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Consequences of prenatal and preweaning growth for yield of beef primal cuts from 30-month-old Piedmontese- and Wagyu-sired cattle

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Abstract. Cattle sired by Piedmontese or Wagyu bulls were bred and grown within pasture-based nutritional systems followed by feedlot finishing. Effects of low (mean 28.6 kg, $n = 120$) and high (38.8 kg, $n = 120$) birthweight followed by slow (mean 554 g/day, $n = 119$) or rapid (875 g/day, $n = 121$) growth to weaning on beef primal cut weights at ~30 months of age were examined. Cattle of low birthweight or grown slowly to weaning had smaller primal cuts at 30 months as a result of reduced liveweight and smaller carcasses compared with their high birthweight or rapidly grown counterparts. Hence they require additional nutritional and economic inputs to reach target market weights. At equivalent carcass weights (380 kg), cattle restricted in growth from birth to weaning yielded slightly more beef and were somewhat leaner than their rapidly grown counterparts, resulting in primal cuts being up to 4% heavier in the slowly grown compared with the rapidly grown cattle. Compositional differences due to birthweight were less apparent at the same carcass weight, although low birthweight cattle had a slightly (~2%) heavier forequarter and slightly lower (~1%) hindquarter retail yield, and less shin-shank meat (~2%) than high birthweight cattle, suggesting only minor effects on carcass tissue distribution. There were few interactions between sire genotype and birthweight or preweaning growth, and interactions between birthweight and preweaning growth were not evident for any variables. However, variability between cohorts in their long-term responses to growth early in life suggests other environmental factors during early-life and/or subsequent growth influenced carcass yield characteristics. Overall, this study shows that effects of birthweight and preweaning growth rate on carcass compositional and yield characteristics were mostly explained by variation in carcass weight and, hence, in whole body growth to 30 months of age.

Additional keywords: calf, fetal programming, newborn.

Introduction

Information is emerging on the long-term consequences of growth during the early life of cattle on beef production (Greenwood *et al*. 2006; Greenwood and Cafe 2007) and for other livestock species and products (Bell 2006). Recently, we have shown that variation in growth early in life results in substantial long-term differences in yield of beef and other carcass characteristics at the same age (Greenwood *et al*. 2006). However, when assessed at an equivalent carcass weight, differences in carcass retail yield and fatness were only evident due to growth rate before weaning and not due to growth *in utero*. This was despite low birthweight cattle having greater depth of rump fat, but not of rib fat, compared with high birthweight cattle at the same carcass weight. These findings, coupled with a significant interaction between birthweight and prenatal growth rate for cross-sectional area of the *M. longissimus* (Greenwood *et al*. 2006), suggest that altered growth during the prenatal and preweaning periods may affect the distribution of carcass tissues in cattle, with implications for the yield of specific beef primal cuts.

The objective of the present study was to investigate the extent to which growth of cattle during the prenatal and preweaning

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periods has long-term consequences for yield of beef primal cuts. We hypothesised that sire genotype may interact with growth early in life to influence primal cut characteristics of cattle at heavy market weights. To achieve these objectives we investigated Piedmontese- and Wagyu-sired low and high birthweight cattle grown slowly or rapidly to weaning obtained from a large study on factors influencing birthweight and growth to weaning (Cafe *et al*. 2006*a*). These cattle were backgrounded on pasture before feedlot finishing and slaughter at ~30 months of age. This study represents the first time that primal cut yields in cattle have been studied following differing growth trajectories early in life. Hence, the details of yields of all primal cuts at the same age (~30 months) and at the same carcass weight (380 kg) are provided due to the importance of this age- and weight-specific information to beef producers and processors. The weight-specific results also allowed for an assessment of treatment effects independent of compositional and distributional effects associated with allometric or relative growth of the body tissues (Hammond 1932; Palsson 1955).

Materials and methods

Animals, experimental design, management and growth early in life

Use of animals and the procedures performed in this study were approved by the North Coast Animal Care and Ethics Committee (approval no. G2000/05).

The animals investigated were those studied and described in detail by Greenwood *et al*. (2006), and were selected from a larger study of influences on birthweight and growth to weaning (Cafe *et al*. 2006*a*) conducted at the New South Wales Department of Primary Industries Grafton Agricultural Research and Advisory Station (29°39′S, 152°55′E, altitude 20 m). The experimental design was a 2 (low and high birthweight groups) × 2 (low and high preweaning growth groups) × 2 (Piedmontese and Wagyu sire genotypes) × 3 (2001-born heifer and 2001- and 2002-born steer cohorts) factorial, with 9–11 calves in each of the 24 cells within the design. The cattle investigated were female (n = 80) or castrate (n = 160) progeny of nine Piedmontese (n = 120 calves) or eight Wagyu (n = 120 calves) bulls mated to Hereford cows. The three cohorts were: female calves born in 2001 (n = 81); castrate male calves born in 2001 (n = 79); and castrate male calves born in 2002 (n = 80). Birthweights, preweaning growth, and age and weight at weaning of the animals within the birthweight × preweaning growth groups within each genotype and cohort are detailed in Greenwood *et al*. (2006).

The objectives for selection of calves into their respective birthweight (low, n = 120; high, n = 120) × preweaning growth (low, n = 119; high, n = 121) groups within each sire genotype and cohort were established before the commencement of the study to represent extremes of prenatal and preweaning growth within the North Coast region of New South Wales. These objectives were to achieve as close as possible to a 30% difference in birthweight coupled with an ~2-fold difference (0.5 *v.* 1.0 kg/day) in preweaning growth rate, ensuring the groups were as balanced as possible for sire, with ~10 calves per cell to facilitate meaningful comparisons of objective measurements. These criteria resulted in the low (28.6 kg) and high (38.8 kg) birthweight and low (554 g/day) and high (875 g/day) preweaning growth rate calves being selected from multi-modal distributions achieved by imposition of low or high maternal nutrition during pregnancy and lactation (see Cafe *et al*. 2006*a*; Greenwood *et al*. 2006). To assess whether the method of sourcing the birthweight × preweaning growth groups was biased by inclusion of animals from matching and non-matching maternal nutrition groups, statistical analyses were performed for the entire dataset and for the subset of data comprising only those cattle obtained from the matching maternal nutrition groups. As with the carcass and beef quality characteristics presented by Greenwood *et al*. (2006), the significance of effects and predicted means differed little between the two data subsets, hence, the results for the entire dataset are presented.

Postweaning management

Following weaning at ~7 months of age, the calves were transported 150 km from Grafton to the New South Wales Department of Primary Industries Agricultural Research and Advisory Station at Glen Innes (29°44′S, 151°42′E, altitude 1057 m) where they were backgrounded on improved temperate perennial pastures until feedlot entry at ~26 months of age. Each cohort grazed as a single group during backgrounding and, when necessary, the cattle were provided with supplements to ensure growth was not retarded below 0.5 kg gain/day for prolonged periods, as described in detail by Greenwood *et al*. (2006). Following backgrounding, the cattle were managed and fed a grain-based diet at the Cooperative Research Centre for Beef Genetic Technologies 'Tullimba' feedlot located at Kingstown, New South Wales (30°30′S, 151°10′E, altitude 560 m), as also detailed by Greenwood *et al*. (2006).

