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Effects of feeding management and breed type on muscle chemical composition and relationships between carcass and muscle compositional traits in steers

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There is little published information on the chemical composition of muscle from beef steers produced in Irish production systems. The objective of this study was to determine the effects of feeding management and breed type on *m. longissimus* chemical composition of steers, and to examine relationships between selected carcass traits and measures of carcass and muscle composition. A total of 117 steers (65 Friesians and 52 Charolais × Friesians) were assigned on weight within breed type to a pre-experimental slaughter group and to one of 12 finishing groups (6 feeding treatments by 2 finishing periods). The 6 feeding treatments were: (1) silage only offered *ad libitum* (SO), (2) and (3) SO plus a low concentrate level, (4) and (5) SO plus a high concentrate level, (6) concentrates *ad libitum*. In Treatments 2 and 4, the silage and concentrates were offered separately whereas in Treatments 3 and 5 they were offered as a total mixed ration (TMR). The two finishing periods were 105 and 175 days. Mean low, high and *ad libitum* concentrate levels were proportionately 0.415, 0.732 and 0.927, respectively, of daily dry matter intake. Carcass weight, fat depth, fat proportion in the rib joint and *m. longissimus* lipid concentration all increased ($P < 0.01$) asymptotically with increasing concentrate level. Carcass fat class ($P < 0.07$), perinephric plus retroperitoneal fat weight ($P < 0.001$), fat depth ($P < 0.06$), fat proportion in the rib joint ($P < 0.001$) and *m. longissimus* lipid concentration ($P < 0.001$) were higher for Friesians than for Charolais crosses. Carcass weight increased ($P < 0.001$) with increased duration of the finishing period, as did carcass fat class ($P < 0.06$), fat proportion in the rib joint ($P < 0.001$) and *m. longissimus* lipid concentration ($P < 0.001$). Method of feeding had no effect on any of the traits measured.

Keywords: breed, cattle, feeding, finishing, muscle composition

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Introduction

The effects and importance of feeding level, method of feeding (feeds offered as discrete ingredients or as a total mixed ration (TMR)) and duration of the finishing period have recently been reported for Irish beef production systems (Caplis *et al*., 2005; Keane, Drennan and Moloney, 2006) but data on muscle chemical composition were not included. A knowledge of the chemical composition of muscle is important in assessing its nutritive value and its role in the human diet. If the fat concentration is too high it may predispose to cardiovascular disease (Kijora *et al*., 2004) but if it is too low organoleptic properties, which are associated with the proportion of fat, may be impaired (Romans, Tuma and Tucker, 1965).

It is widely accepted that the chemical composition of carcass tissues is related to the proportions of these tissues in the carcass, but the relationships may vary with feeding level, breed type or slaughter end point. Some reports suggest that when the plane of nutrition is altered the growth of fat is altered to a greater extent than that of other tissues (Geay and Robelin, 1979; Robelin and Daenicke, 1980), but other reports argue that any effects of nutrition are largely a reflection of its effects on carcass weight (Prior *et al*., 1977; Fortin *et al*., 1980). The possibility that nutritional effects are mediated through carcass weight is not supported by the findings of Binder *et al.* (1986) or Thenard *et al.* (2006). The former observed that at similar carcass weights, all measures of fatness were higher for animals fed a grain rather than a forage diet while Thenard *et al.* (2006) reported that steers on a predominantly forage system had lower levels of fatness, even though they had heavier carcasses, than steers on more intensive systems. As it is not always possible or practical to slaughter cattle from different feeding or production systems at the same carcass weight, it is best to use serial slaughter when studying the carcass and tissue growth patterns of various breed types in different production systems (Berg, Andersen and Liboriussen, 1978; Jones, Price and Berg, 1978a,b).

Interactions between feeding level and breed type for carcass fatness traits have been reported. Fortin *et al.* (1981) observed a difference between Holstein and Angus cattle for the effects of feed energy level on fat distribution; Angus cattle had more internal and intramuscular fat at the higher, but not at the lower, energy intake. Similarly, Thenard *et al.* (2006) observed differences between Montbeliarde and Holstein steers on different production systems. Holstein steers had a significantly lower muscle lipid concentration on an extensive than on an intensive production system whereas there was no effect in Montbeliarde steers.

