The use of double-muscled cattle breeds in terminal crosses: Animal performance and blood metabolites

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Seoane, J. R., Lapierre, H. and Roy, G. L. 1999. **The use of double-muscled cattle breeds in terminal crosses: Animal performance and blood metabolites.** Can. J. Anim. Sci. **79**: 293–299. Eighty-nine calves born of dams from British (50% Hereford and 50% Red Angus) and Continental (50% Simmental and 50% Maine Anjou) breeds crossed with Charolais (CH), Belgian Blue (BB) and Piedmontese (PM) sires were used to evaluate the productivity of using double-muscled cattle in terminal crosses. Breed of sire did not exert a significant effect on any parameter measured before weaning. Calving difficulty was related to breed of dam, being higher in British than in Continental dams ($P < 0.05$) and tended to be higher for male than for female calves ($P < 0.10$). Average daily gains to weaning and weight corrected at 200 d were higher for male than for female calves ($P < 0.05$), and for calves from Continental dams than for those from British dams ($P < 0.05$). Average daily gain during backgrounding was higher for CH than for PM-sired calves ($P < 0.05$). Also, ADG in feedlot (backgrounding + fattening) was higher for male than for female calves ($P < 0.05$). Slaughter weight and dressing percentage were higher in calves from Continental dams than in those from British dams ($P < 0.05$). At similar backfat thickness, slaughter weight was higher in male than in female calves ($P < 0.05$). Total plasma cholesterol, HDL cholesterol and triglycerides were higher in PM sired cattle than in those sired by CH ($P < 0.01$ to 0.10). Similarly, cattle from British dams presented higher values of plasma cholesterol, HDL cholesterol and LDL cholesterol than cattle from Continental dams ($P < 0.01$ to 0.05). Insulin and IGF-I values increased with age ($P < 0.01$). Plasma insulin concentrations during fattening were higher for PM than for BB or CH sired cattle ($P < 0.05$), for cattle from Continental than from British dams ($P < 0.01$) and for males than for females ($P < 0.01$). During fattening, IGF-I values were higher in male than in female cattle ($P < 0.01$). The use of double-muscled sires in terminal crosses resulted in little effect on performance of the progeny.

Key words: Double-muscled, terminal crosses, Belgian Blue, Piedmontese

Seoane, J. R., Lapierre, H. et Roy, G. L. 1999. **Utilisation des races à double musculature en croisements terminaux: Performances zootechniques et profil sanguin.** Can. J. Anim. Sci. **79**: 293–299. Quatre-vingt-neuf veaux issus de mères des races anglaises (50% Hereford et 50% Red Angus) et continentales (50% Simmental et 50% Maine Anjou) croisées avec des taureaux Charolais (CH), Blanc-Bleu Belges (BBB) et Piémontais (PM) ont été utilisés afin d'évaluer la productivité de croisements terminaux avec des taureaux des races à double musculature. La race du taureau n'a eu aucun effet sur les paramètres mesurés avant le sevrage. La difficulté au vêlage était reliée à la race de la mère, étant plus élevée pour les races anglaises que pour les races continentales ($P < 0,05$) et avait tendance à être plus élevée pour les veaux mâles que pour les femelles ($P < 0,10$). Le gain moyen quotidien (GMQ) jusqu'au sevrage et le poids corrigé à 200 jours étaient plus élevés pour les veaux mâles que pour les femelles ($P < 0,05$), et pour les veaux des mères continentales que pour ceux des mères anglaises ($P < 0,05$). Le GMQ durant la semifinition était plus élevé pour les veaux CH que pour les veaux PM ($P < 0,05$). De plus, le GMQ en parquet d'engraissement (semifinition + finition) était plus élevé pour les veaux mâles que pour les femelles ($P < 0,05$). Le poids d'abattage et le rendement des carcasses étaient plus élevés pour les animaux de mères continentales que pour ceux des mères anglaises ($P < 0,05$). À une valeur similaire de gras dorsal, le poids à l'abattage était plus grand pour les veaux mâles que pour les femelles ($P < 0,05$). Les valeurs de cholestérol total, de cholestérol-HDL et des triglycérides plasmatiques étaient plus élevées chez les veaux de race PM que chez ceux de race CH ($P < 0,01$ à 0,10). Les veaux des mères anglaises présentaient des valeurs plus élevées de cholestérol total, de cholestérol-HDL et de cholestérol-LDL comparativement aux veaux des mères continentales ($P < 0,01$ à 0,05). Les valeurs d'insuline et d'IGF-I augmentaient avec l'âge ($P < 0,01$). Les concentrations d'insuline durant la finition étaient plus élevées pour les veaux PM que pour les veaux BBB ou CH ($P < 0,05$), pour les veaux des mères continentales que pour ceux des mères anglaises ($P < 0,01$) et pour les veaux mâles par rapport aux femelles ($P < 0,01$). Les valeurs d'IGF-I durant la finition étaient plus élevées pour les veaux mâles que pour les femelles ($P < 0,01$). Cette étude a démontré que l'utilisation des taureaux à double musculature a peu d'effet sur les performances zootechniques de la progéniture.

