
Genetic Effects on Growth and Development in Jersey and Limousin Cross Cattle

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ABSTRACT: This study examined the importance of direct genetic, maternal, heterosis and recombination effects on weaning (250 day) weight, height, fat depth and a measure of muscularity (ratio of stifle to hip width). The breed combinations comprised two pure breeds (Jersey and Limousin), the Limousin x Jersey F1, and two backcrosses (F1 x Jersey dams and F1 x Limousin dams). The major limitation of the trial was the low numbers of sires: 2 Jersey, 2 Limousin and 3 F1. Direct genetic effects were largest (P<0.001) for weight, height and muscle with the effect of the Jersey being -47±9kg, -7±1.6cm and -21±1.5% respectively. There was also a small direct effect of the Jersey on fat depth (0.5±0.3mm P<0.05). The maternal effect of the Jersey dam was significant for weight (11±5kg P<0.05) and muscle (6±0.9 P<0.001). Heterosis was highly significant (P<0.001) for weight (-17±5kg), fat depth (1.5±0.2mm) and muscle (-10±1.3%). Recombination effects were not significant for any trait. For weight, height and muscle, the breeds ranked in order of percentage Limousin breeding (i.e. purebred Limousin, Limousin backcross, F1 Limousin, Jersey backcross, purebred Jersey). However, fat depth was completely different: F1 was the fattest (1.9mm), then the backcrosses (1.4 and 1.3mm), purebred Jersey (0.9mm) and purebred Limousin (0.5mm). This change in ranking reflected the huge heterosis effect relative to direct genetic effect on fat depth which is in contrast to most other studies.

Key Words: Cattle, Growth, Fatness, Heterosis, Maternal Effects

INTRODUCTION

Recent feedlot trials with crossbred cattle (D.L. Rutley et al., unpublished data) have aimed to develop prediction equations for feedlot performance defined by average daily gain, carcass weight, fat depth and salable beef yield. Four traits that were clearly valuable were weight, height, fat depth and visual muscle score (score developed by McKiernan, 1990). Other traits tested were eye muscle area, length or girth.

It has been demonstrated previously (Pitchford et al., 1993) that weight and height of crossbred cattle from diverse parental breeds are significantly influenced by breed, maternal and heterosis effects. This study was aimed at extending these and other studies by estimating four genetic effects on previous traits (weight and height) and newer traits (fat depth and a measure of muscularity).

MATERIALS AND METHODS

Experimental Design

The 591 calves in this study were all born 1994-98 as part of the Adelaide Cattle Gene Mapping Project. The Project comprised purebred Jersey and Limousin cows mated to Jersey, Limousin, or F1 bulls (Table 1). Jersey and Limousin breeds were chosen because of their extreme differences for many traits. The Jersey is a small frame dairy breed, whereas the Limousin is a moderate-large frame, well muscled beef breed. Calves were born in autumn (March-May, average 26th April), single-suckled, and weaned in the first week in February at the average age of 250 days.

Table 1. Number of calves in each breed combination

<table>
<thead>
<tr>
<th>Jersey sire</th>
<th>Limousin sire</th>
<th>Crossbred sire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jersey dam</td>
<td>79</td>
<td>68</td>
</tr>
<tr>
<td>Limousin dam</td>
<td>0</td>
<td>81</td>
</tr>
</tbody>
</table>

Year and breed were partially confounded. In phase 1 (1994 and 1995), there were purebred Jersey (JJ) and Limousin (LL), and F1 calves (LJ). In phase 2 (1996-98), there were backcross calves resulting from mating F1 bulls to either Jersey (XJ) or Limousin (XL) cows. Within phases, there were common sires and dams. Links across the two phases comprise some purebred Jersey calves born in 1996 and many (280) dams used throughout the project.

Measurements

At weaning, cattle were weighed full (range 103-372kg). 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 (range 90-126cm). Fat depth was measured using an ultrasound scanner (UltrAmac®) at the P8 site on the rump (range 0-9mm). Hip width (bone) and stifle width (muscle) were measured using calipers. Hip widths ranged from 26-45cm and stifle widths ranged from 18-44cm. Stifle width as a proportion of hip width was used as an indication of the amount of muscle similar to that proposed by McKiernan (1990). Hip and stifle widths were measured on all calves, except those from the 1994 drop.

Statistical Analysis

All four traits (weight, height, fat, muscle) were analysed with a model containing fixed effects of year of birth (1994-98), day of birth (5
classes comprising first 20% of calves born, next 20%, etc., sex of calf (heifer or steer), and breed of calf (JJ, XJ, L1, XL, LL) and random effects of sire (2 Jersey, 2 Limousin and 3 F1) and dam (189 Jersey and 91 Limousin). Two-way interactions were tested, but were generally not significant. The analysis was conducted using Proc Mixed (SAS, 1992).