Measurement of both carcass composition and muscle chemical composition are costly and involve a time delay after slaughter. Accordingly, it would be of considerable practical benefit if important carcass and tissue compositional traits could be predicted from routinely recorded slaughter traits, such as carcass weight and carcass fat class. Relationships between compositional traits and carcass weight would likely only apply within breed because of the differences between breeds in the relative growth rates of carcass tissues (Keane *et al*., 1990). Relationships between carcass fat class and muscle lipid concentration might apply across breeds however, because there are only minor differences between breeds in the growth coefficients for the different fat depots (Fortin *et al*., 1981).

The objectives of this study were (i) to determine the effects of feeding level (varying concentrate and grass silage proportions), feeding method (feeds offered

separately or as a total mixed ration (TMR)), breed type (Friesian or Charolais × Friesian) and duration of the finishing period on *m. longissimus* chemical composition of steers, (ii) to describe the relationships between carcass weight and carcass fat class, which are routinely measured at slaughter, and carcass and muscle composition, which are costly to measure and involve a time delay, and (iii) to describe the relationships between *m. longissimus* lipid concentration and *m. longissimus* moisture and protein concentrations with a view to predicting *m. longissimus* composition from measurement of lipid concentration.

Materials and Methods

The experiment from which the present data were derived has been described previously (Keane *et al*., 2006). Briefly 65 Friesian (FR) and 52 Charolais × Friesian (CH) 19-month-old finishing steers, which had been managed together from shortly after birth, were assigned on live weight within breed type, to a pre-experimental slaughter group or to one of 12 finishing groups. The pre-experimental group was slaughtered the following day. The 12 finishing groups were assigned in a 6 × 2 factorial design to 6 feeding treatments × 2 durations of finishing. The 6 feeding treatments were designed to cover the entire range of concentrate to silage ratios from zero to *ad libitum* concentrates. The treatments were:

1. Grass silage only, offered *ad libitum* (SO).
2. SO plus a low level of supplementary concentrates offered separately (LS).
3. SO plus a low level of supplementary concentrates offered as a TMR (LM).
4. SO plus a high level of supplementary concentrates offered separately (HS).
5. SO plus a high level of supplementary concentrates offered as a TMR (HM).
6. Concentrates offered *ad libitum* with restricted silage (AL).

The two durations of finishing were 105 (S) and 175 (L) days.

The concentrate composition (kg/t) was: rolled barley 870, soya bean meal 67.5, molasses 47.5 and mineral/vitamin premix 15. The DM concentration of the silage was 198 g/kg and the mean composition (g/kg) of the silage DM was crude protein 143 and *in vitro* digestibility 698. The pH was 3.9.

Target low, high and *ad libitum* concentrate proportions were 0.375, 0.750 and 0.900 of daily dry matter (DM) intake, respectively. The corresponding actual proportions were 0.415, 0.732 and 0.927.

After slaughter, cold carcass weight was estimated as 0.98 of hot carcass weight. Carcasses were graded for conformation and fatness (Commission of the European Communities, 1982), and perinephric plus retroperitoneal fat weight was recorded. The right side of each carcass was quartered at the 10^{th} rib and fat depth was measured. A rib joint (ribs 6 to 10) was removed and separated into subcutaneous fat, intermuscular fat, *m. longissimus*, other muscle and bone (including *ligamentum nuchae*). A sample of *m. longissimus* was frozen and later chemically analysed for the concentration of moisture, protein and lipid. Lipid and moisture concentrations were determined using an integrated microwave moisture and methylene chloride fat extraction method (Bostian *et al*., 1985) on a CEM moisture/solids analyser. Protein concentration was determined by the method of Sweeney and Rexroad (1987) using a LECO protein analyser.

Statistical analysis

The data were statistically analysed using the general linear model procedure of the Statistical Analysis Systems Institute (SAS, 1996). The initial model had terms for block, feeding treatment, breed, duration of finishing period and all relevant interactions. As none of the interactions were significant for the data reported here, the final model had terms for block, feeding treatment, breed and duration of finishing only. The differences among the feeding treatments were partitioned, using orthogonal contrasts, into the linear, quadratic and cubic effects of concentrate level, the effect of feeding method (separate feeds or TMR) and the interaction between feeding method and level of concentrates. As the cubic effect of concentrate level was not significant it is not reported. Using the data from the pre-slaughter group and the 6 finished groups, rib joint tissue proportions and muscle chemical constituents were linearly regressed on carcass weight and on carcass fat class both within breed and overall. Muscle moisture and protein concentrations were linearly regressed on muscle lipid concentration. The data are presented as means for the pre-slaughter group, the six feeding treatments, the two breed types and the two finishing periods with significance levels indicated. The linear regressions are presented for the overall data set and for the two breed types separately.

