

Genetic Variation in Growth and Body Dimensions of Jersey and Limousin Cross Cattle. 1. Pre-Weaning Performance

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ABSTRACT : During a 5-yr period, 1994-1998, pre-weaning and weaning data were collected on 591 calves produced by mating either straightbred Jersey, straightbred Limousin or F₁ (Limousin×Jersey) bulls to mature purebred Jersey or Limousin cows. Traits recorded included birth and weaning weight, height, length, girth, fat depth and a measure of muscle (ratio of stifle to hip width expressed as a percentage). All traits were analyzed assuming a model with sire and dam random effects that included effects of year and date of birth, sex, breed and year×sex interaction. Main effects were generally significant with few exceptions. Direct genetic effects were large for weight, height, girth and muscle with a breed trend from purebred Jersey (small) to purebred Limousin (large). At weaning, the maternal effect of the Jersey dam was positive for weight (10.9±4.9 kg), girth (3.7±1.0 cm) and muscle (6.0±0.9%). Heterosis was highly significant and positive only for fat depth (1.5±0.2 mm) with the F₁ progeny being the fattest, followed by the backcrosses, then purebred Jersey and purebred Limousin. Also, significant (p<0.001) but negative heterosis was observed for weight, girth and muscle. The change in ranking for fat depth relative to other traits is a reflection of the large heterotic effects relative to direct effects on fat depth. Epistatic effects were not significant on any trait at birth or weaning. This study has indicated the possibility of exploiting the positive heterotic and maternal effects for fat depth and muscularity to meet specific meat quality and quantity demand by consumers. (*Asian-Aust. J. Anim. Sci.* 2002, Vol 15, No. 10 : 1371-1377)

Key Words : Genetic Effects, Weight, Height, Fat, Muscle

INTRODUCTION

Estimates of growth potential in early life of beef cattle can assist in improved selection decisions. However, the maternal ability of dam, expressed in genetic and environmental effects, play a vital role in this regard. Several authors have suggested that calf daily weight gain from birth to around two months of age would be suitable for evaluation of maternal ability (Shimada et al., 1988; Meyer, 1992; Shimada and William, 1992).

Breed diversity in growth performance characteristics is a useful genetic resource for improving the efficiency of beef production. Recent feedlot trials with crossbred cattle (D. L. Rutley unpublished) have shown that weight, height, fat depth and visual muscle score (score developed by McKiernan, 1990) are sufficient to describe variation in feedlot performance of most economically important traits (average daily gain, carcass weight, fat depth and saleable beef yield). Body dimensions can also serve either to supplement body weight as a measure of productivity or as predictors of some less visible characteristics. The influence of breed, maternal and heterosis effects on weight and height of crossbred cattle from diverse parental breeds (Brahman and Hereford) have previously been reported

(Pitchford et al., 1993). The objective of this study was to estimate four genetic effects on pre-weaning and weaning growth and body development in crosses between two very different cattle breeds: Jersey and Limousin.

MATERIALS AND METHODS

Experimental design

The animals used in the study were 591 calves born from 1994 through 1998 as part of the Davies Gene Mapping Herd. In the design, which involved two phases, year and breed were partially confounded (Table 1). In phase 1, two Jersey bulls were mated to Jersey cows to produce purebred Jersey (JJ) calves (1994-1996) and two Limousin bulls were mated to Jersey and Limousin cows to produce purebred Limousin (LL) and F₁ (LJ) calves born in 1994 and 1995. Phase 2 consisted of backcross calves resulting from the mating of three F₁ bulls to purebred Jersey or Limousin cows to produce Jersey backcross (XJ) or Limousin backcross (XL) calves born in 1996-1998. In addition, there were some purebred Jersey calves generated in 1996 from the original two Jersey bulls. Within phases, there were common sires and across the phases, there were many common dams (total 280). Calves were born in autumn (March-May), single suckled and weaned in summer (first week in February) at an average age of 250 days.

Calves were born at Martindale near Mintaro in the cereal zone of South Australia's mid -North. The soil type

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Table 1. Number of calves per breed and year combination

Breed	1994 ^a	1995	1996	1997	1998	Total calves	Sires ^b	Dams ^b
Jersey (JJ)	19	31	29	-	-	79	2	67
LJ×JJ (XJ)	-	-	38	94	73	205	3	134
LL×JJ (LJ)	28	33	-	-	-	61	2	52
LJ×LL (XL)	-	-	43	60	62	165	3	78
Limousin (LL)	26	55	-	-	-	81	2	63
Total	73	119	110	154	135	591	7	280

^a Hip and stifle width not recorded.