Muscular hypertrophy, also known as double muscling (DM), is an inherited condition that involves an increase in the number as well as enlargement of muscle fibers in cattle (Arthur 1995). Although several breeds of cattle carry the DM gene for double muscling, expression of the gene within

Abbreviations: **ADG**, average daily gain; **BB**, Belgian Blue; **CH**, Charolais; **DM**, double-muscled; **FA**, fatty acids; **HDL**, high density lipoproteins; **HDLCh**, HDL cholesterol; **LDL**, low density lipoproteins; **LDLCh**, LDL cholesterol; **TCh**, total cholesterol; **TG**, triglycerides; **PM**, Piedmontese a breed varies according to genetic background, environment, sex and stage of maturity. The highest frequency of double-muscled cattle has been observed in the Belgian Blue and Piedmontese breeds. Individuals showing the DM condition present higher carcass yield and cutability (Arthur et al. 1989) and lean but tender meat. Thus, the use of DM cattle has become quite popular in Europe, where higher prices are paid for DM carcasses (Ménissier 1982). There are some drawbacks, however, associated with the DM condition since reproductive problems and calving difficulty have been consistently reported in double-muscled cattle (Arthur et al. 1988).

The use of crossbreeding has long been recognized as an effective way to increase production and, therefore, farm receipts (Cartwright 1970). When crossbreeding, the choice of the breed of sire to be used represents an important economic decision for cow/calf producers (Baker and Lunt 1990). The use of DM breeds in crosses has been shown to improve carcass characteristics and to partially eliminate some of the reproduction problems associated with DM cattle (Arthur et al. 1989). Carcasses of steers born from Belgian Blue and Piedmontese sires crossed with dairy-type dams had higher dressing percentage and lean yields than crosses using Angus or Charolais bulls (Liboriussen 1982). However, the incidence of calving difficulties remained high unless double-muscled sires were used with dams that showed calving ease (Liboriussen 1982; Arthur et al. 1989).

The objective of the present study was to evaluate the productivity of using double-muscled breeds in terminal crosses with crossbred dams of two different types: large frame from Continental breeds (Simmental and Maine Anjou) or medium frame from British breeds (Hereford and Angus). Parameters studied were calving ease, birth weight, average daily gain (ADG) pre-weaning, weaning age, weaning weight, ADG post-weaning, slaughter age, slaughter weight, backfat thickness, carcass classification, dressing percentage and some blood metabolites.

MATERIALS AND METHODS

Animals and Management

This study was conducted in accordance with the guidelines of the Canadian Council on Animal Care (1993). Procedures and justification for the experiment were approved by the local Animal Care Committee. Starting in the spring of 1994, females from the herd of the Beef Research Farm of Agriculture and Agri-Food Canada at Kapuskasing (Ontario) were divided into two groups: a British (B) group of hybrid cows where the Red Angus and Hereford breeds predominated, and a Continental (C) group of hybrid cows where the predominating breeds were Simmental and Maine Anjou. The cows were inseminated with semen from 15 different sires, 5 CH, 5 BB and 5 PM. Five sires from each breed were chosen to represent as much as possible the genetic variability of the breeds and to minimize any parentage links. Each sire was used randomly in a minimum of four cows of each group. All dams were inseminated within a 33 d interval, from 2 June to 4 July 1994.

