis of this comparison (of predominantly R class Belgian Blue crosses and O class Friesians) it would be concluded that there were large differences between R and O conformation classes in carcass muscle proportion and proportion of higher value muscle.

Unlike Belgian Blue crosses and Friesians that fell into separate conformation classes, MRI crosses were fairly equally distributed between R and O conformation classes. There were essentially no differences between the R and O conformation class MRIs in carcass muscle proportion and while there was some difference in the proportion of higher value muscle, it seems to have been largely due to chance as the value for the Friesians (O conformation) was mid-way between the two MRI values. In brief therefore, when there were only Belgian Blue crosses and Friesians there were large differences in composition between the R and O conformation classes, but when there were only MRIs, there was little difference between these two conformation classes.

The proportions of muscle and of higher value muscle by fat class (for fat classes 3 and 4-) are shown in Table 11. On average, the difference between the two fat classes was 25 g/kg muscle and 2 g/kg higher value muscle. The proportion of higher value muscle would not be expected to be influenced by fat class. As with conformation there was a breed type effect. There was little difference in carcass composition between the MRI crosses and the Friesians in either fat class, but the Belgian Blue crosses had 46 g/kg extra muscle and 10 g/kg extra higher value muscle in fat class 3 than the mean of the MRI crosses and Friesians. The corresponding values for fat class 4- were 45 g/kg muscle and 6 g/kg higher value muscle. In brief, there was an effect of fat class on muscle proportion but the difference between breeds within a fat class was greater than the difference between fat classes.

The mean proportions of muscle and higher value muscle for four important classification cells (O3, 04-, R3, R4-) are shown in Table 12 for Friesian, MRI × Friesian and Belgian Blue × Friesian steers. Differences between the means were rather small but the ranges for the individual means were large and overlapped. For example, the muscle proportion in R4- ranged from 525 to 656 g/kg. This covered the entire range in O3 (555-621 g/kg), practically the entire range in O4- (521-632 g/kg) and most of the range in R3 (596-682 g/kg). Therefore, carcass classification did not effectively discriminate between carcasses on the basis of muscle proportion. There was also a large range in the proportion of higher value muscle. The range in class R4- (371-428 g/kg) covered the entire ranges found in R3 (378-420 g/kg) and O4- (373-421 g/kg) and most of the range in O3 (359-424 g/kg).

While these data strongly infer that carcass classification is an unreliable indicator of carcass composition, it is important to show the statistical evidence for this. Accordingly, the relevant elements of composition were regressed on carcass fat class and on carcass conformation class separately (Table 13). Both fat and muscle proportions were significantly related to carcass fat class. On average, fat proportion increased by 31 g/kg, and muscle proportion decreased by 25 g/kg, per unit increase in fat class. However, while these relationships were statistically significant, fat class accounted for only about one-third of the variance in fat proportion, and only one-half of the variance in muscle proportion.

Carcass conformation class was not significantly related to carcass fat proportion, carcass muscle proportion, higher value muscle proportion or muscle size (*m. longissimus* area). The only element of composition significantly related to carcass conformation class was bone proportion which decreased by 10 g/kg per unit increase in conformation class.

Conclusions

- Carcass weight as a proportion of empty body weight was 588, 594 and 602 g/kg for Friesians, Hereford × Friesians and Charolais × Friesian steers, respectively. Corresponding kill-out proportions (cold carcass weight as a proportion of unfasted final live weight) were 533, 543 and 553 g/kg. Kill-out proportion increased by about 10 g/kg per 100 kg increase in slaughter weight.

- As carcass weight increased, the proportions of bone and muscle decreased and the proportion of fat increased, but the rates of these changes differed amongst breed types.

- Compared with Friesians at 320 kg carcass weight, Hereford crosses were about 30 kg carcass lighter at the same carcass fat proportion. Corresponding differentials for MRI, Limousin, Simmental, Charolais, Blonde d'Aquitaine and Belgian Blue crosses were 10, 40, 60, 90, 100 and 110 kg carcass weight heavier.

- Breed types differed in carcass muscle distribution. Late maturing type cattle had a higher proportion of higher value muscle than Friesians and early maturing breed types, while Friesians had a higher proportion than the early maturing type notwithstanding the fact that the latter had better conformation.

- Mean muscle chemical composition was about 720 g/kg moisture, 220 g/kg protein, 50 g/kg lipid and 10 g/kg ash. Chemical composition varied between joints of the carcass, lipid concentration was lowest for the *m. longissimus*, hind limb and fore limb, and was highest for the flank, thorax and ribs.

- At any carcass weight, Hereford crosses had the highest muscle lipid concentration followed in order by MRI crosses, Friesians, Limousin, Simmental, Charolais, Blonde d'Aquitaine and Belgian Blue crosses. The differences in carcass weight between breeds at similar muscle lipid concentration were less than at similar carcass fat proportion.

- Early maturing breed type steers and heifers had similar proportions of carcass fat when the heifers were about 60 kg carcass lighter than the steers. Despite being about one half class poorer in conformation, heifers had a slightly higher muscle proportion and a considerably higher proportion of higher value muscle than steers. There were big differences in carcass conformation but little difference in carcass composition between Friesians, Holsteins and MRI crosses.