^b Sires and dams used across years and breeds.

within this region ranges between shallow red-brown to heavy texture grey-brown type. The seasonal annual rainfall distribution pattern during the experiment (1994-1998) varied, with an annual average of 586 mm of which 34% fell in summer period (October-March) and 66% fell in winter period (April-September), a condition typical of Mediterranean climates. Calves stayed with their dams on pasture and also have free access to hay supplements provided to dams during the critical feed shortage period (January-June).

Measurements

At birth, calves were weighed. Body measurements were obtained from individual animals using a tape for height (measured as the distance from hip to the ground), length (measured as the distance between the first sacral bone on the shoulder and the pin-bone) and girth (measured as the body circumference immediately posterior to the front leg).

Calves were again weighed at weaning while full. Height was measured as the difference between the distance from the top of the crush down to the top of the hips and the distance to the ground. The length and girth were measured similarly to that at birth. Other measurements at weaning were fat depth scanned at the P8 site on the rump using Ezi-scan® sonic device (AMAC Pty. Ltd.) plus hip width (bone) and stifle width (muscle) measured using calipers. Stifle width as a proportion (%) of hip width was used as an indication of the muscularity. This is similar to that used previously by McKiernan (1990) who developed visual techniques for assessing meat yield. Hip and stifle widths were not measured on calves born in 1994. Growth rate (per day) was calculated for each of the traits measured at both ages (birth and weaning).

Statistical analysis

Fifteen traits were analyzed with a model containing fixed effects of year of birth (1994-98), day of birth (5 classes with each comprising 20% of calves born in succession), sex of calf (heifer or steer), breed of calf (JJ, XJ, LJ, XL, LL). The model also included random effects of sire (2 Jersey, 2 Limousin and 3 F₁) and dam (189 Jersey and 91 Limousin). Since there were no values for weaning

muscularity (WMUS) in 1994, the model for WMUS included the fixed effects of phase and year nested within phase. The year of birth by sex interaction was included in the analysis since it was significant for some traits at weaning. All other two-way interactions tested were not significant. The analysis was conducted using Proc Mixed (SAS, 1992).

Genetic effects were estimated as originally proposed by Dickerson (1969). They were modified because of the breed combinations used. Effects were estimated in a similar manner to Pitchford et al. (1993). Four genetic effects were estimated from the five breed combinations (as shown below).

Jersey direct = JJ-LL-XJ+XL = -Limousin direct

Jersey maternal = (LL-JJ)/2+XJ-XL = -Limousin maternal

Heterosis = LJ-LL-XJ+XL

Epistasis = 2(XJ)-LJ-JJ

All effects were estimated as deviations from the purebred mean. Since there were only 5 breed combinations, epistasis was completely confounded with paternal heterosis. The effects were calculated as linear contrasts between least square means with T-tests for significant deviation from zero. Significance was defined as $p < 0.05$.

RESULTS

Raw correlations between traits measured at weaning and their average daily gains (ADG) after birth to weaning were 0.95, 0.45, 0.67 and 0.64 for weight, height, length and girth, respectively. At birth, there were significant influence of all the fixed effects on weight, length, height and girth (Table 2).

Non-genetic effects

The largest calves (weight, height, length and girth) were those born in 1995 whereas the smallest were those born 1998. At birth, the first 20% of calves born were smaller in weight (26 kg), height (68 cm), length (52 cm) and girth (67 cm) as compared to the remaining 80% (29 kg, 71 cm, 55 cm and 71 cm respectively). Male (bull) calves at birth were 3% heavier and 1% bigger in size (height, length

Table 2. Analysis of variance and tests of significance for pre-weaning and weaning traits