Calvings took place indoors in an insulated unheated barn from 11 March to 24 April 1995. Table 1 presents the type of crosses and the number of calves born in each category. Calvings were given different codes according to difficulty: 0 = without observation, 1 = required no assistance, 2 = required some assistance, 3 = required the use of a mechanical puller, and 4 = required Caesarian section. Male calves were castrated within 3 wk after birth. In early June, calves and their dams were placed out on pasture where they remained until weaning (185 ± 10 d). Pre-weaning calf mortality was 5.6% (three males and two females). After weaning, all calves were weighed, implanted with Ralgro and placed in feedlots. Ralgro implantation was repeated 90 d later. Steers were fed in pens equipped with electronic head gates (American Calan® Inc., Northwood, NH) to measure individual feed intake, whereas the heifers, separated according to the paternal breed, were fed in groups. During backgrounding, each calf received grass silage ad libitum (Table 2) and a daily supplement of 600 g of canola meal and 50 g of a mineral mix. The animals were switched to a finishing diet once they reached a liveweight about 170 kg higher than weaning weight and accumulated 7 mm of backfat including the skin. The finishing diet consisted of 35% rolled barley, 65% grass silage and mineral supplementation. Liveweights were recorded every 4 wk, from weaning until slaughter. As the animals approached the finishing condition, backfat thickness was evaluated every 2 wk by ultrasound (Krautkramer apparatus, Cologne, Germany).

Table 1. Number of calves born according to breed of sire and dam cross

Breed of sire	Sex of Calf	Dam cross[z] British 50% RA	50% HH	Continental 50% SM	50% MA	Total
Charolais	Male	2	3	4	4	13
	Female	5	8	7	2	22
Piedmontese	Male	5	3	5	1	14
	Female	1	5	6	2	14
Belgian Blue	Male	2	8	5	0	15
	Female	4	1	2	4	11
Total		19	28	29	13	89

[z]RA = Red Angus, HH = Hereford, SM = Simmental, MA = Maine Anjou.

Jugular blood samples were taken by venipuncture in heparinized tubes 5 wk after weaning and 6 mo later at the beginning of fattening. Plasma was obtained by centrifugation at 2500 × g for 12 min at 4°C, and stored at –20°C for subsequent analyses of plasma cholesterol (TCh), HDL-cholesterol (HDLCh), LDL-cholesterol (LDLCh), triglycerides (TG), insulin, IGF-1, glucose and non-esterified fatty acids (NEFA).

Slaughter Procedure

Animals were sent to slaughter when the ultrasound reading indicated that 10 mm of backfat thickness, including the skin, had been attained. Because of differences in growing and backfat deposition rates among the different crosses, the slaughtering period started in June and ended in October 1996. All animals were sent to slaughter following 24 h of feed deprivation. They were weighed in the afternoon before departure and were held overnight at the abattoir of Lorrainville situated 450 km from the Research Station.

Table 2. Composition of the silages[z]

Item[y]	Silage 1 (10/95)[x]	Silage 2 (11-12/95)	Silage 3 (01/96)	Silage 4 (02/96)	Silage 5 (03/96)	Silage 6 (04-05/96)	Silage 7 (06-08/96)	Silage 8 (09-10/96)	SEM
n	2	3	3	3	2	4	6	3	
Dry matter (%)	26.6*b*	44.8*a*	24.4*b*	29.6*b*	31.2*b*	30.9*b*	30.6*b*	25.9*b*	1.37
pH	4.39*b*	4.89*a*	4.18*b*	4.37*b*	4.38*b*	4.39*b*	4.77*a*	5.14*a*	0.07
Protein (% DM)	17.1*a*	13.9*c*	15.4*b*	14.3*c*	13.5*cd*	12.2*d*	13.6*c*	14.1*bc*	0.30
NH_3-N (% total N)	8.9*c*	4.6*c*	9.7*c*	7.7*c*	6.4*c*	6.5*c*	12.3*b*	17.2*a*	0.91
Soluble N (% total N)	49.8	57.7	49.2	56.2	51.4	49.2	52.0	48.8	1.15
NDF (% DM)	51.4*c*	59.1*a*	54.6*b*	53.4*bc*	54.9*b*	59.6*a*	58.5*a*	60.7*a*	0.65
ADF (% DM)	30.7*f*	34.6*d*	32.6*ef*	32.4*ef*	34.0*de*	36.5*c*	37.5*bc*	40.8*a*	0.61
ADL (% DM)	3.2*c*	3.6*bc*	3.6*bc*	4.0*abc*	3.8*abc*	4.9*a*	4.6*a*	4.1*abc*	0.14
Ash (% DM)	7.7*b*	7.5*b*	7.7*b*	7.3*b*	8.3*b*	7.6*b*	10.0*a*	11.3*a*	0.31

[z]Least-square means; means followed by a different letter are significantly different at $P < 0.05$.
[y]NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin.
[x]The date under silage identification indicates the time when the respective silage was fed.