- The range in muscle proportion for classes O3, O4-, R3 and R4- was 555 to 621, 521 to 632, 596 to 682 and 525 to 656 g/kg, respectively. Carcass classification grade was a poor indicator of muscle proportion.

- Carcass fat class was related to both carcass fat and muscle proportions but accounted for only one third to one half of the variance in these. Carcass conformation class was not significantly related to carcass muscle proportion, fat proportion, higher value muscle proportion or muscle size but it was negatively related to bone proportion.

Table 1. Weights and proportions of non-carcass parts in three cattle genotypes.

Sire breed[a]	**Friesian**		**Hereford**		**Charolais**	
	kg	**g/kg**	**kg**	**g/kg**	**kg**	**g/kg**
Slaughter weight	570	1000	561	1000	586	1000
Transport loss	23	40	22	40	23	39
Rumen contents	40	70	36	63	35	60
Empty body	507	890	503	897	528	901
g/kg Empty body weight (EBW)						
Gastro-intestinal tract	56	110	50	99	56	106
Hide	35	69	42	84	38	72
Head	17	34	17	34	18	34
Feet	11	21	11	21	12	23
Lungs + heart	10	20	9	18	9	17
Liver + kidneys	8	17	8	16	7	14
Kidney + channel fat	17	34	15	30	14	27
Caul fat	13	25	12	24	11	21
Cod + topside fats	5	9	4	8	4	7
Trim	5	10	6	12	6	11
Blood + miscellaneous	26	52	24	48	28	53
Chill loss	6	11	6	12	7	13
Total parts	209	412	204	406	210	398
Cold carcass	298	533[b]	299	543[b]	318	553[b]
Cold carcass (g/kg EBW)		588		594		602

[a] Mated to Friesian cows; [b] g/kg Slaughter weight

Table 2. Kill-out proportion of three cattle genotype by slaughter weight.

Sire breed[a]	**Friesian**			**Hereford**			**Charolais**		
Slaughter weight (kg)	565	670	775	560	665	770	560	665	770
Empty body weight (kg)	500	600	700	500	600	700	500	600	700
Carcass weight (kg)	297	359	422	301	365	430	305	370	435
Kill-out (g/kg)[b]	526	536	545	538	549	558	545	556	565
Kill-out (g/kg)[c]	594	598	603	602	608	614	610	616	621

[a]Mated to Friesian cows; [b]g/kg Slaughter weight; [c]g/kg Empty body weight

Table 3. Carcass composition (g/kg) of different cattle genotypes by carcass weight.

Carcass weight (kg)	**280**				**340**				**400**			
Tissue	**Sub. Fat[a]**	**IM. Fat[b]**	**Bone**	**Muscle**	**Sub. Fat[a]**	**IM. Fat[b]**	**Bone**	**Muscle**	**Sub. Fat[a]**	**IM. Fat[b]**	**Bone**	**Muscle**
Sire breed[c]												
Friesian	77	104	199	620	102	123	183	592	130	138	168	564
Hereford	91	114	188	607	121	134	175	570	155	150	164	531
MRI	76	102	199	623	98	120	180	602	123	135	165	577
Limousin	65	90	188	657	86	109	169	636	109	126	150	615
Blonde d’Aquitaine	53	74	199	674	72	90	183	655	92	105	167	636
Simmental	61	87	197	655	82	104	181	633	105	119	167	609
Belgian Blue	53	76	189	682	71	91	170	668	89	106	152	653
Charolais	55	80	191	674	74	96	173	657	95	110	155	640

[a] Subcutaneous fat; [b] Intermuscular fat; [c] Mated to Friesian cows

Table 4. Rate of change in proportions of fat and muscle together with carcass weight and muscle proportion at constant (210 g/kg) fat proportion for different cattle genotypes.

	Rate of change[a]		**Carcass weight (kg)**[b]	**Muscle (g/kg)**[b]
Tissue	**Fat**	**Muscle**		
Sire breed[c]				
Friesian	7.25	-4.67	320	601
Hereford	8.33	-6.33	286	603
MRI	6.67	-3.83	328	605
Limousin	6.67	-3.50	363	628
Blonde d'Aquitaine	5.83	-3.17	422	629
Simmental	6.33	-3.83	378	618
Belgian Blue	5.50	-2.42	427	646
Charolais	5.83	-2.83	409	638

[a] g/10 kg carcass weight; [b] At 210 g/kg carcass fat; [c] Mated to Friesian cows.

Table 5. Distribution of carcass muscle (g/kg) for three cattle genotypes by muscle weight.