Growth and liveweight characteristics of the cattle during backgrounding and feedlotting are presented by Greenwood *et al*. (2006). Liveweight at feedlot exit is presented in Table 1.

Slaughter procedures, carcass yield measurements and preparation of primal cuts

Cattle were transported 370 km (6 h) from 'Tullimba' to John Dee abattoir, Warwick, Queensland, on the day before slaughter and penned overnight until slaughter the next day. Each animal was slaughtered by captive bolt stunning and exsanguination, standard carcasses were prepared (AUS-MEAT 1998), split into two sides and chilled overnight.

One side of each carcass was used to determine weights of beef primal cuts, retail beef yield, fat trim and bone (Perry *et al*. 2001). During the bone-out procedure, carcasses were split into 12-rib forequarters [Handbook of Australian Meat (HAM) primal cut number 1060: AUS-MEAT 1998] and 1-rib hindquarters (HAM 1010). The forequarter was boned-out into the cube roll (HAM 2240), chuck roll (HAM 2275), blade (HAM 2300), chuck tender (HAM 2310) and shin-shank (HAM 2360) primal cuts, and bone, lean trimmings and fat trimmings. The hindquarter was boned-out into topside (HAM 2000), eye round (HAM 2040), outside flat (HAM 2050), knuckle (HAM 2070), rump (HAM 2090), striploin (HAM 2140), tenderloin (HAM 2150), flank steak (HAM 2210) and shin-shank (HAM 2360) primal

Table 1. Predicted means for live, carcass and side weights and yield characteristics of beef carcasses (n = 240) at ~30 months of age and when adjusted to equivalent carcass weight (380 kg), as affected by birthweight, preweaning growth, sire genotype and cohort

n, number of cattle. Weights are least-squares means and adjusted weights are least-squares means using hot standard carcass weight (HSCW, W_L linear or W_Q quadratic if significant) as a covariate, and appropriate s.e.d. for each weight comparison. Significant ($P < 0.05$) main effects and interactions are shown for each weight variable. Values in parentheses are the percentage of boned out components, derived from predicted means

Effect	*n*	Feedlot exit weight (kg)	HSCW (kg)	Cold side weight (kg)	Retail yield (kg)	Adjusted retail yield (kg)	Bone (kg)	Adjusted bone (kg)	Fat trim (kg)	Adjusted fat trim (kg)
					Birthweight (B)					
Low	120	648	364	179.9	239 (67.2)	249 (67.2)	64.3 (18.1)	66.9 (18.1)	52.3 (14.7)	54.6 (14.7)
High	120	701	396	194.0	257 (66.7)	247 (66.6)	70.2 (18.2)	67.9 (18.3)	58.3 (15.1)	56.0 (15.1)
s.e.d.		6.5	3.9	1.83	2.7	1.1	0.81	0.55	1.17	1.17
					Preweaning growth (P)					
Low	119	656	368	181.0	242 (65.8)	251 (66.1)	65.7 (17.9)	67.8 (17.8)	50.9 (13.8)	52.8 (13.9)
High	121	693	393	192.9	254 (64.6)	246 (64.7)	68.8 (17.5)	66.7 (17.6)	59.6 (15.2)	57.8 (15.2)
s.e.d.		6.4	3.9	1.80	2.7	1.1	0.81	0.55	1.17	1.12
					Sire genotype (G)					
Wagyu	120	667	371	182.0	233 (62.8)	240 (63.2)	66.2 (17.8)	67.8 (17.8)	62.0 (16.7)	63.3 (16.7)
Piedmontese	120	682	390	191.9	263 (67.4)	257 (67.6)	68.3 (17.5)	66.8 (17.6)	48.6 (12.5)	47.2 (12.4)
s.e.d.		11.8	3.9	3.92	2.7	1.0	0.81	0.53	1.17	1.08
					Cohort (C)					
2001-born heifers	81	626	352	173.6	230 (65.3)	248 (65.3)	58.7 (16.7)	63.3 (16.7)	54.3 (15.4)	58.4 (15.4)
2001-born steers	79	658	373	183.9	244 (65.4)	248 (65.3)	67.3 (18.0)	68.4 (18.0)	54.5 (14.6)	55.2 (14.5)
2002-born steers	80	739	415	203.4	270 (65.1)	248 (65.3)	75.8 (18.3)	70.1 (18.4)	57.1 (13.8)	52.2 (13.7)
s.e.d.		8.5	4.8	2.44	3.4	1.6	0.99	0.82	1.44	1.68
					Significance					
Main effects		B, P, C	B, P, G, C	B, P, G, C	B, P, G, C	P, G, W_L	B, P, G, C	C, W_L	B, P, G	P, G, C, W_Q
Interactions		B × C	B × C	B × C	B × C		B × C			

cuts, and bone, lean trimmings and fat trimmings. Some of the variation in cut weights between sex-year cohorts is due to slight differences in preparation of specific cuts to meet the commercial requirements of the abattoir on the separate occasions that the cohorts were boned-out. Primal cuts were trimmed to a maximum of 5 mm fat depth over all cuts. Recovery of boned-out components was 99.0 ± 1.0% (mean ± s.d.) of cold side weights.

Statistical analyses

Associations between the set of measured variables and the animal classification factors generated by the experimental design were examined by fitting linear models using restricted maximum likelihood. Factors in each model included terms for birthweight category, preweaning growth category, sire genotype, sex of calf and year born, with sire within breed as a random effect. The absence of 2002-born heifers in this study meant that effects due to breeding cycle or year of birth were not separable from those due to calf sex and so a three-level 'cohort' indicator (2001-born heifer; 2001-born steer; 2002-born steer) was used as a proxy term for the combined effects of calf sex and breeding cycle. Terms to allow for first order interactions between the main factors were also included in each model. An additional animal-based covariate (hot standard carcass weight, HSCW) was included in the models when appropriate. The statistical importance of each term was assessed by construction of ANOVA tables.

The models enabled prediction of the response for any factor or combination of factors averaged over the remaining factors, and these predictions were used to summarise and discuss the data.

Analyses were performed through use of the GENSTAT software (Payne and Arnold 1997), with statistical significance of main effects, interactions and covariates accepted at $P < 0.05$.

Results

Data for yield and beef primal cut characteristics were examined to establish effects using least-squares means from actual values, and using predicted values using HSCW as a covariate (linear and where significant quadratic) to enable comparisons at equivalent carcass weight (380 kg). Hence, the percentage differences reported in the text of this section refer to the difference in weight of carcass components. The results for weight of the carcass components, and for the carcass components as a percent of carcass or side composition, are provided in Tables 1–6.