Animals were slaughtered following conventional procedures. Carcasses were weighed, chilled at 2°C, graded 24 h postmortem and allowed to age at 2°C for 7 d. The loins were obtained and saved frozen at –40°C for subsequent analyses.

Chemical Analysis

Silage samples were analyzed for DM by oven drying at 103°C for 24 h, for N by the Kjeldahl method No. 7.022 of the Association of Official Analytical Chemists (1984) and for hot-water-insoluble N by the technique of Goering and Van Soest (1970) using fresh samples. Juice was squeezed from silage with a laboratory press and used for determination of pH and ammonia (specific ion electrode). Silages were analyzed for NDF, ADF and ADL using the non-sequential detergent procedure of Goering and Van Soest (1970) in oven-dried samples (55°C, 90 h).

Blood lipids were determined by colorimetric techniques (Technicon RA-500, Tarrytown, NY). Total cholesterol and TG were measured by enzymatic procedures (Randox Laboratories Ltd., Antrim, UK). The HDLCh fraction was measured after cold micro-centrifugation of a serum, heparin (6%) and $MnCl_2$ (41.58 g dL^{-1}) mix (20:1:1). LDL cholesterol was obtained by the equation: LDLCh = TCh – (TG/5 + HDLCh).

Double antibody RIA were used to measure concentrations of insulin (Lapierre et al. 1992) and IGF-1 (Abribat et al. 1993). Interassay and intraassay coefficients of variation were 4.8 and 5.1% for insulin and 3.9 and 4.2% for IGF-1, respectively. Plasma glucose concentration was determined by an enzymatic procedure (Kit 166391, Boehringer Mannheim, Dorval, QC). Nonesterified fatty acids were determined with a commercial kit (Kit 990-75401, Wako Chemical, Dallas, TX) as described by McCutcheon and Bauman (1986).

Statistical Analyses

Growth performance and carcass data were analyzed by analyses of variance according to a 3 × 2 × 2 factorial design with three breeds of sire, two types of dams and two sexes of the progeny, taking into account the effect that some calves were sired by the same bull. The MIXED procedure of the SAS Institute Inc. (1998) software was used for statistical analyses (Littell et al. 1998) according to the following model:

$$Y_{ijklm} = \mu + B_i + F_j + (BF)_{ij} + S_k + (BS)_{ik} + (FS)_{jk} + (BFS)_{ijk} + P_l(B_i) + e_{ijklm}$$

where Y_{ijklm} is the individual observation of the *m*th animal of the *l*th sire (*P*) of the *i*th breed (*B*), the *j*th dam origin (*F*), the *kth* sex of the progeny (*S*) and μ is the overall mean. $P_l(B_i)$ corrects for the effect of calves born from the same sire. All main effects were fixed except for $P_l(B_i)$ and the error e_{ijklm}, which were independent random variables.

Blood data were analyzed by analyses of variance with repeated measures according to a 3 × 2 × 2 × 2 factorial design with three breeds of sire, two types of dams, two sexes of the progeny and two times of sampling, taking into account the effect that some calves were sired by the same bull. The MIXED procedure of the SAS Institute, Inc. (1998) software was used for statistical analyses (Littell et al. 1998) according to the following model:

$$\begin{aligned} Y_{ijklmn} = {} & \mu + B_i + F_j + (BF)_{ij} + S_k + (BS)_{ik} + (FS)_{jk} \\ & + (BFS)_{ijk} + T_m + (BT)_{im} + (FT)_{jm} + (BFT)_{ijm} \\ & + (ST)_{km} + (BST)_{ikm} + (FST)_{jkm} + (BFST)_{ijkm} \\ & + P_l(B_i) + e_{ijklmn} \end{aligned}$$

where Y_{ijklmn} is the individual observation of the *l*th sire (*P*) of the *i*th breed (*B*), the *j*th female type (*F*), the *k*th sex of the progeny (*S*), the *m*th sample (*T*) and the *n*th animal and μ is the overall mean. $P_l(B_i)$ corrects for the effect of calves born from the same sire. All main effects were fixed except for $P_l(B_i)$ and the error e_{ijklmn}, which were independent random variables.