Trait	Effect							
	YOB ^a	DOB ^a	Sex ^a	Breed ^a	YOB×Sex ^a	Sire ^b	Dam ^b	Residual ^b
Birth								
Weight (kg)	10.1***	8.0***	46.4***	172.2***	0.5	0.4	2.8	12.0
Height (cm)	29.4***	9.1***	8.6**	48.2***	2.3	0.5	2.8	12.1
Length (cm)	5.7***	9.9***	5.6*	35.0***	0.3	0.6	2.2	8.1
Girth (cm)	11.7***	13.5***	11.5***	152.0***	0.1	0.0	3.5	9.8
Weaning								
Weight (kg)	92.7***	17.2***	61.6***	39.0***	3.1*	43.5	206.7	514.2
Height (cm)	20.7***	12.6***	57.0***	57.0***	2.9*	1.7	1.2	13.7
Length (cm)	10.2***	6.1***	1.3	3.3**	1.6	2.5	6.3	26.8
Girth (cm)	44.1***	15.2***	36.0***	26.6***	1.6	0.9	8.7	31.5
Fat depth (mm)	116.0***	1.6	13.1***	13.6***	0.9	0.0	0.1	1.3
Muscle (%)	4.6***	1.2	15.4***	195.7***	1.6	0.3	0.2	29.0
ADG								
Weight (g/d)	101.6***	1.0	50.6***	26.1***	2.6*	510.6	2,091.5	5,390.7
Height (mm/d)	38.9***	6.4***	18.7***	2.6*	1.2	13.9	7.3	206.1
Length (mm/d)	27.1***	13.7***	0.5	2.2	1.5	15.2	25.7	364.8
Girth (mm/d)	70.2***	11.5***	13.3***	8.1***	0.8	5.3	77.1	1,359.6
Fat depth (µm/d)	110.3***	1.1	13.8***	12.8***	1.0	0.2	13.5	153.0

^a Fixed effects type III mean squares, ^b Random effect variances.

* p<0.05, ** p<0.01, *** p<0.001.

YOB: Year of birth. DOB: Date of birth. ADG: Average daily gains.

and girth) than the female (heifers) calves.

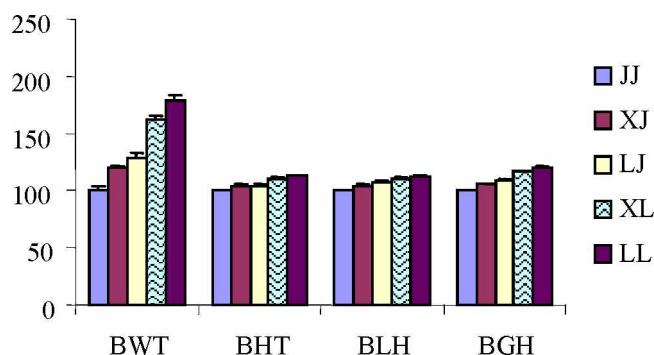
At weaning, effects of year of birth significantly (p<0.01) influenced all the traits and average daily gain (ADG) in all traits (Table 2). Calves born in 1995 were fatter and on the average performed better with regards to weight, length and girth than calves from other years. In other years, the majority of calves had no detectable subcutaneous fat. The most highly muscled calves were those born in 1996 (85±0.6%), while the least were the 1998 drop (82±0.6%). The effect of the sex of calf was not significant for length, but was highly significant (p<0.01) for every other trait at weaning. Steers were heavier, taller and bigger in girth; more muscled and has less fat than the heifers. There were also significant year by sex interactions for weight and height. The steers born in 1995 were 12% heavier and 4% taller than heifers born in the same year. However, in the other years on the average, steers were only 7% (weight) and 2% (height) bigger than heifers. For average daily gains, the year by sex interaction was only significant (p<0.05) for weight with steers born in 1995 growing 12% faster than the heifers of the same year. The rate of growth of the former as compared to the latter was lower on the average (6%) for other years.

Day of birth was significant at weaning for weight, height, length and girth but not for fat depth or muscle score. For weight, the first 60% of calves were similar (238 kg), followed by the next 20% (229 kg) and the last 20% (215 kg). However, for height, length and girth, the first 80% were similar (111 cm, 115 cm, 146 cm) and larger than the last 20% (108 cm, 112 cm, 141 cm) respectively. Effects due to day of birth were significant for ADG in height,

length and girth but not for weight and fat depth (Table 2).

Breed and genetic effects

At birth, breed rankings for all traits (p<0.001) depended primarily on the proportion of Limousin genes: LL>XL>LJ>XJ>JJ (Figure 1). Thus, there was a gradual increase in breed mean as proportion of Limousin genes increased for all birth traits from purebred Jersey to purebred Limousin (Table 3). The direct genetic effect of the Jersey decreased birth weight, height, length and girth (Table 4). Jersey maternal effects were not significant for all



Standard errors.

BWT=Birth-weight, BHT=Birth-height, BLH=Birth-length
BGH=Birth-girth.

JJ=Jersey, XJ=Jersey backcross, LJ=F1(JJ×LL)

XL=Limousin backcross, LL=Limousin.

