EVIDENCE OF NON-ADDITIVE GENETIC EFFECTS ON PREDICTED CARCASS COMPOSITION

R.A. Afolayan, C.D.K. Bottema and W.S. Pitchford

Livestock Systems Alliance, Adelaide University, Roseworthy, SA 5371 Australia

INTRODUCTION

Genetic effects on pre- and post-weaning body weight and developmental traits of Jersey and Limousin cross cattle has been reported (Afolayan *et al*., 2001). As in this earlier study which indicated the importance of epistasis at older ages, maternal effects (Meyer, 1992) and heterotic effects (Pitchford *et al*., 1993) have also been found on post-weaning growth traits of some breed of beef cattle. Genetic improvement programs in beef cattle could be enhanced through understanding of the genetic effects on live animal traits at various ages. However, the value of beef cattle lies better in their ability to efficiently produce a carcass composed of optimal proportions of muscle, bone and fat at market weight (Tatum *et al*., 1986). In essence, the knowledge of the genetic effects on different carcass components is of more importance to the breeders/producers of livestock. This study, therefore, examines the estimates of four genetic effects on predicted carcass traits using live-animal measurements.

MATERIALS AND METHODS

Animals. Two hundred and forty steers from two projects [Southern Crossbreeding Project (SXB) and Davies Gene Mapping Project (DGM)] were used to develop the prediction equations for the carcass traits. 182 steers by 26 sires were progeny from SXB and 59 steers (14 Jersey, 28 Limousin, 17 Limousin x Jersey) were part of DGM animals born to 4 sires (2 Jersey and 2 Limousin). The developed prediction equations were then used for the data from all 591 DGM progeny (steers and heifers) which comprised pure Jersey (JJ), pure Limousin (LL), Limousin x Jersey (LJ), Jersey backcross (XJ) and Limousin backcross (XL). Detailed experimental design and management of SXB animals (Pitchford *et al*., 1998) and DGM animals (Afolayan *et al*., 2001) have been reported.

Live measurements. Measurements of weight, height, length, girth, fat depth and a measure of muscularity defined as the ratio (%) of stifle width (muscle) to hip width (bone) were taken on the 591 calves at 600-day postpartum. The methods used for the live measurements have been described elsewhere (Afolayan *et al*., 2001). The same measurements were taken prior to slaughter (at 750 days) on the 241 steers used for developing the prediction equations for carcass traits (carcass kg; meat kg, %; bone kg, %; fat kg, %). The slaughter and bone out procedure for the steers were previously reported (Pitchford *et al*., 1998).

Statistical Analysis. The REG procedure in SAS (1992) was used for the carcass trait prediction and the detailed stepwise method employed is as described by Afolayan *et al*. (2002). Predicted equations were adapted on live measurements at 600-day postpartum described above and estimates of seven predicted carcass traits were analysed. The model used contain 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 by sex interaction with sire and dam fitted as random effects (SAS, 1992).

Genetic effects were defined in terms of direct, maternal, heterosis and 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 five genotype combinations, epistatic effects were 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.

$$\text{Jersey direct} = JJ - LL - XJ + XL = -\text{ Limousin direct}$$
$$\text{Jersey maternal} = (LL - JJ)/2 + XJ - XL = -\text{ Limousin maternal}$$
$$\text{Heterosis} = LJ - LL - XJ + XL$$
$$\text{Epistasis} = 2(XJ) - LJ - JJ$$

RESULTS

Means and ranges for the predicted carcass traits based on live-animal measurements at 600-day postpartum were determined (Table 1). The mean predicted carcass composition was 69.0% meat, 21.1% bone and 7.8% fat. These values were approximately ratio of 7:2:1 similar to those obtained for the steers from which the prediction equations were developed (Afolayan *et al*., 2002).

Table 1. Summary statistics for prediction of carcass traits at 600-day postpartum

Predicted variables	Mean	CV	Minimum value	Maximum value	R^2	Residual SD
Carcass (kg)	209.3	11	93.8	438.3	87	22.7
	141.1	13	48.0	328.1	87	17.8
Meat (kg) (%)	69.0	2	63.9	79.1	69	1.5
	45.2	10	24.3	73.7	77	4.3
Bone (kg) (%)	21.1	3	15.6	23.6	80	0.7
	17.6	24	-5.6	42.2	60	4.3
Fat (kg) (%)	7.8	15	-0.7	11.6	76	1.2

Jersey direct effects were highly significant (P<0.01) for all the kilogram carcass traits (Table 2). The effects resulted in lower meat, bone and fat weight. However, there was no direct effect (P>0.05) on percentage carcass products. The effect due to Jersey dam on progeny was positive for bone and fat weight, but not significant for carcass or meat weight. For the percent meat, Jersey maternal effect was negative. This effect also resulted in an increase (P<0.05) in percent bone.