Feedlot exit, carcass and yield weights

Effects of birthweight

Low birthweight cattle had lower feedlot exit (7.6% less), HSCW (8.1%) and cold side (7.3%) weights, and lower weight of carcass retail beef yield (7.0%), bone (8.4%) and fat trim (10.3%), than high birthweight cattle at ~30 months of age (Table 1).

Table 2. Predicted means for yield characteristics of beef forequarters ($n = 240$) at ~30 months of age and when adjusted to equivalent carcass weight (380 kg), as affected by birthweight, preweaning growth, sire genotype and cohort

n, number of cattle. Weights are least-squares means and adjusted weights are least-squares means using hot standard carcass weight (HSCW, W_L linear or W_Q quadratic if significant) as a covariate, and appropriate s.e.d. for each weight comparison. Significant ($P < 0.05$) main effects and interactions are shown for each weight variable. Values in parentheses are the percentage of cold side weight, derived from predicted means

Effect	*n*	Forequarter (kg)	Adjusted forequarter (kg)	Forequarter retail yield (kg)	Adjusted forequarter retail yield (kg)	Forequarter bone (kg)	Adjusted forequarter bone (kg)	Forequarter fat trim (kg)	Adjusted forequarter fat trim (kg)
				Birthweight (B)					
Low	120	99.4 (55.3)	103.5 (55.4)	65.8 (36.6)	68.6 (36.7)	18.6 (10.3)	19.3 (10.3)	14.9 (8.3)	15.7 (8.4)
High	120	107.0 (55.2)	102.9 (55.0)	69.8 (36.0)	67.2 (35.9)	20.2 (10.4)	19.6 (10.5)	16.9 (8.7)	16.2 (8.7)
s.e.d.		1.13	0.34	0.79	0.39	0.25	0.19	0.40	0.40
				Preweaning growth (P)					
Low	119	99.7 (55.1)	103.3 (55.3)	66.1 (36.5)	68.5 (36.6)	19.0 (10.5)	19.6 (10.5)	14.6 (8.1)	15.3 (8.2)
High	121	106.6 (55.3)	103.2 (55.2)	69.5 (36.0)	67.3 (36.0)	19.8 (10.3)	19.3 (10.3)	17.3 (9.0)	16.7 (8.9)
s.e.d.		1.11	0.33	0.77	0.37	0.24	0.18	0.40	0.38
				Sire genotype (G)					
Wagyu	120	101.3 (55.7)	104.2 (55.7)	64.2 (35.3)	66.2 (35.4)	19.1 (10.5)	19.6 (10.5)	18.0 (9.9)	18.4 (9.8)
Piedmontese	120	105.1 (54.8)	102.2 (54.7)	71.4 (37.2)	69.5 (37.2)	19.7 (10.3)	19.2 (10.3)	14.0 (7.3)	13.5 (7.2)
s.e.d.		2.19	0.31	1.56	0.48	0.46	0.15	0.62	0.60
				Cohort (C)					
2001-born heifers	81	97.5 (56.2)	105.4 (56.4)	62.1 (35.8)	67.3 (36.0)	18.6 (10.7)	19.9 (10.6)	16.9 (9.7)	18.3 (9.8)
2001-born steers	79	100.5 (54.6)	102.3 (54.7)	65.9 (35.8)	67.2 (35.9)	18.8 (10.2)	19.1 (10.2)	15.9 (8.6)	16.1 (8.6)
2002-born steers	80	111.5 (54.8)	102.0 (54.6)	75.5 (37.1)	69.1 (37.0)	20.9 (10.3)	19.3 (10.3)	15.1 (7.4)	13.5 (7.2)
s.e.d.		1.49	0.48	1.04	0.58	0.32	0.26	0.52	0.60
				Significance					
Main effects		B, P, C	C, G, W_L	B, P, G, C	B, P, G, C, W_Q	B, P, C	G, C, W_L	B, P, G, C	P, G, C, W_Q
Interactions				B × C, P × C			P × G		

Carcass retail yield, bone and fat trim did not differ due to birthweight at an equivalent carcass weight of 380 kg (Table 1).

Effects of preweaning growth

Low preweaning growth cattle were 5.3% lighter at feedlot exit, and had hot carcasses and cold sides that weighed 6.4 and 6.2% less, respectively, than high preweaning growth cattle (Table 1). Carcasses of high preweaning growth cattle had 5.0% more retail beef, 4.7% more bone and 11.4% more fat trim than their low growth counterparts at ~30 months of age.

Low preweaning growth cattle produced carcasses with 2.0% more retail beef and 2.5% less fat trim at 380 kg carcass weight than the high preweaning growth cattle (Table 1).

Effects of sire genotype

Piedmontese- and Wagyu-sired cattle did not differ significantly in feedlot exit weight (Table 1). However, carcasses of Piedmontese-sired cattle were 5.1% heavier, produced 12.9% more retail beef and had 3.2% more bone and 21.6% less fat trim than Wagyu-sired cattle at the same age.

Piedmontese-sired cattle yielded 7.1% more retail beef than Wagyu-sired cattle at the same carcass weight, and cattle sired by Wagyu bulls had 34.1% more fat trim than those sired by Piedmontese bulls (Table 1).

Interactions

The difference in feedlot exit weight, HSCW and retail yield between low and high birthweight cattle was greater for the 2001-born heifers and the 2002-born steers than for the 2001-born steers. Although high birthweight cattle had more bone than their low birthweight counterparts within all cohorts, the magnitude of the difference between birthweight groups was greater among 2002-born steers and 2001-born heifers than among the 2001-born steers.

Forequarter characteristics

Effects of birthweight

Weight of the forequarter was 7.1% less and weights of retail beef yield 6.1%, bone 7.9% and fat trim 11.8% less in the forequarter of low than of high birthweight cattle at the same age (Table 2). Within the forequarter, all primal cuts were smaller at ~30 months of age in low than in high birthweight cattle: cube roll by 5.5%, chuck roll 7.2%, blade 6.5%, chuck tender 7.1%, shin-shank 8.4% and lean trim 5.3% (Table 3).