Figure 1. Breed means as a proportion (%) of purebred Jersey genes for birth traits.

Table 3. Least square means for the fixed effect of breed for pre-weaning and weaning traits

Trait	Breed				
	Jersey (JJ)	LJ×JJ (XJ)	LL×JJ (LJ)	LJ×LL (XL)	Limousin (LL)
Birth					
Weight (kg)	19.6±0.7	23.4±0.6	25.2±0.8	31.8±0.6	35.0±0.8
Height (cm)	65.9±0.7	68.6±0.6	68.9±0.9	73.0±0.6	74.4±0.9
Length (cm)	50.3±0.7	52.3±0.6	53.6±0.8	55.9±0.6	56.4±0.8
Girth (cm)	63.3±0.5	66.3±0.5	68.7±0.7	73.5±0.5	75.9±0.7
Weaning					
Weight (kg)	197.8±6.0	220.9±5.1	226.7±7.0	245.9±5.2	269.6±6.8
Height (cm)	104.7±1.1	108.6±0.9	110.5±1.2	113.4±0.9	116.7±1.2
Length (cm)	112.0±1.4	114.5±1.2	113.6±1.6	116.2±1.2	115.8±1.6
Girth (cm)	138.3±1.1	144.3±1.0	144.4±1.4	147.3±1.0	151.7±1.4
Fat depth (mm)	1.0±0.2	1.3±0.2	2.0±0.2	1.4±0.2	0.5±0.2
Muscle (%)	71.6±1.0	77.4±0.7	82.9±1.5	86.2±0.7	101.3±1.4
ADG					
Weight (g/d)	614.1±19.8	693.1±17.1	698.3±23.3	755.8±17.4	811.9±22.7
Height (mm/d)	134.3±3.3	140.4±2.9	145.1±4.0	141.6±2.9	148.6±3.9
Length (mm/d)	214.2±3.9	217.5±3.5	210.0±4.8	211.5±3.5	207.9±4.7
Girth (mm/d)	259.2±3.3	270.6±3.0	264.4±4.5	258.1±3.1	265.7±4.3
Fat depth (µm/d)	3.3±0.7	4.5±0.6	6.7±0.9	4.7±0.9	1.8±0.9

ADG Average daily gains.

± Standard errors.

Table 4. Genetic effects and tests of significance (difference from zero) for pre-weaning and weaning traits

Trait	Genetic effect			
	Jersey direct	Jersey maternal	Heterosis	Epistasis
Birth				
Weight (kg)	-6.9±1.0***	-0.8±0.6	-1.3±0.7	1.8±2.0
Height (cm)	-4.1±1.0***	-0.2±0.6	-1.0±0.7	2.3±2.1
Length (cm)	-2.5±1.0**	-0.6±0.6	0.9±0.6	0.6±1.9
Girth (cm)	-5.4±0.7***	-0.9±0.5*	0.0±0.6	0.7±1.6
Weaning				
Weight (kg)	-46.8±8.5***	10.9±4.9*	-17.9±5.1***	17.3±16.1
Height (cm)	-7.2±1.5***	1.2±0.9	-1.4±0.8	2.0±2.8
Length (cm)	-2.1±2.0	0.2±1.1	-0.6±1.1	3.5±3.7
Girth (cm)	-10.4±1.6***	3.7±1.0***	-4.3±1.2***	5.9±3.4
Fat depth (mm)	0.5±0.3*	-0.3±0.2	1.5±0.2***	-0.4±0.6
Muscle (%)	-20.8±1.5***	6.0±0.9***	-9.6±1.6***	0.3±3.0
ADG				
Weight (g/d)	-135.1±28.4***	36.2±16.2*	-50.9±16.4**	73.9±53.2
Height (mm/d)	-13.1±4.9**	6.0±2.8*	-2.3±3.0	1.4±9.3
Length (mm/d)	0.3±5.7	2.9±3.4	-4.0±4.0	10.9±11.5
Girth (mm/d)	-19.0±4.9***	15.8±3.1***	-13.8±4.1***	17.6±10.7

* p<0.05, ** p<0.01, *** p<0.001.