RESULTS AND DISCUSSION

Reproductive Traits

Average length of gestation was 285.6 d and was not affected by the breed of sire or by the type of dam. Only a tendency was observed due to sex of the newborn calf ($P < 0.10$, Table 3), gestation of male calves lasting 2 d longer than

Table 3. Effects of crossing normal or double-muscled sires with British or Continental dams on reproductive traits of dams and preweaning growth of the progeny (main effects)[z]

	Breed of sire			Origin of dam		Sex of calf		
Parameter	Charolais	Piedmontese	Belgian Blue	British	Continental	Male	Female	SEM
Length of gestation (d)	286	286	285	286	285	287*aT*	285*b*	0.54
Calving difficulty[y]	1.23	1.18	1.37	1.38*a**	1.14*b*	1.37*aT*	1.15*b*	0.06
Birth weight (kg)	44.6	42.1	41.1	42.1	43.1	43.8*aT*	41.4*b*	0.68
Weaning weight (kg)	221	213	223	213	225	228*a**	210*b*	3.77
Weaning age (d)	184	186	185	185	184	186	184	1.10
ADG to weaning (kg)	0.96	0.92	0.98	0.92*bT*	0.99*a*	1.00*a**	0.91*b*	0.02
Weight corrected at 200 d (kg)	237	227	237	226*bT*	241*a*	243*a**	224*b*	4.03

[z]Least-squares means. For a given parameter within a main effect, means followed by a different letter are significantly different, T = tendency $P < 0.10$, * = $P < 0.05$. There was a significant frame × sex interaction for weight corrected at 200 d; male calves born from Continental dams were 40 kg heavier than females, whereas male calves born from British dams were 2.3 kg lighter than females.

[y]Calving difficulty was rated as follows: 0 = without observation, 1 = required no assistance, 2 = required some assistance, 3 = required the use of a mechanical puller, and 4 = required Caesarian section.

that of females. Few problems were observed related to ease of calving and these were not due to the breed of the sire, but to the origin of the dam. In effect, British dams presented more difficult births than Continental dams ($P < 0.05$, Table 3), but average values stayed close to "no assistance required". Similarly, incidence of calving difficulty tended to be higher ($P < 0.10$) in male than in female calves, but average values were close to those found under normal conditions. These results support previous findings indicating that the incidence of calving difficulties can be decreased if DM sires are used with large-frame dams or dams that exhibit calving ease (Liboriussen 1982; Arthur et al. 1989). As indicated by Arthur (1995), by using a normal female in the DM mating, the female component of calving difficulty, associated to the DM gene, is eliminated. In addition, the conformation of the crossbred progeny is not as muscular as the purebred DM, thus reducing risks of calving difficulty. Average birth weight of calves was 41.9 kg and was not significantly affected by breed of sire, type of dam or sex of calf (Table 3).

Preweaning Traits

Weaning took place at 185 d after calving. Average weaning weight was 216.7 kg and was not affected by the parental breeds. However, sex of calf had an effect on weaning weight, male calves were 9% heavier than female calves ($P < 0.05$). These differences resulted from a 10% higher preweaning ADG in male calves compared with females ($P < 0.05$, Table 3). Breed of sire did not exert any effect on ADG preweaning, which agrees with results reported by Baker and Lunt (1990) comparing PM and CH sires. However, calves issued from Continental dams had a tendency towards higher ADG than British calves ($P < 0.10$). This agrees with previous reports where the predominating beef cattle breeds in Canada were compared (Amer et al. 1992); higher ADG obtained with Continental dams probably reflects higher milk production. Weight corrected at 200 d averaged 231 kg and followed the same pattern as weaning weight, it was not affected by the breed of sire, but was higher for male calves ($P < 0.05$, Table 3) and tended to be higher for calves from Continental dams ($P < 0.10$). Although weights at 200 d were not statistically affected by sire, BB calves weighed 237 kg compared with PM, which weighed 226 kg. These observations are similar to those of Cundiff et al. (1997) who reported weights at 200 d of 239 kg for BB and 231 kg for PM progeny.