At the same carcass weight, forequarter weight did not differ due to birthweight (Table 2). Forequarter retail yield was 2.1% greater in low birthweight cattle compared with high birthweight cattle at 380 kg HSCW, whereas forequarter bone and fat trim did not differ due to birthweight (Table 2). Weight of shin-shank was 2.5% less and of lean trim 3.1% more in low compared with

Table 3. Predicted means for beef forequarter primal cuts ($n = 240$) at ~30 months of age and when adjusted to equivalent carcass weight (380 kg), as affected by birthweight, preweaning growth, sire genotype and cohort

n, number of cattle. Weights are least-squares means and adjusted weights are least-squares means using hot standard carcass weight (HSCW, W_L linear or W_Q quadratic if significant) as a covariate, and appropriate s.e.d. for each weight comparison. Significant ($P < 0.05$) main effects and interactions are shown for each weight variable. Values in parentheses are the percentage of cold side weight, derived from predicted means

Effect	*n*	Cube roll (kg)	Adjusted cube roll (kg)	Chuck roll (kg)	Adjusted chuck roll (kg)	Blade (kg)	Adjusted blade (kg)	Chuck tender (kg)	Adjusted chuck tender (kg)	Shin-shank (kg)	Adjusted shin-shank	Lean trim (kg)	Adjusted lean trim (kg)
Birthweight (B)													
Low	120	4.79 (2.66)	4.99 (2.67)	8.13 (4.52)	8.45 (4.52)	9.76 (5.42)	10.16 (5.43)	1.43 (0.79)	1.48 (0.79)	3.81 (2.12)	3.94 (2.11)	37.8 (21.0)	39.5 (21.1)
High	120	5.07 (2.61)	4.88 (2.61)	8.76 (4.52)	8.43 (4.51)	10.44 (5.38)	10.06 (5.38)	1.54 (0.79)	1.50 (0.80)	4.16 (2.14)	4.04 (2.16)	39.9 (20.6)	38.3 (20.5)
s.e.d.		0.070	0.056	0.139	0.123	0.123	0.079	0.019	0.017	0.051	0.043	0.53	0.34
Preweaning growth (P)													
Low	119	4.81 (2.66)	4.97 (2.66)	8.08 (4.46)	8.35 (4.47)	9.89 (5.46)	10.24 (5.48)	1.45 (0.80)	1.49 (0.80)	3.90 (2.15)	4.01 (2.14)	38.0 (21.0)	39.4 (21.1)
High	121	5.05 (2.62)	4.90 (2.62)	8.82 (4.57)	8.53 (4.56)	10.31 (5.34)	9.99 (5.34)	1.52 (0.79)	1.48 (0.79)	4.08 (2.12)	3.97 (2.12)	39.7 (20.6)	38.4 (20.5)
s.e.d.		0.069	0.054	0.138	0.118	0.121	0.076	0.018	0.016	0.050	0.041	0.52	0.33
Sire genotype (G)													
Wagyu	120	4.80 (2.64)	4.93 (2.64)	8.18 (4.49)	8.38 (4.48)	9.51 (5.23)	9.81 (5.25)	1.41 (0.77)	1.44 (0.77)	3.74 (2.05)	3.82 (2.04)	36.6 (20.1)	37.9 (20.3)
Piedmontese	120	5.06 (2.64)	4.94 (2.64)	8.72 (4.54)	8.50 (4.55)	10.68 (5.57)	10.41 (5.57)	1.56 (0.81)	1.53 (0.82)	4.24 (2.21)	4.16 (2.23)	41.1 (21.4)	40.0 (21.4)
s.e.d.		0.111	0.088	0.175	0.110	0.264	0.101	0.039	0.026	0.105	0.049	0.95	0.34
Cohort (C)													
2001-born heifers	81	4.71 (2.71)	5.07 (2.71)	7.56 (4.35)	8.15 (4.36)	8.96 (5.16)	9.72 (5.20)	1.34 (0.77)	1.42 (0.76)	3.56 (2.05)	3.83 (2.05)	35.9 (20.7)	39.1 (20.9)
2001-born steers	79	4.64 (2.43)	4.71 (2.52)	8.40 (4.57)	8.53 (4.56)	9.70 (5.27)	9.91 (5.30)	1.45 (0.79)	1.47 (0.79)	4.03 (2.19)	4.10 (2.19)	37.7 (20.5)	38.4 (20.5)
2002-born steers	80	5.44 (2.67)	5.01 (2.68)	9.39 (4.62)	8.64 (4.62)	11.62 (5.71)	10.70 (5.72)	1.68 (0.83)	1.58 (0.85)	4.36 (2.14)	4.04 (2.16)	43.0 (21.1)	39.2 (21.0)
s.e.d.		0.090	0.085	0.173	0.174	0.163	0.117	0.025	0.025	0.067	0.063	0.69	0.49
Significance													
Main effects		B, P, G, C	C, W_L	B, P, G, C	C, W_L	B, P, G, C	P, G, C, W_Q	B, P, G, C	G, C, W_L	B, P, G, C	B, G, C, W_L	B, P, G, C	B, P, G, C, W_L
Interactions						B × C				B × C	B × G	B × C, P × C	

Table 4. Predicted means for yield characteristics of beef hindquarters ($n = 240$) at ~30 months of age and when adjusted to equivalent carcass weight (380 kg), as affected by birthweight, preweaning growth, sire genotype and cohort

n, number of cattle. Weights are least-squares means and adjusted weights are least-squares means using hot standard carcass weight (HSCW, W_L linear or W_Q quadratic if significant) as a covariate, and appropriate s.e.d. for each weight comparison. Significant ($P < 0.05$) main effects and interactions are shown for each weight variable. Values in parentheses are the percentage of cold side weight, derived from predicted means

Effect	*n*	Hindquarter (kg)	Adjusted hindquarter (kg)	Hindquarter retail yield (kg)	Adjusted hindquarter retail yield (kg)	Hindquarter bone (kg)	Adjusted hindquarter bone (kg)	Hindquarter fat trim (kg)	Adjusted hindquarter fat trim (kg)
				Birthweight (B)					
Low	120	76.0 (42.2)	79.0 (42.3)	53.8 (29.9)	55.8 (29.8)	11.7 (6.5)	12.1 (6.5)	10.5 (5.8)	11.0 (5.9)
High	120	82.4 (42.5)	79.7 (42.6)	58.0 (29.8)	56.1 (30.0)	12.6 (6.5)	12.2 (6.5)	11.7 (6.0)	11.3 (6.0)
s.e.d.		0.77	0.32	0.60	0.37	0.15	0.12	0.26	0.26
				Preweaning growth (P)					
Low	119	77.1 (42.6)	79.5 (42.5)	54.8 (30.3)	56.5 (30.2)	11.9 (6.6)	12.3 (6.6)	10.3 (5.7)	10.7 (5.7)
High	121	81.3 (42.1)	79.1 (42.3)	57.0 (29.5)	55.4 (29.6)	12.4 (6.4)	12.1 (6.5)	11.9 (6.2)	11.6 (6.2)
s.e.d.		0.75	0.30	0.58	0.35	0.14	0.11	0.25	0.25
				Sire genotype (G)					
Wagyu	120	76.4 (42.0)	78.4 (41.9)	52.0 (28.6)	53.4 (28.6)	11.9 (6.5)	12.2 (6.5)	12.5 (6.9)	12.7 (6.8)
Piedmontese	120	82.0 (42.7)	80.3 (43.0)	59.8 (31.2)	58.5 (31.3)	12.4 (6.5)	12.1 (6.5)	9.8 (5.1)	9.5 (5.1)
s.e.d.		1.60	0.41	1.29	0.58	0.37	0.17	0.35	0.40
				Cohort (C)					
2001-born heifers	81	74.2 (42.7)	79.6 (42.6)	53.1 (30.6)	56.8 (30.4)	10.9 (6.3)	11.7 (6.3)	10.3 (5.9)	11.0 (5.9)
2001-born steers	79	77.3 (42.0)	78.6 (42.0)	55.0 (29.9)	55.9 (29.9)	12.3 (6.7)	12.5 (6.7)	9.9 (5.4)	10.1 (5.4)
2002-born steers	80	86.1 (42.3)	79.8 (42.9)	59.6 (29.3)	55.2 (29.5)	13.3 (6.5)	12.4 (6.6)	13.2 (6.5)	12.2 (6.5)
s.e.d.		1.02	0.47	0.79	0.55	0.20	0.18	0.32	0.39
				Significance					
Main effects		B, P, G, C	B, G, C, W_L	B, P, G, C	P, G, C, W_L	B, P, C	C, W_L	B, P, G, C	P, G, C, W_L
Interactions								B × G	