Muscle weight	**180 kg**			**210 kg**			**240 kg**		
Sire breed[a]	**FR**	**HF**	**CH**	**FR**	**HF**	**CH**	**FR**	**HF**	**CH**
Carcass joint									
Hind limb	307	302	311	299	294	302	292	288	296
Loin	61	62	61	60	61	61	60	60	60
Flank	55	58	51	56	59	53	57	60	54
Ribs	52	55	52	54	57	54	55	59	55
Thorax	390	389	394	397	396	401	403	402	407
Fore limb	135	134	131	134	133	129	133	131	128
Hind quarter	423	422	423	415	414	416	409	408	410
Fore quarter	577	578	577	585	586	584	591	592	590
Higher value muscle[b]	368	364	372	359	355	363	352	348	356
Carcass weight (kg)[c]	290	297	267	355	368	320	425	452	375

[a] Mated to Friesian cows; [b] Muscle in hind limb + loin; [c] At which the respective muscle weights occur;

FR = Friesian, HF = Hereford, CH = Charolais

Table 6. Mean chemical composition (g/kg) of muscle[a] from different carcass joints.

	Moisture	**Protein**	**Lipid**
Carcass joint			
Hind limb	728	225	37
Loin	721	223	46
M. longissimus	726	228	36
Fore limb	726	222	42
Flank	710	218	62
Thorax	712	214	64
Ribs	686	207	97

[a] Of steer progeny of Friesian, Hereford and Charolais sires mated to Friesian cows

Table 7. Mean chemical composition (g/kg) of *m. longissimus* for cattle of different genotypes by carcass weight.

Carcass weight	**280 kg**			**340 kg**			**400 kg**		
Constituent	**Moisture**	**Protein**	**Lipid**	**Moisture**	**Protein**	**Lipid**	**Moisture**	**Protein**	**Lipid**
Sire breed[a]									
Friesian	745	223	22	728	221	43	707	215	67
Hereford	743	221	26	722	218	50	703	210	77
MRI	745	223	22	724	220	46	704	213	73
Limousin	746	224	20	734	221	35	719	218	53
Blonde d'Aquitaine	748	226	16	742	223	25	734	219	37
Simmental	747	225	18	738	222	30	727	218	45
Belgian Blue	748	226	16	742	223	25	734	219	37
Charolais	748	226	16	740	222	28	729	218	43

[a] Mated to Friesian cows

Table 8. Comparative carcass traits of steers and heifers

	Steers	**Heifers**
Carcass weight (kg)	326	267
Carcass conformation class[a]	3.1	2.7
Carcass fat class[b]	3.8	3.7
Carcass composition (g/kg)		
Bone	164	169
Muscle	623	627
Fat	213	204
Higher value muscle[c]	382	392

[a] Scale 1 (poorest) to 5 (best); [b] Scale 1 (leanest) to 5 (fattest); [c] g/kg muscle

Table 9. Carcass traits of Friesian, Holstein and Meuse-Rhine-Issel (MRI) steers.

	Friesian	**Holstein**[a]	**MRI**[b]
Slaughter weight (kg)	590	595	603
Carcass weight (kg)	311	310	327
Kill-out (g/kg)	527	521	542
Carcass conformation class[c]	2.21	1.97	2.61
Carcass fat class[d]	3.39	3.23	3.46
Carcass composition (g/kg)			
Fat	200	195	195
Muscle	600	598	604
Higher value muscle[e]	395	389	396

[a] Holstein × (Holstein × Friesian); [b] MRI × Friesian; [c] Scale 1 (poorest) to 5 (best); [d] Scale 1 (leanest) to 5 (fattest); [e] g/kg muscle

Table 10. Proportions of muscle and higher value muscle by carcass conformation class and genotype.

Carcass conformation class	**R**		**O**	
Genotype	**Belgian Blue**	**MRI**	**MRI**	**Friesian**
No. carcasses	26	16	13	24
Muscle (g/kg carcass)	648	604	589	593
Higher value muscle[a]	404	398	390	394

[a] g/kg muscle

Table 11. Proportions of muscle and higher value muscle by carcass fat class and genotype.

Carcass fat class	**3**			**4-**		
Genotype	**Belgian Blue**	**MRI**	**Friesian**	**Belgian Blue**	**MRI**	**Friesian**
No. carcasses	20	15	17	7	14	11
Muscle (g/kg carcass)	652	610	601	626	584	578
Higher value muscle[a]	405	395	395	400	393	395

[a] g/kg muscle

Table 12. Proportions of muscle and high value muscle by conformation and fat class.

Carcass conformation class	**O**		**R**	
Carcass fat class	**3**	**4-**	**3**	**4-**
No. carcasses	26	12	26	20
Muscle[a] - mean	596	581	625	597
- range	555-621	521-632	596-682	525-656
Higher value muscle[b] - mean	393	392	405	397
- range	359-424	373-421	378-420	371-428

[a] g/kg carcass; [b] g/kg muscle

Table 13. Regressions of carcass composition variables on carcass fat class and carcass conformation class.

	Fat class			Conformation class		
	b[a]	**s.e.**	**R^2**[b]	**b**[a]	**s.e.**	**R^2**[b]
Variable						
Fat (g/kg)	30.7	9.35	0.33	8.0	10.50	0.18
Muscle (g/kg)	-25.2	7.19	0.54	2.1	8.26	0.37
Bone (g/kg)				-10.2	3.68	0.15
Higher value muscle				3.2	3.20	0.07
L. dorsi area (cm^2)				46.2	23.2	0.32

[a] Linear regression coefficient; [b] Proportion of variance accounted for.