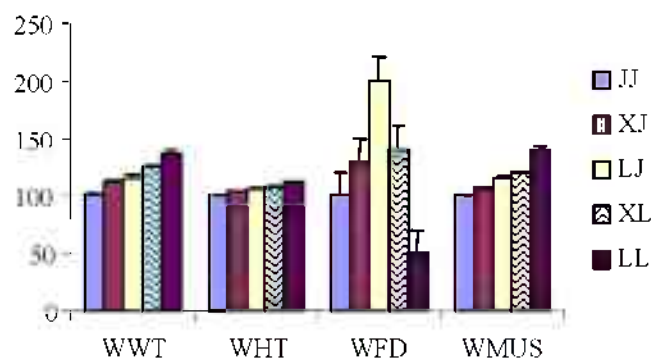
ADG=Average daily gains.

±=Standard errors.

the birth traits except for girth, which was negative. Heterosis and epistatic effects were not significant for any of the birth traits.

At weaning, breed means for weight, height and girth show the same rankings as at birth (Table 3). In addition, the purebred Limousin was more muscular with the purebred Jersey at the other extreme (Figure 2). However,

some breeds were the same for length at weaning (Table 3). Basically, Jersey (JJ) calves were shorter than most of the other breeds (Table 3). The F₁ calves had the greatest fat depth with the two purebreds having the least. Jersey direct genetic effects were significant for all the traits at weaning with the exception of the length (Table 4). The Jersey direct genetic effects resulted in calves with far less weight, height,



Standard errors.

WWT=Weaning weight, WHT=Weaning height

WFD=Weaning fat depth, WMUS=Weaning muscle score.

JJ, XI, LJ, XL, LL, as in Figure 1.

Figure 2. Breed means as a proportion (%) of purebred Jersey genes for weaning traits.

girth and muscle. There was also a small positive effect of the Jersey genes on fat depth. Jersey maternal effects were expressed to a large extent on girth and muscle with a smaller effect on weight and no effects on length, height or fat depth. Heterosis effects, though, were negative for weight, girth and muscle, and positive for fat depth, but not significant for length or height. Epistatic effects were not significant for any of the traits.

Breed effects for pre-weaning gains were the same as for weaning with one exception. This exception was for height where the maternal effect of the Jersey increased daily gain in height but was not significant for weaning height (Table 4).

DISCUSSION

Non-genetic fixed effects

The links across the years through common dams helped address the partial confounding between year and breed. Calves born in 1995 were bigger in birth-weight and skeletal growth performance compared to other years. These observed effects are due to environmental conditions such as pasture availability, which to a large extent cannot be controlled. During the experiment, 1995 was the best season with adequate rains into spring. As expected, similar patterns were observed for pre-weaning and weaning performance in weight, height, length girth, fat depth and muscularity. Gilbert et al. (1993) observed a significant influence of year on body dimensional traits with calves born in one year being shorter at withers, longer in body and cannon bone circumference than calves born in another year. However, if the difference between the largest (271 kg) and the smallest (202 kg) weaning weights is examined herein, then it can be concluded that year effects at weaning are larger for weight (34%) than body

dimensions [e.g. height (2%)]. While growth as a whole can be considered as an increase in mass, it includes not only cell division and enlargement but also changes in body composition (e.g. fat deposition) (Owen et al., 1993). Different body tissues respond differently depending upon the stage of cell maturity and feed availability. Thus, although there was a large year effect on weight relative to height, the animals also changed shape as well as being larger overall in 1995.

At birth, female calves were significantly lighter in weight and shorter in body dimensions than the male calves. Earlier reports have also acknowledged that male calves are bigger than female calves at birth (Smith et al., 1976; Gregory et al., 1978; Gregory et al., 1979). However, the maintenance of birth weight advantage to weaning age, as observed herein, is an indication of differences in maternal ability of cows when suckling heavier calves, which tend to be male (Newman et al., 1993) or of calf's ability to eat grass. The differences between male and female calves on weight, height, length, girth and muscle at weaning were similar to the results reported by Gilbert, et al. (1993). In that report, steers were larger than heifers in height at withers, body and head length, head and muzzle width and cannon bone circumference but not in height and width at hips and frame score. Herein, the female calves were also fatter than the male calves at weaning.