Postweaning Traits

All animals spent approximately 194 d (±37 d SD) on a high forage diet during backgrounding. No differences were detected due to breed of sire, origin of dam or sex of calf (Table 4). Average daily gains during backgrounding were higher for CH than for PM calves (0.95 and 0.88 kg, respectively, $P < 0.05$). Values obtained for BB crosses were intermediate. No differences due to type of dam were detected for ADG during backgrounding, but male calves gained faster than females (0.94 vs. 0.89, respectively, $P < 0.05$). Average feed conversion during backgrounding was 7.6 kg of feed per kilogram of gain and was not affected by breed of sire, origin of dam or sex of calf.

After backgrounding, all animals were changed to a higher energy diet for the fattening period. Time of fattening to attain at least 10 mm of backfat thickness (including the skin) averaged 121 d and was not affected by breed of sire or sex of calf, but was affected by origin of dam. Cattle born of British dams stayed 33 d less in the feedlot compared to cattle from Continental dams ($P < 0.01$, Table 4). This partially resulted from a numerically higher ADG observed in cattle from British dams, and also from the capacity of British breeds to accumulate backfat faster than Continental breeds. Average ADG during fattening was 0.70 kg, and was higher for steers than for heifers (0.79 vs. 0.62 kg for steers and heifers, respectively, $P < 0.05$). These values are lower than those reported by Cundiff et al. (1997) in steers sired by Piedmontese or Belgian Blue bulls, but probably reflect the poor quality of the silage fed towards the end of the fattening period (Table 2). Silage quality also had an effect on feed conversion during fattening; the average feed to gain ratio of 13.1 indicated that the animals did not utilize their feed efficiently. Feed to gain ratio was higher ($P < 0.05$) for heifers (14.5) than for steers (11.8).

Slaughter Traits

Animals were slaughtered at an average of 500 d of age and

Table 4. Effects of crossing normal or double-muscled sires with British or Continental dams on postweaning growth and slaughter traits of the progeny (main effects)[z]

	Breed of sire			Origin of dam		Sex of calf		
Parameter	Charolais	Piedmontese	Belgian Blue	British	Continental	Male	Female	SEM
Backgrounding								
Duration (d)	192	196	193	197	191	198	190	4.05
ADG (kg)	0.95*a**	0.88*b*	0.91*ab*	0.91	0.92	0.94*a**	0.89*b*	0.01
Feed/gain (kg kg^{-1})	7.75	7.78	7.57	7.79	7.61	7.75	7.65	0.08
Final weight (kg)	402*a**	385*b*	397*ab*	391	399	413*a***	377*b*	3.54
Backfat with skin (mm)	7.6	7.5	7.6	7.6	7.6	7.5	7.7	0.09
Fattening								
Duration (d)	120	125	119	105*b***	138*a*	115*bT*	128*a*	3.97
ADG (kg)	0.75	0.68	0.67	0.73	0.67	0.78*a***	0.62*b*	0.02
Feed/gain (kg kg^{-1})	12.46	13.18	13.84	13.10	13.21	11.82*b***	14.49*a*	0.38
Slaughter weight (kg)	492	470	476	468*b***	491*a*	504*a***	454*b*	5.29
Backfat with skin (mm)	10.1	10.1	10.2	10.2	10.1	10.2	10.1	0.06
Age at slaughter (d)	496	509	492	487*b***	511*a*	499	499	4.81
Dressing percentage (%)	55.8	56.3	57.1	55.6*b***	57.2*a*	56.4	56.4	0.22
Backfat thickness (mm)[y]	5.3	4.9	5.3	5.0	5.3	5.1	5.2	0.10

[z]Least-squares means. For a given parameter within a main effect, means followed by a different letter are significantly different, *T* = tendency $P < 0.10$, * = $P < 0.05$, ** = $P < 0.01$.
[y]Measured without the skin.