high birthweight cattle, while the weight of the other forequarter primal cuts was not affected by birthweight when compared at the same carcass weight (Table 3).

Effects of preweaning growth

Forequarter weight was 5.5% lower, in slowly grown cattle compared with rapidly grown cattle, at ~30 months of age (Table 2). Forequarter retail yield of slowly grown cattle was 5.1% lower, bone 4.0% lower, and fat trim 15.6% lower compared with their rapidly grown counterparts (Table 2). Weight of cube roll was lower by 4.8%, chuck roll by 8.4%, blade by 4.1%, chuck tender by 4.6%, shin-shank by 4.4% and lean trim by 4.3% in cattle grown slowly compared with those grown rapidly to weaning (Table 3).

Forequarter weight did not differ due to preweaning growth at 380 kg carcass weight; however, cattle grown slowly had 2.1% more retail beef and 15.6% less fat trim than those grown rapidly to weaning (Table 2). At the same carcass weight, blade weighed 2.5% more and lean trim 2.6% more in cattle grown slowly compared with those grown rapidly to weaning, and weights of cube roll, chuck roll, chuck tender, and shin-shank did not differ due to preweaning growth (Table 3).

Effects of sire genotype

Piedmontese-sired cattle had a forequarter 3.8% heavier than Wagyu-sired cattle at the same age (Table 2). Piedmontese-sired cattle yielded 11.2% more retail beef from the forequarter than Wagyu-sired cattle. Piedmontese-sired cattle had 3.1% heavier bones in the forequarter than Wagyu-sired cattle. Wagyu-sired cattle had 28.6% more fat trim from the forequarter than Piedmontese-sired cattle. Piedmontese-sired cattle had a heavier cube roll (by 5.4%), chuck roll (6.6%), blade (12.3%), chuck tender (10.6%), shin-shank (13.4%) and forequarter lean trim (12.3%) than Wagyu-sired cattle at ~30 months of age (Table 3).

Forequarter weight at 380 kg carcass weight was 1.9% less in Piedmontese-sired cattle compared with Wagyu-sired cattle (Table 2). Piedmontese-sired cattle yielded 5.0% more forequarter retail beef than Wagyu-sired cattle at equivalent carcass weight. Piedmontese-sired cattle had 2.0% less bone than Wagyu-sired cattle at 380 kg HSCW. Piedmontese-sired cattle had 26.6% less fat trim than Wagyu-sired cattle at the 380 kg HSCW. Piedmontese sire cattle had a larger blade (6.1% heavier), chuck tender (6.3%), shin-shank (8.9%) and lean trim (5.5%) in the forequarter than Wagyu-sired cattle at the same HSCW (Table 3).

Interactions

The difference in forequarter retail yield, blade, shin-shank and lean trim between the low and high birthweight cattle was greater within the 2002-born steers and the 2001-born heifers than within the 2001-born steers for which the differences were

Table 5. Predicted means for beef hindquarter primal cuts (*n* = 240) at ~30 months of age and when adjusted to equivalent carcass weight (380 kg), as affected by birthweight, preweaning growth, sire genotype and cohort

n, number of cattle. Weights are least-squares means and adjusted weights are least-squares means using hot standard carcass weight (HSCW, W_L linear or W_Q quadratic if significant) as a covariate, and appropriate s.e.d. for each weight comparison. Significant ($P < 0.05$) main effects and interactions are shown for each weight variable. Values in parentheses are the percentage of cold side weight, derived from predicted means

Effect	*n*	Topside (kg)	Adjusted topside (kg)	Eye round (kg)	Adjusted eye round (kg)	Outside flat (kg)	Adjusted outside flat (kg)	Knuckle (kg)	Adjusted knuckle (kg)	Rump (kg)	Adjusted rump (kg)
						Birthweight (B)					
Low	120	8.82 (4.90)	9.13 (4.88)	2.64 (1.47)	2.74 (1.47)	6.44 (3.58)	6.68 (3.57)	6.24 (3.47)	6.47 (3.46)	6.53 (3.63)	6.81 (3.64)
High	120	9.44 (4.87)	9.15 (4.89)	2.84 (1.46)	2.74 (1.47)	6.92 (3.57)	6.69 (3.58)	6.71 (3.46)	6.49 (3.47)	7.07 (3.64)	6.80 (3.64)
s.e.d.		0.151	0.147	0.039	0.034	0.075	0.048	0.077	0.058	0.105	0.900
						Preweaning growth (P)					
Low	119	8.92 (4.93)	9.18 (4.91)	2.70 (1.49)	2.78 (1.49)	6.53 (3.61)	6.75 (3.61)	6.36 (3.51)	6.55 (3.50)	6.61 (3.65)	6.84 (3.66)
High	121	9.35 (4.85)	9.10 (4.87)	2.77 (1.44)	2.70 (1.44)	6.83 (3.54)	6.63 (3.55)	6.60 (3.42)	6.41 (6.43)	6.98 (3.62)	6.78 (3.63)
s.e.d.		0.148	0.141	0.038	0.032	0.074	0.046	0.076	0.055	0.104	0.087
						Sire genotype (G)					
Wagyu	120	8.32 (4.57)	8.52 (4.56)	2.40 (1.32)	2.47 (1.32)	6.23 (3.42)	6.41 (3.43)	6.06 (3.33)	6.22 (3.33)	6.45 (3.54)	6.62 (3.54)
Piedmontese	120	9.94 (5.18)	9.77 (5.23)	3.08 (1.61)	3.01 (1.61)	7.13 (3.72)	6.96 (3.72)	6.89 (3.59)	6.74 (3.61)	7.14 (3.72)	7.00 (3.74)
s.e.d.		0.224	0.172	0.072	0.053	0.172	0.095	0.159	0.092	0.166	0.077
						Cohort (C)					
2001-born heifers	81	9.15 (5.27)	9.72 (5.20)	2.66 (1.53)	2.85 (1.52)	6.20 (3.57)	6.66 (3.56)	5.54 (3.19)	5.95 (3.18)	6.64 (3.82)	7.15 (3.82)
2001-born steers	79	9.97 (5.42)	10.12 (5.41)	2.77 (1.51)	2.81 (1.50)	6.50 (3.53)	6.63 (3.55)	6.09 (3.31)	6.22 (3.33)	6.61 (3.59)	6.72 (3.59)
2002-born steers	80	8.28 (4.07)	7.59 (4.06)	2.78 (1.37)	2.57 (1.37)	7.34 (3.61)	6.77 (3.62)	7.80 (3.83)	7.27 (3.89)	7.14 (3.51)	6.55 (3.50)
s.e.d.		0.192	0.215	0.051	0.051	0.101	0.073	0.102	0.077	0.135	0.126
						Significance					
Main effects		B, P, G, C	G, C, W_Q	B, G	P, G, C, W_L	B, P, G, C	P, G, C, W_Q	B, P, G, C	P, G, C, W_Q	B, P, G, C	G, C, W_L
Interactions				B × C		B × C	P × G	B × C			