Results

Selected slaughter and rib joint compositional traits, together with *m. longissimus* chemical composition are shown in Table 1. Initial live weight was similar for the pre-slaughter group, the six feeding treatment groups and the two finishing period groups, but CH were heavier ($P < 0.001$) than FR. At slaughter, L was heavier ($P < 0.001$) than S as designed. There were significant ($P < 0.001$) linear and quadratic effects of concentrate level on slaughter weight but there were no significant effects of feeding method or breed type and there was no evidence for any interaction between feeding method and level of concentrates for any trait. There was a significant ($P < 0.001$) linear effect of concentrate level on kill-out proportion which was greater ($P < 0.001$) for CH than FR, and for L than S. Both the linear and quadratic effects of concentrate level were significant ($P < 0.001$) for carcass weight, which was greater ($P < 0.001$) for CH than FR, and for L than S. There was no effect of feeding method on carcass weight.

Carcass fat class, perinephric plus retroperitoneal fat weight, and fat depth all increased ($P < 0.001$) asymptotically with increasing concentrate level. The breed type ($P < 0.07$) and duration of finishing ($P < 0.06$) effects on carcass fat class were close to significance but there was no method of feeding effect. There were significant ($P < 0.01$) linear and quadratic effects of concentrate level on the total fat and bone proportions in the rib joint, and a significant ($P < 0.05$) linear effect on total muscle proportion. The breed type effect was significant ($P < 0.001$) for total fat, muscle and bone proportions and the duration of finishing effect was significant ($P < 0.001$) for total fat and muscle proportions. Concentrate level had significant linear ($P < 0.001$) and quadratic ($P < 0.05$) effects on moisture, protein and lipid concentrations in the *m. longissimus*. There were also breed type and duration of finishing effects for moisture and lipid concentrations, with moisture concentration higher ($P < 0.001$) and lipid concentration lower ($P < 0.001$) for CH than FR, and for S than L.

Regressions of selected variables on carcass weight, carcass fat class and

Table 1. Effects of feeding treatment, breed type and duration of finishing on slaughter traits, rib joint composition, and *m. longissimus* chemical composition of finishing steers

Variable	Pre-experimental group	Feeding treatment[1] (F)						Breed type[2] (B)		Duration of finishing[3] (D)		s.e.[4]	Significance[5]				
		SO	LS	LM	HS	HM	AL	FR	CH	S	L		F	B	D	Lin[6]	Q[6]
Initial weight (kg)	477 (37.1)[7]	476	476	476	476	476	476	466	486	475	478	6.3		***			
Slaughter weight (kg)	477 (37.1)	506	601	605	630	626	641	601	602	577	626	9.1	***		***	***	***
Kill-out (g/kg)	506 (15.3)	510	520	523	529	526	536	504	543	515	532	4.2	***	***	***	***	
Carcass weight (kg)	241.4 (24.5)	258.5	312.5	316.5	332.5	328.8	343.7	303.2	327.6	297.4	333.4	4.93	***	***	***	***	***
Conformation class[8]	2.04 (0.320)	2.02	2.25	2.34	2.47	2.43	2.78	1.97	2.80	2.42	2.35	0.088	***	***		***	
Fat class[9]	1.92 (0.419)	2.78	3.51	3.54	3.62	3.59	3.70	3.37	3.54	3.37	3.54	0.106	***	<0.07	<0.06	***	***
Perinephric + retro-peritoneal fat (kg)	3.9 (3.05)	6.4	12.1	12.3	12.0	12.4	12.5	12.7	9.9	9.5	13.5	0.83	***	***	***	***	***
Fat depth (mm)	2.1 (2.11)	4.9	9.1	9.7	10.4	10.6	11.3	8.9	9.8	8.3	10.3	0.61	***	<0.06	***	***	***
Composition of rib joint (g/kg)																	
Subcutaneous fat	41 (12.2)	33	56	55	61	64	63	52	59	54	57	3.7	***	*		***	***
Intermuscular fat	108 (28.0)	129	153	160	176	179	182	180	146	146	181	7.6	***	***	***	**	<0.08
Total fat	150 (31.0)	163	209	216	237	242	245	232	205	199	238	9.1	***	***	***	***	**
M. longissimus	181 (15.9)	208	192	198	196	197	202	185	212	204	194	4.9		***	*		*
Other muscle	449 (24.6)	401	393	386	376	372	369	375	391	395	371	6.6	**	**	***	*	
Total muscle	630 (29.3)	609	584	584	572	569	571	560	603	599	565	8.0	**	***	***	*	
Bone	221 (16.1)	228	207	201	190	189	184	208	192	202	198	4.2	***	***		***	**
Composition of *m. longissimus* (g/kg)																	
Moisture	757 (8.6)	752	731	727	724	720	721	724	734	738	721	3.2	***	***	***	***	***
Protein	226 (4.7)	220	228	227	227	229	229	225	228	226	227	1.6	**	<0.08		**	*
Lipid	10 (9.7)	19	33	39	41	43	42	42	30	28	44	3.9	***	***	***	**	**