Table 5. Effects of crossing normal or double-muscled sires with British or Continental dams on plasma lipids (mg dL^{-1}) of the progeny (main effects)[z]

	Breed of sire			Origin of dam		Sex of calf		
Parameter	Charolais	Piedmontese	Belgian Blue	British	Continental	Male	Female	SEM
			After weaning					
Cholesterol	99.5*b**	117.0*a*	112.0*ab*	119.9*a***	99.0*b*	100.7*b***	118.3*a*	2.81
HDL-cholesterol	70.7*b***	81.8*a*	77.8*ab*	81.0*a***	72.5*b*	72.7*b***	80.8*a*	1.58
LDL-cholesterol	25.4	30.4	30.3	34.8*a***	22.6*b*	23.5*b***	33.9*a*	1.54
HDL/LDL cholesterol	3.2	3.1	3.1	2.7*b***	3.6*a*	3.6*a***	2.7*b*	0.13
Triglycerides	18.2*b***	24.9*a*	21.2*ab*	21.9	21.0	23.8*a***	19.1*b*	0.71
			During fattening					
Cholesterol	112.5	122.4	112.1	123.1*a***	108.1*b*	117.9	113.4	2.61
HDL-cholesterol	75.9	81.0	75.6	80.6*a**	74.4*b*	78.0	77.0	1.36
LDL-cholesterol	32.9	36.8	32.3	38.7*a***	29.3*b*	35.4	32.6	1.63
HDL/LDL cholesterol	2.9	2.7	2.6	2.4*b**	3.1*a*	2.6	2.9	0.16
Triglycerides	19.6*b**	23.8*a*	22.7*ab*	20.8	23.2	23.7*a***	20.4*b*	0.60

[z]Least-squares means. For a given parameter within a main effect, means followed by a different letter are significantly different, * = $P < 0.05$, ** = $P < 0.01$.

478.3 kg of body weight. Calves from British dams were slaughtered 24 d earlier than those from Continental dams ($P < 0.01$). Slaughter weight was affected by dam and by sex of the animal. Cattle from Continental dams were 24 kg heavier than those from British dams ($P < 0.01$), and steers were 50 kg heavier than heifers ($P < 0.01$).

Dressing percentage averaged 56.4%; it was not affected by sire or sex, but was higher in cattle from Continental dams compared with those from British dams ($P < 0.01$). In similar studies, Arthur et al. (1989) reported that dressing percentage was higher for DM-sired cattle than for normal sires. This is probably explained by less abdominal fat and smaller digestive tracts in DM sired cattle. Our results show numerically higher values in dressing percentage for DM sired cattle (1.3%), but these values were not statistically different. Baker and Lunt (1990) also observed that PM-sired cattle had 2.4% higher dressing percentage than CH sired cattle, but the difference was not statistically significant. Backfat thickness measured without the skin averaged 5.2 mm and it was not affected by sire, dam or sex. Small differences in backfat thickness could reflect the differences observed in slaughter weights.

Plasma lipids

Plasma TCh increased by 5.6% as the animals became older ($P < 0.01$). At weaning, plasma TCh was significantly higher in PM sired cattle compared with those sired by CH ($P < 0.05$; Table 5); BB cattle showed intermediate levels. Previous studies have also shown that plasma TCh was higher in DM than in normal cattle (Basarab et al. 1982). A similar sire effect was detected for plasma HDLCh and TG, the progeny of PM bulls had higher levels than the progeny of CH bulls. The breed of sire effect on TCh and HDLCh remained until fattening but became non-significant, thus resulting in a sig-

Table 6. Effects of crossing normal or double-muscled sires with British or Continental dams on plasma metabolites of the progeny (main effects)[z]

	Breed of sire			Origin of dam		Sex of calf		
Parameter	Charolais	Piedmontese	Belgian Blue	British	Continental	Male	Female	SEM
			After weaning					
Glucose (mg dL^{-1})	73.5	75.3	74.6	72.6*b**	76.3*a*	72.3*b***	76.6*a*	0.84
NEFA (µEq L^{-1})	498	460	494	479	489	517	451	13.9
Insulin (ng mL^{-1})	0.31	0.36	0.32	0.31	0.35	0.33	0.33	0.01
IGF-1 (ng mL^{-1})	163	166	188	188*a**	157*b*	175	170	7.74
			During fattening					
Glucose (mg dL^{-1})	79.4	83.8	82.2	78.1*b***	85.4*a*	82.9	80.6	1.16
NEFA (µEq L^{-1})	450	374	471	402	461	418	445	19.4
Insulin (ng mL^{-1})	0.80*b**	1.13*a*	0.79*b*	0.73*b***	1.09*a*	1.09*a***	0.72*b*	0.06
IGF-1 (ng mL^{-1})	365	360	370	379	351	429*a***	301*b*	12.9