not significant. The difference in forequarter retail beef yield and lean trim between the cattle grown rapidly and slowly to weaning was greater for the 2001-born steers and the 2002-born steers than in the 2001-born heifers in which weight of the cattle did not differ due to birthweight. Within the Piedmontese-sired cattle, those of high birthweight had more shin-shank meat than those of low birthweight, whereas within the Wagyu-sired cattle the difference was not significant. The effect of sire breed on bone weight at 380 kg HSCW was primarily due to the difference within the cattle grown rapidly compared with those grown slowly to weaning.

Hindquarter characteristics

Effects of birthweight

Hindquarter weight was 7.8% less and weights of retail beef 7.2%, bone 7.1%, and fat trim 10.3% lower in the hindquarter in low than in high birthweight cattle (Table 4). Within the hindquarter, low birthweight cattle had lower weights of all primal cuts: weight of topside differed by 6.6%, eye round 7.0%, outside flat 6.9%, knuckle 7.0%, rump 7.6%, striploin 6.4%, tenderloin 7.6%, flank steak 13.0%, shin-shank 7.5% and lean trim 6.7% between the low birthweight cattle compared with high birthweight cattle (Tables 5 and 6).

Hindquarter weight was 0.9% less in low birthweight cattle compared with high birthweight cattle at the same HSCW, whereas hindquarter retail yield, bone and fat trim were unaffected by birthweight (Table 4). Among the hindquarter primal cuts, only the weight of shin-shank, which was 1.5% less in the low birthweight cattle compared with high birthweight cattle, differed due to birthweight when compared at the same carcass weight (Tables 5 and 6).

Effects of preweaning growth

The hindquarter of cattle grown slowly weighed 5.2% less than that of those grown rapidly to weaning, and retail yield was 3.9% lower, bone was 4.0% lower, and fat trim was 13.4% lower at ~30 months of age (Table 4). Weights of topside (4.6% lower), outside flat (1.3%), knuckle (3.6%), rump (5.3%), striploin (6.1%), tenderloin (4.2%) and shin-shank (3.3%) were lower in cattle grown slowly compared with those grown rapidly to weaning, while eye round, flank steak and lean trim weights did not differ due to preweaning growth (Tables 5 and 6).

At 380 kg HSCW, hindquarter weight did not differ due to preweaning growth; however, retail yield was 2.0% greater and fat trim 7.8% lower in cattle grown slowly to weaning compared with their rapidly grown counterparts (Table 4). Weights of eye round (3.0% heavier), outside flat (1.8%) and knuckle (2.3%) were heavier at the same HSCW in cattle grown slowly compared with those grown rapidly to weaning, and did not differ due to preweaning growth for the other hindquarter primal cuts (Tables 5 and 6).

Table 6. Predicted means for beef hindquarter primal cuts (*n* = 240) at ~30 months of age and when adjusted to equivalent carcass weight (380 kg), as affected by birthweight, preweaning growth, sire genotype and cohort

n, number of cattle. Weights are least-squares means and adjusted weights are least-squares means using hot standard carcass weight (HSCW, W_L linear or W_Q quadratic if significant) as a covariate, and appropriate s.e.d. for each weight comparison. Significant ($P < 0.05$) main effects and interactions are shown for each weight variable. Values in parentheses are the percentage of cold side weight, derived from predicted means

Effect	*n*	Striploin (kg)	Adjusted striploin (kg)	Tenderloin (kg)	Adjusted tenderloin (kg)	Flank steak (kg)	Adjusted flank steak (kg)	Shin-shank (kg)	Adjusted shin-shank (kg)	Lean trim (kg)	Adjusted lean trim (kg)
Birthweight (B)											
Low	120	5.73 (3.19)	5.96 (3.19)	2.67 (1.48)	2.76 (1.47)	0.87 (0.48)	0.90 (0.48)	4.33 (2.41)	4.47 (2.39)	9.7 (5.39)	10.2 (5.46)
High	120	6.12 (3.15)	5.90 (3.16)	2.89 (1.49)	2.81 (1.50)	1.00 (0.52)	0.98 (0.52)	4.68 (2.41)	4.54 (2.43)	10.4 (5.36)	10.0 (5.35)
s.e.d.		0.081	0.064	0.028	0.028	0.053	0.060	0.051	0.040	0.25	0.25
Preweaning growth (P)											
Low	119	5.74 (3.17)	5.93 (3.17)	2.72 (1.50)	2.80 (1.50)	0.94 (0.52)	0.96 (0.51)	4.43 (2.45)	4.55 (2.43)	10.0 (5.52)	10.3 (5.51)
High	121	6.11 (3.17)	5.93 (3.17)	2.84 (1.47)	2.77 (1.48)	0.93 (0.48)	0.92 (0.49)	4.58 (2.37)	4.46 (2.39)	10.1 (5.24)	9.9 (5.30)
s.e.d.		0.079	0.061	0.033	0.026	0.053	0.057	0.050	0.038	0.24	0.25
Sire genotype (G)											
Wagyu	120	5.66 (3.11)	5.82 (3.11)	2.64 (1.45)	2.70 (1.44)	0.87 (0.48)	0.89 (0.48)	4.13 (2.27)	4.23 (2.26)	9.3 (5.11)	9.5 (5.08)
Piedmontese	120	6.19 (3.23)	6.04 (3.23)	2.93 (1.53)	2.87 (1.54)	1.00 (0.52)	0.99 (0.53)	4.86 (2.53)	4.79 (2.56)	10.8 (5.63)	10.7 (5.72)
s.e.d.		0.137	0.087	0.070	0.042	0.050	0.056	0.120	0.063	0.35	0.22
Cohort (C)											
2001-born heifers	81	5.68 (3.27)	6.10 (3.26)	2.59 (1.49)	2.76 (1.48)	0.82 (0.47)	0.87 (0.47)	4.08 (2.35)	4.36 (2.33)	9.8 (5.65)	10.6 (5.67)
2001-born steers	79	5.80 (3.15)	5.90 (3.16)	2.76 (1.50)	2.80 (1.50)	0.97 (0.53)	0.97 (0.52)	4.51 (2.45)	4.58 (2.45)	9.3 (5.06)	9.5 (5.08)
2002-born steers	80	6.29 (3.09)	5.79 (3.10)	2.99 (1.47)	2.79 (1.49)	1.02 (0.50)	0.97 (0.52)	4.92 (2.42)	4.58 (2.45)	11.1 (5.46)	10.2 (5.46)
s.e.d.		0.103	0.094	0.044	0.041	0.065	0.085	0.069	0.060	0.31	0.36
Significance											
Main effects		B, P, G, C	G, C, W_L	B, P, G, C	G, W_L	B, G, C	W_L	B, P, G, C	B, P, G, C, W_L	B, G, C	G, C, W_L
Interactions		B × C	P × C	B × C				B × C			