[1] SO = silage only, LS/LM = Low concentrates + silage fed separately (S) or mixed (M), HS/HM = High concentrates + silage fed separately (S) or mixed (M), AL = concentrates *ad libitum*.
[2] FR = Friesian, CH = Charolais × Friesian.
[3] S = 105 days, L = 175 days.
[4] For feeding treatments (n = 18).
[5] There was no significant effects of method of feeding (separate *v* mixed) and no significant interactions.
[6] Lin, Q = linear and quadratic effects of concentrate level, respectively.
[7] s.d.
[8] EU Beef Carcass Classification Scheme – scale 1 = P (poorest) to 5 = E (best).
[9] EU Beef Carcass Classification Scheme – scale 1 (leanest) to 5 (fattest).

m. longissimus lipid concentration for the breed types separately and overall are shown in Table 2. While most relationships were highly significant, the corresponding R^2 values tended to be low. For the overall data set, carcass weight was moderately predictive of kill-out proportion, carcass conformation class, carcass fat class and perinephric plus retroperitoneal fat weight. Fatness traits were more closely related to carcass weight for FR than for CH but the opposite was observed for kill-out proportion. Carcass weight was generally a better predictor of rib joint composition for FR than for CH, and *m. longissimus* composition, particularly moisture and lipid concentrations, were more closely related to carcass weight for FR than for CH.

Carcass fat class was a better predictor of perinephric plus retroperitoneal fat weight, the proportions of fat, muscle and bone in the rib joint, and of *m. longissimus* moisture concentration, for FR than CH. However, it was a better predictor of *m. longissimus* lipid concentration for CH. *M. longissimus* lipid concentration was closely related to *m. longissimus* moisture concentration for both breed types and overall, but *m. longissimus* lipid concentration was poorly related to protein concentration.

Discussion

The present results are best evaluated alongside those published previously (Keane *et al*., 2006). The similarity in kill-out proportion for the pre-slaughter and silage only groups would have been expected from the low live-weight gains of the latter during the finishing period, as kill-out proportion is low when feeding level and growth rate are low (Kempster, 1992). However, other than subcutaneous fat which was similar, all measures of fatness were higher for the silage only group than for the pre-slaughter group indicating that some fat deposition occurs even at a low rate of gain.

As CH were heavier than the FR initially, and usually grow faster (More O'Ferrall and Keane, 1990; McGee *et al*., 2005), a difference in slaughter weight would be expected. However, higher finishing gains for Friesians compared with Charolais crosses have been observed previously (Keane, 1998). Despite the similar slaughter weights for the two breed types, CH had heavier carcasses due to their higher kill-out proportion. This superiority of CH for kill-out proportion supports earlier findings (More O'Ferrall and Keane, 1990; McGee *et al*., 2005).

The tendency towards a higher carcass fat class and greater fat depth in CH is contrary to reports in the literature (More O'Ferrall and Keane, 1990; McGee *et al*., 2005), but the lower perinephric plus retroperitoneal fat weight of CH is in agreement with previous results (More O'Ferrall and Keane, 1990; Keane, 1998; McGee *et al*., 2005). The lower fat and bone proportions and greater muscle proportion in the rib joint of CH are also in agreement with previous findings (More O'Ferrall and Keane, 1990; Keane, 1998; McGee *et al*., 2005).