Genetic effects were estimated as proposed by Dickerson (1969), although the procedure was modified according to Pitchford et al. (1993) because of the breed combinations utilised. Four genetic effects were estimated from the five breed combinations (as shown below). All effects are estimated as deviations from the purebred mean. Since there are only 5 breed combinations, recombination was completely confounded with paternal heterosis. The effects were calculated as linear contrasts between least squares means with T-tests of significant deviation from zero.

\[
\text{Jersey direct} = JJ - LL - XJ + XL = - \text{Limousin direct}
\]

\[
\text{Jersey maternal} = (LL - JJ)/2 + XJ - XL = - \text{Limousin maternal}
\]

\[
\text{Heterosis} = LJ - LL - XJ + XL
\]

\[
\text{Recombination} = 2(XJ) - LJ - JJ
\]

### RESULTS

#### Non-genetic Effects

Year effects were significant for all traits (Table 2). The heaviest (271kg), tallest (112cm) and fattest (4.3mm) were born in 1995 and the lightest (201kg) and shortest (110cm) were born in 1994. Calves in most years were much leaner than in 1995: 0.7mm in 1994; 0.5mm in 1996; 0.1mm in 1997; and 0.6mm in 1998. Thus, in most years, the majority of calves had no detectable fat. The most highly muscled calves were born in 1996 (85%) and the least in 1998 (82%).

Day of birth effects were significant for weight and height, but not for fat or muscle. For weight, the first 3 classes comprising 60% of calves were the same weight at weaning (238kg), the next 20% were lighter (228kg) and the last 20% were lighter again (215kg). For height, the first 80% were the same (111cm) and the last 20% were shorter (108cm).

Steer calves were 17kg heavier (8%), 2cm taller (2%), 0.3mm leaner (23%), and 2% more muscled than heifers.

#### Genetic Effects

Breed effects were significant for all traits (Table 2). Sire and dam variation was generally small compared to residual variation. Least squares means for breed were calculated (Table 3). The purebred Limousin was the heaviest, tallest and most muscular with the purebred Jersey at the other extreme. For weight, height and muscle, there was a gradual trend in breed means from purebred Jersey to purebred Limousin. However, fat depth was greatest for the F1 and least for the two purebreds (Figure 1).

Genetic effects and tests of their significance were also examined (Table 4). The direct genetic effect of the Jersey was far less weight (-47kg), height (-7cm) and muscle (-21%). There was also a small positive effect of the Jersey on fat depth (0.5mm).

Since the Jersey is a dairy breed, maternal effects were expected to be large. This was the case for muscle (6%) with a smaller effect for weight (11kg) (Table 4). Maternal effects were not significant for height, or fat depth.

Heterosis was highly significant, although negative, for weight (-17kg) and muscle (-10%). Heterosis was not significant for height but was highly significant and positive for fat depth (1.5mm). Recombination effects were not significant for any trait.

### Table 2. Analysis of variance and tests of significance and variance components for weaning weight, height, P8 fat depth and muscle score

<table>
<thead>
<tr>
<th>Effect</th>
<th>Weight</th>
<th>Height</th>
<th>Fat depth</th>
<th>Muscle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of birth</td>
<td>48743***</td>
<td>290.2***</td>
<td>149.76***</td>
<td>135.3**</td>
</tr>
<tr>
<td>Day of birth</td>
<td>8616***</td>
<td>163.3***</td>
<td>2.02</td>
<td>35.1</td>
</tr>
<tr>
<td>Sex</td>
<td>33899***</td>
<td>782.6***</td>
<td>14.21***</td>
<td>426.0***</td>
</tr>
<tr>
<td>Breed</td>
<td>19383***</td>
<td>757.0***</td>
<td>17.65***</td>
<td>5693.0***</td>
</tr>
<tr>
<td>Sire</td>
<td>45</td>
<td>1.8</td>
<td>0.01</td>
<td>0.3</td>
</tr>
<tr>
<td>Dam</td>
<td>223</td>
<td>1.5</td>
<td>0.09</td>
<td>0.2</td>
</tr>
<tr>
<td>Residual</td>
<td>513</td>
<td>13.7</td>
<td>1.25</td>
<td>29.0</td>
</tr>
</tbody>
</table>

*Fixed effects type III mean squares, Random effect variances, ** P<0.01, *** P<0.001
Table 3. Least squares means for weaning weight, height, P8 fat depth and muscle score for the five breed combinations