Effects of sire genotype

Piedmontese-sired cattle had a hindquarter 7.3% heavier than Wagyu-sired cattle (Table 4). Piedmontese-sired cattle yielded 15.0% more retail beef from the hindquarter than Wagyu-sired cattle. Piedmontese-sired cattle had 4.2% heavier bones in the hindquarter than Wagyu-sired cattle. Wagyu-sired cattle had 27.6% more fat trim from the hindquarter than Piedmontese-sired cattle. Piedmontese-sired cattle had a heavier topside (19.5% heavier), eye round (28.3%), outside flat (14.4%), knuckle (13.7%), rump (10.7%), striploin (9.4%), tenderloin (11.0%), flank steak (13.0%), hindquarter shin-shank (17.7%) and lean trim (16.1%) than Wagyu-sired cattle at the same age (Tables 5 and 6).

Hindquarter weight at 380 kg carcass weight was 2.4% greater in Piedmontese-sired compared with Wagyu-sired cattle (Table 4). Piedmontese-sired cattle yielded 9.6% more hindquarter retail beef than Wagyu-sired cattle at equivalent carcass weight. At the same carcass weight (380 kg), hindquarter bone weight did not differ due to sire genotype. Piedmontese-sired cattle had 25.2% less hindquarter fat trim than Wagyu-sired cattle. Weight of topside at 380 kg HSCW was 14.7% heavier in Piedmontese-sired than in Wagyu-sired cattle. Eye round weight was greater by 21.9%, outside flat by 8.5%, knuckle by 8.4%, rump by 5.7%, striploin by 3.8%, tenderloin by 11.0%, hindquarter shin-shank meat by 13.3% and hindquarter lean trim by 12.6% (Tables 5 and 6).

Interactions

The difference between the high and low birthweight cattle was greater in the 2002-born steers and the 2001-born heifers than in the 2001-born steers for the eye round, outside flat, knuckle, striploin, tenderloin and shin-shank, with the weights of these primal cuts not differing due to birthweight within the 2001-born steers. There was also an interaction between preweaning growth and cohort, with the cattle grown slowly from birth to weaning having a heavier striploin for the 2001-born steer cohort, tending to have a smaller striploin for the 2001-born heifer cohort, with no difference apparent for the 2002-born steer cohort. The difference in fat trim between the low and high birthweight cattle was greater in those sired by Wagyu bulls than those sired by Piedmontese bulls for which the difference was not significant. At 380 kg HSCW, the difference in weight of outside flat due to growth to weaning was primarily due to a significant difference within the Piedmontese-sired cattle.

Discussion

This study is the first to assess the long-term impact of growth during gestation and from birth to weaning on beef primal cuts. The results demonstrate that cattle of low birthweight or grown slowly to weaning have smaller primal cuts at 30 months of age as a result of having reduced liveweight and smaller carcasses compared with their high birthweight and rapidly grown counterparts. However, when compared at equivalent carcass weights (380 kg) those cattle restricted in growth from birth to weaning were leaner than their rapidly grown counterparts and yielded slightly more beef, which resulted in some primal cuts being heavier in the slowly compared with the rapidly grown cattle. Compositional differences due to birthweight were less apparent at the same carcass weight, although the low birthweight cattle had slightly higher forequarter retail yield and smaller hindquarter, less shin-shank meat, and more forequarter lean trim at the same carcass weight than the high birthweight cattle, suggesting some minor alterations to the distribution of carcass tissues as a result of growth during prenatal life. There were few interactions between sire genotype and birthweight or between sire genotype and preweaning growth for the yield-related variables. Interactions between birthweight and preweaning growth rate were not evident for any of the variables studied. However, there was some variability between cohorts in the long term responses to growth early in life, particularly when comparing low and high birthweight cattle.

Overall, the present findings are consistent with our previous results, in that significantly lower birthweight has little influence on yield and indices of carcass fatness beyond differences normally attributable to variation in live or carcass weights at 30 months of age (Greenwood *et al*. 2006; Greenwood and Cafe 2007). Our findings are also generally consistent with studies on consequences of nutritional restriction (Tudor 1972; Tudor and O'Rourke 1980; Tudor *et al*. 1980) or supplementation of cattle during late pregnancy (Stalker *et al*. 2006) or of low birthweight due to twinning (de Rose and Wilton 1991; Clarke *et al*. 1994; Wilkins *et al*. 1994; Gregory *et al*. 1996) in which compositional differences at equivalent slaughter weights or ages are small and not significant. However, the findings in cattle contrast those in low birthweight sheep that became fatter than higher birthweight sheep during growth to ~20 kg (Greenwood *et al*. 1998), 35 kg (Villette and Theriez 1981) and 60 kg (Louey *et al*. 2005) liveweight. Differences between the results for the two species are probably influenced by the more severe intrauterine growth retardation in the fetal sheep compared with cattle in the present study, and the more intensive postnatal environments within which the sheep were reared.

While there appeared to be some shift due to birthweight in the weight of some carcass components at an equivalent carcass weight within the present study, these were few and small in magnitude, and likely to be of limited economic consequence for beef processors. However, of potentially more serious consequence for beef cattle producers is the reduction in HSCW and, therefore, weight of beef primal cuts due to low birthweight compared with high birthweight at the same slaughter age. This would result in lower payments to producers and in processing inefficiencies due to smaller carcasses, or increased feed costs to ensure feedlot entry or slaughter weights of low birthweight cattle are similar to those of their high birthweight counterparts (Alford *et al*. 2007, 2009).