The increase in muscle moisture concentration and the decrease in lipid concentration with increasing feeding level has been reported previously (Robelin and Daenicke, 1980), as has the negligible effect of feeding level on muscle protein concentration (Keane *et al*., 1991). Taken together with the negligible effects of breed type and duration of finishing on protein concentration, the data indicate that muscle protein concentration is largely unaffected by production factors such as nutrition level, breed type and slaughter weight. The absence of a breed effect on muscle protein concentration,

Table 2. Regressions (y = a + bX) of carcass traits, rib joint tissue proportions and *m. longissimus* chemical constituents on carcass weight, carcass fat class and *m. longissimus* lipid proportion

Dependent variable (y)	All data				Friesians only				Charolais × Friesians only			
	Intercept	Regression coefficient	Adjusted R^2	Sig.	Intercept	Regression coefficient	Adj R^2	Sig.	Intercept	Regression coefficient	Adj R^2	Sig.
					Independent variable(X) = Carcass weight (kg)							
Kill-out (g/kg)	407 (14.0)[1]	0.37 (0.045)	0.36	***	434 (14.60)	0.23 (0.049)	0.26	***	433 (16.4)	0.33 (0.051)	0.45	***
Conformation class[2]	0.32 (0.325)	0.0064 (0.0010)	0.24	***	0.95 (0.225)	0.0034 (0.0007)	0.23	***	0.93 (0.474)	0.006 (0.0015)	0.21	***
Fat class[2]	0.47 (0.355)	0.0093 (0.0011)	0.36	***	−1.11 (0.467)	0.015 (0.0016)	0.58	***	1.92 (0.501)	0.005 (0.0016)	0.14	***
Perinephric + retro-peritoneal fat (kg)	−6.7 (2.71)	0.057 (0.0087)	0.27	***	−15.4 (3.73)	0.092 (0.0124)	0.46	***	−5.7 (2.95)	0.048 (0.0091)	0.34	***
Total fat[3] (g/kg)	18.7 (29.30)	0.64 (0.094)	0.28	***	−76.7 (35.97)	1.02 (0.119)	0.53	***	39.8 (40.35)	0.51 (0.125)	0.24	***
Total muscle[3] (g/kg)	660 (28.2)	−0.26 (0.091)	0.06	**	721 (31.9)	−0.53 (0.106)	0.27	***	685 (38.8)	−0.26 (0.120)	0.07	*
Total bone[3] (g/kg)	322 (11.3)	−0.39 (0.036)	0.49	***	356 (16.1)	−0.49 (0.054)	0.56	***	275 (14.8)	−0.25 (0.046)	0.37	***
Moisture[4] (g/kg)	812 (10.9)	−0.26 (0.035)	0.32	***	844 (13.9)	−0.39 (0.046)	0.53	***	811 (13.6)	−0.23 (0.042)	0.37	***
Protein[4] (g/kg)	213 (4.6)	0.04 (0.015)	0.06	**	216 (7.4)	0.03 (0.025)	0.008		210 (5.9)	0.05 (0.018)	0.13	**
Lipid[4] (g/kg)	−33 (11.9)	0.22 (0.038)	0.22	***	−67 (16.2)	0.36 (0.054)	0.40	***	−29 (14.6)	0.18 (0.045)	0.23	***
					Independent variable (X) = Fat class							
Perinephric + retropertoneal fat (kg)	−0.06 (1.997)	3.30 (0.589)	0.21	***	−1.20 (2.505)	4.09 (0.724)	0.33	***	0.55 (3.041)	2.60 (0.875)	0.13	**
Total fat[3] (g/kg)	60 (19.7)	46.8 (5.81)	0.36	***	62 (21.9)	50.6 (6.60)	0.48	***	36 (34.5)	48.8 (9.93)	0.31	***
Total muscle[3] (g/kg)	667 (19.0)	−25.7 (5.62)	0.15	***	654 (18.4)	−27.9 (5.53)	0.28	***	723 (32.1)	−35.2 (9.25)	0.21	***
Total bone[3] (g/kg)	273 (9.1)	−21.1 (2.68)	0.34	***	284 (10.5)	−22.7 (3.17)	0.44	***	241 (15.6)	−13.6 (4.48)	0.14	**
Moisture[4] (g/kg)	780 (8.2)	−14.7 (2.43)	0.24	***	783 (9.3)	−17.4 (2.80)	0.37	***	781 (14.2)	−13.0 (4.10)	0.15	**
Protein[4] (g/kg)	220 (3.32)	1.9 (0.978)	0.02	*	217 (4.7)	2.5 (1.26)	0.04	*	226 (5.7)	0.30 (1.649)	0.12	
Lipid[4] (g/kg)	−6 (8.76)	12.4 (2.58)	0.16	***	−8 (10.6)	14.6 (3.18)	0.24	***	−18 (8.2)	0.23 (0.039)	0.40	***
					Independent variable (X) = Lipid[4] (g/kg)							
Moisture[4] (g/kg)	763 (1.33)	−0.92 (0.033)	0.87	***	763 (1.92)	−0.91 (0.042)	0.88	***	765 (1.93)	−0.95 (0.057)	0.85	***
Protein[4] (g/kg)	229 (1.29)	−0.08 (0.032)	0.04	*	230 (1.92)	−0.104 (0.043)	0.07	**	227 (1.81)	−0.03 (0.053)	0.02	