[z]Least-squares means. For a given parameter within a main effect, means followed by a different letter are significantly different, * = $P < 0.05$, ** = $P < 0.01$.

nificant breed × time interaction ($P < 0.05$). Cattle from British dams had higher levels of TCh, HDLCh and LDLCh than cattle from Continental dams ($P < 0.05$) and this effect remained during fattening (Table 5). The ratio HDL to LDL-cholesterol was significantly higher in cattle from Continental dams than in those from British dams ($P < 0.01$), an effect that remained until slaughter. This may influence cholesterol content of meat because LDL are used for cholesterol distribution to tissue depots and HDL are necessary to return excess cholesterol from peripheral cells to the liver to be used for bile synthesis or resynthesis of new VLDL particles (Bauchart 1993). The effect of sex on plasma lipids was variable. At weaning, male calves had lower ($P < 0.01$) levels of TCh, HDLCh and LDLCh than females, but the differences disappeared during fattening resulting in a significant sex × time interaction ($P < 0.01$). On the other hand, the ratio of HDL to LDL-cholesterol and plasma TG were higher in male than in female calves ($P < 0.01$). The effect of sex on HDL to LDL ratio disappeared during fattening, but that on plasma TG remained highly significant.

Plasma Metabolites

Plasma glucose concentrations increased with time, from 74.4 to 81.8 mg dL^{-1}, as the animals changed from a high protein diet during backgrounding to a high energy diet during fattening ($P < 0.001$; Table 6). The increase in glucose concentration during fattening was probably associated with increased production of propionic acid in the rumen resulting from the presence of barley in the diet (Journet et al. 1995). Breed of sire did not exert any effect on plasma glucose. There was a significant sex × time interaction because plasma glucose was higher ($P < 0.01$) in female calves than in male calves, but only during backgrounding. Calves born from Continental dams had higher plasma glucose concentrations than those born from British dams, and these differences remained through fattening ($P < 0.01$).

Plasma NEFA were affected only by time, average NEFA values decreasing from 484 µEq L^{-1} during backgrounding to 431 µEq L^{-1} during fattening ($P < 0.05$). Changes in NEFA were probably related to changes in plasma insulin, as the animals changed to a higher energy diet during fattening. An increase in plasma insulin would produce a decrease in plasma NEFA, since the hormone exerts an inhibitory effect on lipolysis. Average plasma insulin concentrations increased markedly from 0.33 to 0.91 ng mL^{-1} ($P < 0.0001$), as the animals progressed from backgrounding to fattening. Similar fluctuations on plasma insulin concentrations have been observed in cattle growing at different rates (Hornick et al. 1998). Main treatment effects on plasma insulin were apparent only during fattening and this resulted in a significant interaction of main effects with time ($P < 0.03$). Plasma insulin was higher in calves from PM sires than in calves from CH and BB sires ($P < 0.05$; Table 6), and in calves from Continental dams than in those from British dams ($P < 0.01$). Furthermore, plasma insulin was higher in male calves compared with females ($P < 0.01$). Such differences may be associated to sex differences in growth rate during fattening (Table 4).

Average plasma IGF-1 concentrations increased from 172 ng mL^{-1} during backgrounding to 365 ng mL^{-1} during fattening ($P < 0.001$; Table 6). Similar changes in IGF-1 concentrations as animals get older have been previously reported in cattle (Stick et al. 1998). Furthermore, plasma IGF-1 concentrations have been positively associated with ADG and feed efficiency (Stick et al. 1998); similar relations were obtained in the present study, but only during fattening. Plasma IGF-1 concentrations during fattening were correlated with ADG ($r = 0.73$; $P < 0.01$) and with feed conversion ($r = -0.76$; $P < 0.01$), thus confirming the relation between IGF-1 and rate of growth.

CONCLUSIONS

The results obtained indicate that performance of the progeny of DM sires was similar to that of a conventional large breed. The use of double-muscled sires in terminal crosses will be determined by the market and consummer demands. Double-muscled sires should be used preferably with large-frame females to avoid problems at calving.

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