GENETIC EFFECTS ON SHAPE AND FATNESS OF CALVES FROM DIVERSE CROSSES

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SUMMARY
The importance of direct genetic, maternal, heterosis and epistatic effects were examined on pre- and post-weaning dry and wet season average daily gains in weight, height, fat depth and a measure of muscle (ratio of stifle to hip width). The genotype used were two pure breeds (Jersey, JJ and Limousin, LL), the Limousin x Jersey LJ, and two backcrosses (LJ x Jersey dams and LJ x Limousin dams). Direct genetic effects were large ($P<0.01$) in all the traits. Jersey maternal effects were large for weight ($P<0.01$), fat depth ($P<0.001$) and muscle ($P<0.001$) in the post-weaning wet season performance. This is an indication of the impact of Jersey genes beyond weaning. There were large heterosis effects relative to direct effects on fat depth at pre- and post-weaning ages. Epistatic effects were observed only in post-weaning gain in weight and fat depth which is an indication that this effect is more expressed in advanced age.

Key words: Genetic effects, weight, height, fat depth, muscle.

INTRODUCTION
Body weight of beef cattle is influenced by both direct and maternal effects (Pitchford et al. 1993). Many reports limit the assessment of these effects to weight and changes in weight expressed in early life of the calf. Body composition measurements (bone, fat and muscle) are also required to sufficiently describe variation in saleable yield performance of beef cattle. Therefore, the objective of this study was to evaluate four genetic effects on growth and development of Jersey and Limousin cross cattle in different seasons and stages of growth.

MATERIALS AND METHODS
General procedures. In 1993, 280 purebred Jersey and Limousin dams were procured as part of the Davies Mapping herd. These dams were mated to purebred Jersey (2) and Limousin (2) sires to produce purebred Jersey (JJ), purebred Limousin (LL) or LJ calves born in 1994 and 1995. Mating LJ (3) bulls to parental breed cows (Jersey and Limousin) began in 1995 and backcross progeny [3/4 Jersey (XJ), 3/4 Limousin (XL)] were produced from 1996 until 1998. In the design, which involved two phases, year and genotype were partially confounded. However, some purebred JJ calves were produced in 1996 to link the two phases. Sires and dams were commonly used across years.

Calving took place each year in autumn from early March through mid-May. Calves stayed with their dams on pasture until weaning (average age of 250 days). After weaning, calves grazed grass pasture for 430 – 500 days. The animals’ post-weaning weight (Wt), height (Ht), fat depth scanned at P8 site (Fat) and muscularity (Mus) (McKiernan 1990) (measured, using calipers, by stifle width as a proportion of hip width expressed as percent) were obtained at approximately 400- and 600-days after birth, corresponding to the winter after the dry season (dry season) and summer after the wet season (wet season) respectively. So, season was confounded with age. The degree of muscularity was not
taken at weaning for calves born in 1994 and at 400 days of age for the 1996 drop. Also, there was no 600-day measurement of height, for heifers born in 1994. The growth rate (for Wt, Ht, Fat, Mus) was calculated from birth to weaning (1), between weaning and 400-days (2), and between 400 and 600-days (3). Fat was assumed to be 0mm at birth. Mus was also not measured at birth.

Statistical Analysis. Eleven traits (Table 1) were analysed with a model containing fixed effects of year of birth (1994-1998), day of birth (5 classes with each comprising 20% of calves born in succession to allow for non-linearity), sex of calf (heifer or steer), genotype of calf (JJ, XJ, LJ, XL, LL) and year x sex interaction with sire and dam fitted as random effects (SAS 1992). Since there were no values for weaning muscle in 1994 and 400-day muscle in 1996, the model for Mus2 included the fixed effect of genotype nested within phase.