Breed and genetic effects

The gradual trend in increased weight gains and many of the body dimensions from birth to weaning as the amount of Jersey genes decreased was expected. This was because the two breeds used in this study are at opposite extremes for many beef and dairy traits. The level of heterozygosity observed in the F_1 and backcross progeny brings to focus the additive and non-additive gene action associated with crossbreeding. The direct genetic effect of the Jersey genes that resulted in decreased birth weight was similar to some earlier findings on pure and crossbred cattle (Cunningham and Magee, 1988; Newman et al., 1993; Davis et al., 1998). The lack of a significant maternal effect on birth weight in this study supported the results of Pitchford et al. (1993) on calves from Brahman and Hereford crosses. However, the observation was contrary to the significant effect obtained by Cunningham and Magee (1988) with Angus, Charolais, Holstein-Friesian and Simmental crosses and by Alenda et al. (1980) with Angus, Charolais and Hereford crosses. The result herein suggests that mothering ability and/or post-natal nutrient supply may be more important components of the maternal effect than pre-natal nutrient supply. Heterotic or epistatic effects, which were not significant for any of the birth traits, strengthen the findings that non-additive genetic effects are not a source of variation in birth weight (Dillard et al.,

1980).

The direct genetic effect of Jersey relative to Limousin on weaning traits resulted in smaller calves with much less muscle. In previous studies, both Jersey and Limousin breeds had low subcutaneous fat levels (Cundiff et al., 1988), but in the study herein, the Jersey had more fat than Limousin (Tables 3 and 4). For most traits (muscle and bone), the direct effects were the largest genetic effects. However, there were small (but significant) deviations from this trend due to heterosis and maternal effects. In contrast, the direct effect for fat depth at weaning was only just significant ($p < 0.05$). The negative Jersey direct and positive maternal effects on pre-weaning and weaning weights were similar to earlier studies. Kress et al. (1996) reported breed individual effects for weight at 40 days of age, but by 120 days there was no significant effect. The authors also observed no significant maternal effects for early calf weight (40 day), but at 120 days, significant differences due to maternal effects were found.

The impact of Jersey genes on progeny due to large milk production of this breed had a slight effect on height and no effect on length at weaning. However, the calves with Jersey dams were bigger in girth, heavier and well muscled. High and positive estimates of maternal effects were reported for weaning weight of Angus (Neville et al., 1984), Charolais and Simmental breeds (Cunningham and Magee (1988). The results herein indicate a strong and positive maternal effect on girth and muscularity not commonly found in earlier studies.

The observed decrease in weight and muscle as well as a large increase in fatness due to heterotic effects at weaning was unexpected. Rarely has heterosis been estimated to have a negative effect on growth as in this study (-7%). Dillard et al. (1980) observed positive specific individual heterotic effects on weight among Angus, Charolais, and Hereford crosses. Cunningham and Magee (1988) also found a positive and significant influence of individual heterotic effects on weaning weight among Angus, Charolais, Hereford, Holstein-Friesian, and Simmental crosses. When the breed means are plotted relative to purebred Jersey (Figure 2), the huge effect of heterosis on fat depth is obvious in the F_1 calves. This trend continued until these calves were slaughtered, where the F_1 progeny were much fatter than the purebreds (Pitchford et al., 1998).

Many studies have reported heterotic effects on growth but only a few examined the effects on fat depth and fewer on muscularity. The estimates of heterotic effects in this study, which were positive for fat depth and negative for muscle, support earlier reports of Gregory et al. (1994) and Pitchford et al. (1993). In 1994, Gregory et al. observed that heterosis levels were retained in three composite lines. Among the three lines, two (MARCII and MARCIII) had

significantly lower percentage lean meat and higher percentage fat trim than the mean of the contributing purebreds. In part of the study on Brahman-Hereford crosses (Pitchford et al., 1993), there was also positive heterosis for condition score (Hearnshaw et al., 1994).

A limitation of this study is the very small number of sires per breed (2-3) and this may explain the heterosis effects on growth deviating from expectation. Thus, it is possible for the negative heterosis estimates obtained for weight to be essentially a sampling error. However, the 280 dams in this study were bought from a large number of studs across South-eastern Australia and were a good representation of the Jersey and Limousin population. An alternative hypothesis is that the large differences in body composition of the breeds used herein might be a contributory factor.

This study has demonstrated a strong and positive maternal effect (6%) of the Jersey (relative to Limousin) on muscularity due to high milk supply of the Jersey dam. Also, the crossbred calves (LJ, XJ and XL) were fatter than the mean of their purebred parents because of the strong and positive heterosis on fat depth. It is, therefore, possible to exploit the positive heterosis and maternal effects in both fat depth and muscularity to meet specific consumer demands for high quality and quantity meat. However, the two breeds utilized herein may not be the most representative models in a crossbreeding program to meet various demands. There is a need to further explore the potential derivable from other diverse breeds. In addition, it is essential to examine the genetic effects beyond weaning for this type of crossbreeding program.

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