[1] s.e.
[2] See footnotes to Table 1.
[3] In rib joint.
[4] In *m. longissimus*.

and the higher moisture concentration in CH, are in agreement with previous findings (Keane *et al*., 1991), while the lower lipid concentration for CH has also been reported previously (Keane *et al.*, 2001). The effect of the longer finishing period on muscle lipid concentration supports the findings of Hessle, Nadeau and Johnsson (2006) in that animals finished for longer had higher marbling. Generally, the changes in *m. longissimus* chemical composition observed here support the conclusions of Robelin and Tulloh (1992) who stated that after a certain live weight, the protein concentration of muscle remains relatively stable whereas the lipid concentration increases and the moisture concentration decreases with increasing weight.

The rather poor relationship between carcass weight and kill-out proportion, even within breed type, may have been due to differences in gut contents and inaccuracies in the measurement of slaughter weight, one of the components of kill-out proportion. Kempster (1992) drew attention to the possibility of such inaccuracies arising from variation among individuals in the diurnal pattern of defecation. This is exacerbated when there are large differences between feeding levels and feed types as in the present study. Relationships involving carcass conformation and fat class were probably affected by the relatively narrow ranges of these in the data set. The overwhelming majority of carcasses fell into two conformation classes (O and R, numerical values 2 and 3), and into the fat classes 3 and 4L (numerical values 3.0 and 3.7). The fact that the majority of carcasses were contained in two fat classes and two conformation classes, and that in each case one of the two classes accounted for a very high proportion of the carcasses, means that correlations between these traits and continuously distributed traits (like carcass weight) will be low.

Since the relationship between carcass weight and composition differs with breed (Geay and Robelin, 1979), the different regression coefficients for rib joint tissue proportions on carcass weight for the two breed types would be expected. As carcass weight was a better predictor of fat and bone proportions than of muscle proportion, it appears that when predicting rib joint composition, and ultimately carcass composition (Moloney and Keane, 2001), from carcass weight, it would seem preferable to predict fat and bone proportions from the regression equations and then estimate muscle proportion by difference. It is not surprising that *m. longissimus* protein concentration was poorly related to carcass weight given that protein concentration of muscle is relatively stable above a certain live weight (Robelin and Tulloh, 1992). The closer relationships between carcass weight and *m. longissimus* moisture and lipid concentrations within breeds than overall is due to the fact that relationships between weight and tissue composition differ with breed type (Robelin and Tulloh, 1992).

While most of the relationships presented were highly significant statistically only a few are likely to be useful in predicting carcass classification or compositional traits from carcass weight or carcass fat class. For Friesians, carcass weight predicted carcass fat class, rib joint fat and bone proportions, and *m. longissimus* moisture and lipid concentrations with reasonable precision. For Charolais crosses, the only trait predicted from carcass weight with reasonable precision was kill-out proportion. The probable reason for the better relationships between carcass weight and fat variables in Friesians was their greater range in fatness.

The close relationship between *m. longissimus* lipid and moisture concentrations, both within breeds and overall, suggests

that for practical purposes, measurement of one or other of these should be sufficient to estimate chemical composition of muscle. As ash concentration is low and stable, and protein concentration is also relatively stable, and all constituents must sum to 1000 g/kg, measurement of either moisture or lipid would permit estimation of the others.

It is concluded that at similar slaughter weights, Charolais crosses had a higher kill-out proportion and carcass weight than Friesians. They also had better carcass conformation, had higher muscle and lower fat and bone proportions in the ribs joint, and had higher moisture and lower lipid in *m. longissimus*. *M. longissimus* moisture concentration decreased and lipid concentration increased with increasing concentrate level and length of finishing period. Relationships of carcass weight and carcass fat class with composition of the rib joint were better for Friesians than for Charolais crosses.

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