Genetic effects were defined in terms of direct additive, maternal additive, direct heterosis and direct epistatic effects. These effects were estimated as originally proposed by Dickerson (1969) but modified because of the genotype combinations used. Effects were estimated in a similar manner to Pitchford et al. (1993). The four genetic effects were estimated from the five genotype combinations (as shown below) as deviations from the purebred mean. Because there were only 5 genotype combinations, the epistatic effect was completely confounded with paternal heterosis. The effects were calculated as linear contrasts between genotype least square means with T-tests for significant deviation from zero. Significance was defined as P<0.05.

\[
\begin{align*}
\text{Jersey direct} &= \text{JJ} - \text{LL} - \text{XJ} + \text{XL} = - \text{Limousin direct} \\
\text{Jersey maternal} &= (\text{LL} - \text{JJ})/2 + \text{XJ} - \text{XL} = - \text{Limousin maternal} \\
\text{Heterosis} &= \text{LJ} - \text{LL} - \text{XJ} + \text{XL} \\
\text{Epistasis} &= 2(\text{XJ}) - \text{LJ} - \text{JJ}
\end{align*}
\]

RESULTS

Genotype and genetic effects. Genotype effects were highly significant (P<0.01) for all the traits. For pre-weaning traits, the purebred Limousin were the heaviest (Wt) and highest (Ht) with the purebred Jersey at the other extreme. These traits showed a gradual trend in genotypes from purebred Jersey to purebred Limousin. The LJ calves were the fattest with the two purebreds having the least back fat. The significant Jersey direct genetic effects resulted in calves with far lower Wt and Ht (Table 1). There was also a small Jersey maternal effect on Wt. Heterosis was large (P<0.001) and positive for Fat only. Epistatic effects were not significant for any of the pre-weaning traits.

In the dry season (weaning to 400d), XL calves had the highest Wt gain, followed by XJ = LL, LJ and JJ. The ranking order for Ht was similar to pre-weaning. Mus also followed the same trend (Figure 1a). However, there was a significant Fat loss in LJ and the XJ and XL gained less than the purebred mean. The direct Jersey effects resulted in increased Mus gain but reduced Wt and Fat gain. There was a positive but low Jersey maternal effect on Ht and Fat, and a negative and low maternal effect on Mus. Heterosis and epistasis were the same as for pre-weaning (Table 1).

In the wet season (400d to 600d), the gains in all traits were faster than the dry season for all the genotypes. The ranking was similar to the dry season performance. However, the amount of Fat and Mus lost in the dry season by genotypes affected the level of the wet season gain (Figure 1b).
direct Jersey effects in the wet- and dry- season were similar for gain in Wt, Fat and Mus. However, the wet season as compared to the dry season led to greater expression of the direct effect on Wt, Fat and Mus gain (Table 1). Also, the significant direct effect on dry season Ht was no longer apparent in the wet season. The Jersey maternal effect on Wt was significant and was higher in significance for Fat and Mus in wet compared to dry season. The maternal effect resulted in calves with increased Wt, additional Fat and less Mus gain. The heterosis effect was significant and positive for Mus with calves gaining more muscle. However, the significant heterosis on Fat gain in the dry was not evident in the wet season. Although no epistatic effect was observed for any dry season trait, there was a positive epistatic effect for Wt and negative epistatic effect for Fat during the following wet season.

Table 1. Genetic effects and tests of significance (diff. from zero) for pre and post-weaning traits