Slower growth to weaning resulted in smaller primal cuts and less retail meat from lighter cattle with smaller carcasses compared with cattle grown more rapidly to weaning when compared at 30 months of age, again with economic consequences for producers and processors (Alford *et al*. 2007, 2009). At the same carcass weight, total retail yield was higher, fat trim was lower, and weight of the blade, eye round, outside flat, knuckle, hindquarter shin-shank, and forequarter lean trim were greater in the cattle grown slowly to weaning compared with those grown rapidly. However, these primal cuts are generally of lower value and the extent of any economic advantage to processors from these leaner carcasses remains to be established. On a broader level, the results of the present study for effects of growth to weaning on yield components and carcass composition are consistent with other studies in cattle, which were reviewed by Berge (1991) and Greenwood and Cafe (2007) and, for cattle within similar production systems to those of the present study, by Hearnshaw (1997).

The failure to find any interactions between birthweight and preweaning growth is intriguing as it is in contrast to the literature relating to human health in which interactions between prenatal nutrition and/or growth and diet during the postnatal period are believed to influence long-term outcomes for health and wellbeing, including obesity (Hales and Barker 2001; Breier *et al*. 2004; Langley-Evans 2006). It is now believed that severely restricted growth during human fetal life results in a so-called 'thrifty phenotype' (Hales and Barker 2001), which is adapted to an environment in which the supply of nutrients is limited. This phenotype is apparently predisposed to obesity, particularly within the abdominal region, and to other metabolic disorders and associated health problems such as type 2 diabetes if exposed to lifestyles with excessive supply of calories and limited physical activity. In our experiment, the cattle were grown within a pasture-based system, with provision of some supplementation as concentrate when growth rates were deemed too slow during postnatal life (see Cafe *et al*. 2006*a*; Greenwood *et al*. 2006). However, they experienced prolonged, moderate rates of growth that required foraging at pasture during postnatal life until 26 months of age. Hence, the overall lack of adverse effects of growth during prenatal and preweaning life on indices of fatness and on muscle mass observed within the present study and by Cafe *et al*. (2006*b*), Greenwood *et al*. (2006) and Greenwood and Cafe (2007), and on efficiency in the feedlot (Greenwood and Cafe 2007; Cafe *et al*. 2009), may well be due to the postweaning environment in which the animals grew before feedlot entry. This suggests that any influences of growth early in life on body and carcass composition may be overridden by environmental influences, particularly nutrition, during subsequent phases of growth. In contrast to the present experiment, cattle in the study of Tudor *et al*. (1980) were substantially fatter and had smaller muscles at the same live and carcass weights when held near their birthweights for 200 days compared with well grown controls when both groups were fed concentrates from weaning until ~400 kg liveweight. Similarly to the present study, however, when cattle within the study of Tudor *et al*. (1980) were grown from weaning to ~400 kg liveweight on pasture, differences in body and carcass composition due to growth early in life were not evident. These findings emphasise the importance of the diet during recovery from severe growth retardation early in life of cattle in determining long-term outcomes for compositional characteristics.

Despite the lack of interactions between birthweight and prenatal growth, interactions were evident between birthweight category and cohort for liveweight at feedlot entry, for hot carcass and cold side weights, and for various beef primal cuts, with the effects of birthweight generally being smallest within the 2001-born steers. While the design of the present experiment did not enable the cause or causes of these interactions to be identified, the findings do suggest that there are environmental factors that remain to be determined that may exacerbate or ameliorate the adverse effects of restricted birthweight on subsequent growth, carcass and yield characteristics. In this regard, there was variation in nutrition and other environmental factors between cohorts from conception to feedlot exit (see Cafe *et al*. 2006*a*, 2009; Greenwood *et al*. 2006).

In relation to effects of sire genotype, the results of this study and those reported by Greenwood *et al*. (2006) are consistent with expected differences in yield and fatness characteristics for Wagyu- and Piedmontese-sired cattle. Piedmontese cattle carry a loss of function mutation for myostatin, which results in increased muscling and reduced fatness (McPherron and Lee 1997). The Piedmontese-sired cattle in the present study were confirmed to be heterozygous for this mutation. By comparison, Wagyu cattle have been genetically selected for their capacity to produce intramuscular or marbling fat, and all Wagyu-sired cattle in the present study were confirmed to be homozygous for the normal myostatin gene. It is not possible, however, within the present study to determine the extent to which differences in yield, fatness, primal cut and other characteristics reported here and by Greenwood *et al*. (2006), Greenwood and Cafe (2007) and Cafe *et al*. (2009) are due to the mutant myostatin allele, or are due to other genetic factors associated with the Piedmontese and Wagyu breeds.

The present study also aimed to determine the extent to which genotype may interact with nutrition early in life to influence yield characteristics in the long term. However, there were few interactions between birthweight or growth to weaning and sire genotype, the only occurrences being for weights of forequarter bone, forequarter shin-shank meat and the outside flat at the same carcass weight, and for weight of hindquarter fat trim at the same age. Again, the findings of the present study are generally consistent with those of Cafe *et al*. (2006*a*, 2009) and Greenwood *et al*. (2006) for growth, efficiency, compositional, and beef quality characteristics, where interactions between genotype and growth early in life were not evident. They are also consistent with the lack of interactions between backgrounding growth rate and genotype for subsequent carcass characteristics in the recent study of McKiernan *et al*. (2009) in which slower backgrounding growth also resulted in leaner cattle than more rapid backgrounding growth.

Finally, while the present study has shown a reduction in the yield of primal cuts at 30 months of age, but few adverse effects at the same carcass weight, due to chronic growth retardation early in life, there remains a need for research to assess effects of more acute influences during development on beef production parameters. This includes more specifically targeted research during the embryonic, fetal and neonatal periods.

Conclusions

The cattle of low birthweight or grown slowly to weaning had smaller primal cuts at 30 months of age as a result of having reduced liveweight and smaller carcasses when compared with their high birthweight and more rapidly grown counterparts. When compared at equivalent carcass weights (380 kg), cattle restricted in growth from birth to weaning were leaner and yielded slightly more beef than their rapidly grown counterparts, which resulted in some primal cuts being heavier in the slowly grown compared with the rapidly grown cattle. Compositional differences due to birthweight were less apparent at the same carcass weight, although the low birthweight cattle had a higher forequarter retail yield, a smaller hindquarter, less shin-shank meat, and more forequarter lean trim at the same carcass weight than the high birthweight cattle, suggesting some minor alterations to the distribution of carcass tissues as a result of growth during prenatal life. There were few interactions between sire genotype and birthweight or between sire genotype and preweaning growth for the yield-related variables. Interactions between birthweight and preweaning growth rate were not evident for any of the variables studied. However, there was some variability between cohorts in the long-term responses to growth early in life, particularly when comparing low and high birthweight. Overall, this study shows that effects of birthweight and preweaning growth rate on carcass compositional and yield characteristics were mostly explained by variation in carcass weight and, hence, in whole body growth to 30 months of age.

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