<table>
<thead>
<tr>
<th>Breed (sire x dam)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>P8 Fat depth (mm)</th>
<th>Muscle (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jersey (JJ)</td>
<td>197±6</td>
<td>105±1.1</td>
<td>0.9±0.2</td>
<td>72±1.0</td>
</tr>
<tr>
<td>LJ x Jersey (XJ)</td>
<td>221±5</td>
<td>109±0.9</td>
<td>1.3±0.2</td>
<td>77±0.6</td>
</tr>
<tr>
<td>Limo. x Jers. (LJ)</td>
<td>226±7</td>
<td>111±1.2</td>
<td>1.9±0.2</td>
<td>83±1.5</td>
</tr>
<tr>
<td>LJ x Limo. (XL)</td>
<td>246±5</td>
<td>113±0.9</td>
<td>1.4±0.2</td>
<td>86±0.7</td>
</tr>
<tr>
<td>Limousin (LL)</td>
<td>269±7</td>
<td>117±1.2</td>
<td>0.5±0.2</td>
<td>101±1.4</td>
</tr>
</tbody>
</table>

Table 4. Genetic effects and tests of significance (difference from zero) for weaning weight, height, P8 fat depth and muscle score

<table>
<thead>
<tr>
<th>Genetic effect</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>Fat depth (mm)</th>
<th>Muscle (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jersey direct</td>
<td>-47±9***</td>
<td>-7±1.6***</td>
<td>0.5±0.3*</td>
<td>-21±1.5***</td>
</tr>
<tr>
<td>Jersey maternal</td>
<td>11±5*</td>
<td>1±0.9</td>
<td>-0.3±0.2</td>
<td>6±0.9***</td>
</tr>
<tr>
<td>Heterosis</td>
<td>-17±5***</td>
<td>-1±0.8</td>
<td>1.5±0.2***</td>
<td>-10±1.3***</td>
</tr>
<tr>
<td>Recombination</td>
<td>17±16</td>
<td>2±2.8</td>
<td>-0.3±0.6</td>
<td>0±2.9</td>
</tr>
</tbody>
</table>

P<0.05, ** P<0.01, *** P<0.001

Figure 1. Breed means as a proportion (%) of purebred Jersey
DISCUSSION

Year and breed were partially confounded. However, there were links across the years through the sires and dams. Thus, independent of breed, 1995 was clearly the best season with good rains into spring. While this affected most traits, it had no effect on muscularity. That said, since hip and stifle width were not measured in 1994, the links across years for muscularity were inferior to the links for other traits.

The direct genetic effect of the Jersey relative to the Limousin was as expected: smaller calves with much less muscle. Both the Limousin and Jersey have low levels of subcutaneous fat. However, this study has demonstrated that the Jersey had slightly higher subcutaneous fat thickness than the Limousin. For weight, height and muscle, direct genetic effects were the dominant factor. When breed means are presented as a proportion of the Jersey (Figure 1), it is clear that there was a gradation from purebred Jersey to purebred Limousin. There were small (but significant) deviations from this trend due to heterosis and maternal effects, but the direct genetic effect was the over-riding factor. In stark contrast, direct effects for fat depth were only just significant (Table 4).

The large milk supply from the Jersey dam had no effect on height, but resulted in much heavier and well muscled calves.

The heterosis effects were not as expected. Heterosis resulted in a decrease in weight and muscle and a large increase in fatness. When the breed means are plotted relative to purebred Jersey (Figure 1), the huge effect of heterosis on fat depth is obvious. This trend continued until these calves were slaughtered, where the LJ was much fatter than both of the purebreds (JJ and LL) (Pitchford et al., 1998). Pitchford et al. (1993) found that heterosis effects were 1-21% for mature weight and 0-4% for mature height depending on the environment. Rarely has heterosis been estimated to have a negative effect on growth as in this study (-7%). Unfortunately, the very small number of sires per breed (2-3) limited this study and this may explain the heterosis effects on growth deviating from expectation. The 280 dams in this study were bought from a large number of studs across south-eastern Australia and are a good representation of the Jersey and Limousin breeds. However, by sampling only a small number of sires per breed, there is a probability that they are a poor representation of their breed or cross. Thus, it is possible that the negative heterosis estimate for weight is essentially a sampling error.

Despite the many studies on heterosis effects on growth, there are very few that report effects on fat depth and even less on some measure of muscularity. In 1994, Gregory et al. reported retained heterosis levels in three composite lines. Two of the three lines (MARCII and MARCIII) had significantly lower percentage lean and higher percentage fat trim than the mean of the contributing purebreds.

The estimates of heterosis effects in this study (positive for fat and negative for muscle) support those of Gregory et al. (1994). Although not published, in the Brahman-Hereford study reported by Pitchford et al. (1993), there was also positive heterosis for condition score.

It is possible that heterosis for increased fat contributes to increased reproductive rate of crossbred cows compared to purebred cows. Pitchford et al. (1993) proposed that this was likely due to their increased intake. However, this study suggests they may be fatter at any given body weight which would enable crossbred cows to continue cycling during times of feed shortage while leaner purebred cows continue a period of anoestrus.

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REFERENCES


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