<table>
<thead>
<tr>
<th>Trait</th>
<th>Purebred mean</th>
<th>Jersey direct</th>
<th>Jersey maternal</th>
<th>Heterosis</th>
<th>Epistasis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt1(g/d)</td>
<td>713±22</td>
<td>-135±28***</td>
<td>36±16</td>
<td>-51±16**</td>
<td>74±53</td>
</tr>
<tr>
<td>Wt2(g/d)</td>
<td>168±18</td>
<td>-45±22*</td>
<td>16±15</td>
<td>-20±22</td>
<td>89±52</td>
</tr>
<tr>
<td>Wt3(g/d)</td>
<td>957±37</td>
<td>-282±49***</td>
<td>86±29***</td>
<td>-39±34</td>
<td>231±96**</td>
</tr>
<tr>
<td>Ht1(mm/d)</td>
<td>142±4</td>
<td>-13±5**</td>
<td>6±3</td>
<td>-2±3</td>
<td>1±9</td>
</tr>
<tr>
<td>Ht2(mm/d)</td>
<td>48±5</td>
<td>-15±6**</td>
<td>8±4</td>
<td>-2±5</td>
<td>6±13</td>
</tr>
<tr>
<td>Ht3(mm/d)</td>
<td>53±5</td>
<td>-5±4*</td>
<td>-1±4</td>
<td>-7±6</td>
<td>22±14</td>
</tr>
<tr>
<td>Fat1(µm/d)</td>
<td>3±1</td>
<td>-2±1</td>
<td>-1±1</td>
<td>5±1***</td>
<td>-1±2</td>
</tr>
<tr>
<td>Fat2(µm/d)</td>
<td>2±1</td>
<td>-4±2***</td>
<td>3±1</td>
<td>-9±2***</td>
<td>8±4</td>
</tr>
<tr>
<td>Fat3(µm/d)</td>
<td>20±3</td>
<td>-18±4***</td>
<td>9±2***</td>
<td>3±3</td>
<td>-16±8*</td>
</tr>
<tr>
<td>Mus2(%/d x 10^{-3})</td>
<td>-5±1</td>
<td>43±14***</td>
<td>-21±9*</td>
<td>25±13</td>
<td>-</td>
</tr>
<tr>
<td>Mus3(%/d x 10^{-3})</td>
<td>4±1</td>
<td>16±2***</td>
<td>-8±1***</td>
<td>10±2***</td>
<td>-</td>
</tr>
</tbody>
</table>

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

Figure 1a and b. Breed means as a percentage of JJ for post-weaning dry and wet season gains. Bars- indicates standard errors. Wt2,Wt3; Ht2,Ht3; Fat2,Fat3; Mus2,Mus3 = Dry and wet season gains in weight, height, fat depth and muscle. JJ= Jersey, XJ= Jersey backcross, LJ= JJ x LL, XL= Limousin backcross, LL= Limousin.
DISCUSSION
The genetic effects on growth were smaller in the dry compared to the wet season due to improved nutrition. Arthur et al. (1994) acknowledged the significance of the influence of post-weaning environment on the magnitude and direction of the genetic effect on a trait. The direct genetic effects were larger than the other genetic effects. Jersey direct effects were consistent across the ages for Wt, Ht and Fat but not for muscle. For example, it led to low Wt, Ht and Fat gain but high post-weaning muscle gain. Koch et al. (1994) also reported that the post-weaning muscle is primarily influenced by direct effect. The unexpected positive direct effect on muscle gain at older ages, since the effect was negative at weaning (-21%, unpublished), may be due to faster maturation of Jersey relative to Limousin at these ages.

The Jersey is a dairy breed and has high milk supply. Thus, the positive pre- and post-weaning Jersey maternal effects on most traits were due to large milk supply from the Jersey dam. However, there was a negative effect on post-weaning muscle gain. This may be due to the expression of compensatory growth in calves with Limousin dam relative to Jersey dam when exposed to a good post-weaning environment. This is further demonstrated in the genotype by seasonal re-ranking in Wt (Dry: JJ<JJ<XL<LL<XL Vs Wet: JJ<XJ<XL<LL<JJ) and Ht (Dry: JJ<XL<XL<JJ<LL Vs Wet: LJ<XJ<XL<LL<XL).

The Fat differences of the LJ calves, as compared to other genotypes at all ages, was mainly due to heterosis but also partly due to the maternal effect. The significant negative heterotic effect on Wt is contrary to earlier reports. Pitchford et al. (1993) found that heterotic effects were 1-21% for mature weight and 0-4% for mature height depending on the pre-weaning environment. Also, in male and female lines of three composite populations (MARC I, II and III), heterosis was positive for gain from weaning to 368-day, 368-day weight, and 368-day condition score (Gregory et al. 1991). Rarely has heterosis been estimated to have a negative effect on growth as in this study. The limitation of small number of sires per breed (2-3) may partly explained the reason for the deviation. However, there were large numbers of dams from a wide range of sources. Also, the difference between breeds (Limousin and Jersey) especially for carcass traits, is larger than for most other studies. The study has also shown that the epistatic effects on Wt and Fat may be larger at older than younger ages. The breed re-ranking referred to above was also a function of non-additive genetic effects.

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REFERENCES