Heterosis effects were significant for carcass composition. There was a positive effect on meat percent with corresponding negative effects on bone and fat percent. There was also a significant negative effect on bone weight. Epistasis effects were also large for carcass composition with changes in the same direction as heterosis. In addition, there was a corresponding effect on low fat weight (Table 2).

Table 2. Genetic effects and tests of significance (difference from zero) for predicted carcass traits at 600-day postpartum

Traits		Jersey direct	Jersey maternal	Heterosis	Epistasis
Carcass	kg	-58.4±9.3***	9.3±5.1	-5.3±4.7	7.3±16.3
Meat	kg	-41.3±7.5***	3.6±4.1	-1.3±3.8	15.1±13.1
	%	0.6±0.4	-1.4±0.2***	0.7±0.3*	3.9±0.8***
Bone	kg	-10.3±1.7***	2.5±0.9**	-2.0±0.9*	-1.6±3.0
	%	0.3±0.2	0.2±0.1*	-0.5±0.2**	-0.8±0.4*
Fat	kg	-8.2±1.1***	4.4±0.7***	-1.1±0.9	-10.1±2.3***
	%	0.7±0.4	0.4±0.2	-0.9±0.3***	-2.0±0.7***

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

DISCUSSION

Reliable prediction of the genetic effects on carcass components from live-animal measurements could be a strong tool towards value based and easy genetic improvement strategies for important economic traits. The strong negative Jersey direct effects on the predicted carcass traits on kilogram weight basis were expected since the Jersey breed is smaller size than the Limousin breed. In a study comprising many different breeds, pure Limousin progeny and those sired by Limousin also ranked higher in carcass, meat and bone weight (Pitchford *et al*., 1998). However, the positive but not significant Jersey direct for the percentage carcass products may reflect an attribute of Jersey genes on proportion of carcass products. Jersey had greater proportion of bone than Limousin (Pitchford *et al*., 1998).

The positive Jersey maternal effects on carcass bone and fat weights indicate the importance of the carry-over effects of pre- and post-natal nutrition from Jersey cows relative to Limousin cows. Maternal effect from Jersey dams, being a dairy breed with high milk supply, contributed significantly to the expression of these traits. However, the non-significant maternal effects on carcass and meat weight suggest a limit for the dam influence on progeny performance. Also, the negative but significant Jersey maternal effect on percent meat indicates compensatory growth exhibited by calves born and nursed by Limousin dams, probably due to improved post-weaning nutrition.

Most reported studies have indicated heterosis effects only on growth and corresponding quantitative traits (Koch *et al*., 1985 ; Pitchford *et al*., 1993). Koch *et al*. (1985) obtained a greater than expected retained heterosis for post-weaning gain and final weight while Pithford *et al*. (1993) found that heterosis effects were 1-21% for mature weight and 0-4% for mature height depending on the environment. Also, the study by Gregory *et al*. (1991) observed no significant heterotic effects even on post-weaning muscle, an indication of expected carcass products. However, this study has shown reasonable evidence (Table 2) for non-additive genetic effects on carcass composition (% traits). The positive heterosis and epistasis estimates on meat percent and negative effects on bone and fat percent supported this. Thus, non-additive genetic effects (heterosis and epistasis) should be considered when developing a composite population. The large phenotypic differences between the breeds used in this study (Limousin and Jersey) could be the reason for the significant non-additive genetic effects on the percentage carcass products in contrast to other studies.

CONCLUSION

This study has revealed that the genetics of carcass composition may involve complex gene action that could impact on both breeding value estimation and marker or genotype-assisted beef cattle selection programs.

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REFERENCES

Afolayan, R.A., Pitchford, W.S. and Bottema, C.D.K. (2001) *Proc. Aust. Assoc. Anim. Brd. Gen.* **14** : 481-484.

Afolayan, R.A, Deland, M.P.B., Rutley, D.L., Bottema, C.D.K., Ewers, A.L., Ponzoni, R.W. and Pitchford, W.S. (2002) *Proc. Aust. Soc. Anim. Prod.* (Submitted).

Dickerson, G.E. (1969) *Anim. Breed. Abstr.* **37** : 191-202.

Gregory, K.E., Cundiff, L.V. and Koch, R.M. (1991) *J. Anim. Sci.* **69** : 3202-3212.

Koch, R.M., Dickerson, G.E., Cundiff, L.V. and Gregory, K.E. (1985) *J. Anim. Sci.* **60** : 1117-1132.

Meyer, K. (1992) *Livest. Prod. Sci.* **31** : 179-204.

Pitchford, W.S., Barlow, R. and Hearnshaw, H. (1993) *Livest. Prod. Sci.* **33** : 141-150.

Pitchford, W.S., Ewers, A.L., Ponzoni, R.W. and Deland, M.P.B. (1998) *Proc. 6th WCGALP* **23** : 117-120.

SAS (1992) Technical report P- 229. SAS/STAT Software: Changes and Enhancements.