Proc. Assoc. Advmt. Anim. Breed. Genet. 22:149-152

EXPRESSION OF HETEROSIS FOR LIVE WEIGHT IN GROWTH CURVES OF NEW ZEALAND DAIRY HEIFERS

R.C. Handcock[1], N. Lopez-Villalobos[1], L.R. McNaughton[2], G.R. Edwards[3] and R.E Hickson[1]

[1]Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Private Bag 11-222, Palmerston North, New Zealand
[2]Livestock Improvement Corporation, Private Bag 3016, Hamilton 3240, New Zealand
[3]Faculty of Agriculture and Life Sciences, PO Box 85084, Lincoln University, Lincoln 7647, Christchurch

SUMMARY

The objective of this study was to model the growth curves of New Zealand dairy heifers and to estimate breed and heterosis effects between Holstein Friesian (F), Jersey (J) and Holstein Friesian-Jersey crossbreed (FxJ) heifers before first calving at 2 years of age. Data consisted of 1,653,214 liveweight (LWT) records obtained from 189,936 spring-born dairy heifers located in 1,547 herds. A fourth order Legendre polynomial was fitted to the LWT data to model growth curves. At all ages F heifers were heavier than FxJ which were heavier than J heifers. The difference among the breeds varied over the growth period studied; F heifers were not a constant percentage heavier than FxJ or J heifers. This demonstrates that the breeds in this study exhibited different growth patterns. Breed effects, defined as F-J, were positive and ranged from 12.8 kg to 55.3 kg. Heterosis effects, expressed in kilograms, were positive and increased up to 18 months of age. Expressed as a percentage of the average of the parental breeds, heterosis was greatest at nine months of age (3.6%) and least at 22 months of age (2.0%). In conclusion, in New Zealand dairy heifers, heterosis effects were different throughout the growth period and F, J and FxJ heifers exhibited different growth patterns.

INTRODUCTION

The predominant dairy breeds in New Zealand are Holstein-Friesian (F), Jersey (J) and Holstein-Friesian x Jersey crossbred (FxJ) (Livestock Improvement Corporation and DairyNZ 2016). Holstein-Friesian is a later maturing and heavier breed compared with the lighter and early maturing J (Leche 1971; Hickson *et al.* 2012). Jersey heifers attained puberty at a younger age compared with F heifers (Hickson *et al.* 2011), further emphasising their earlier maturity. Heterosis is present in FxJ animals for mature liveweight (LWT) and ranges from 7.2 to 10 kg (Harris *et al.* 1996; Harris 2005), but has not been documented in growing heifers in New Zealand. Current target LWTs for dairy heifers are 30%, 60% and 90% of mature LWT at six, 15 and 22 months of age (Burke *et al.* 2007). There are differences in the proportion of target achieved between breeds (McNaughton and Lopdell 2013; Handcock *et al.* 2016), suggesting a potential difference in growth pattern and therefore, indicating that appropriate target percentage may be different among breeds. Due to the pasture-based farming systems in New Zealand, dairy heifers tend to follow a seasonal pattern of growth that matches pasture quality and quantity (Litherland *et al.* 2002; Handcock *et al.* 2016). The objective of this study was to use the model of the growth curves for New Zealand dairy heifers to estimate breed and heterosis effects.

MATERIALS AND METHODS

Liveweight records of New Zealand dairy heifers were extracted from the Livestock Improvement Corporation database. Heifers that were spring-born between the 2006-07 and 2013-14 dairy seasons, had at least two LWT records between birth and 12 months of age and two LWT records between 13 months of age and first calving at approximately two years of age, or 24 months of age if the heifer did not have any recorded calving dates were considered. Initial data cleaning was completed by calculating the mean and standard deviation of LWT for each age (in months), and for each breed. Liveweight records that were more than four standard deviations from their corresponding breed-age mean were removed (Pietersma *et al.* 2006). This method was iterated until no more records were deleted (Pietersma *et al.* 2006). This left a dataset comprised of 1,656,433 LWT records obtained from 189,936 dairy heifers located in 1,547 herds. Of these heifers, 48,026 were F; 12,407 were J and 129,503 were FxJ. Only heifers with known dam and sire and less than 2/16 (12.5%) of breeds other than F or J were included in the dataset.

Based on recorded pedigree and sire and dam breed proportions; individual animal's breed proportions were known, and were used to calculate coefficient of specific heterosis.

Statistical analysis. A Legendre polynomial of order four was fitted to LWT data using random regression to obtain regression coefficients for each heifer using ASReml (Gilmour *et al.* 2015). To remove outlier observations the relative measurement error (RME) was calculated as:

$$\mathrm{RME} = \left(\frac{Predicted\ LWT - Actual\ LWT}{Predicted\ LWT}\right) \times 100$$

Any actual LWT between three and 23 months of age that had an absolute RME greater than 18% (mean + four standard deviations) was considered an outlier and removed from the dataset. The RME calculates the percentage deviation of the actual LWT from the predicted LWT by assuming that the predicted LWT is the "true" value. At birth, one, two and 24 months of age the accuracy of the fourth-order polynomial was low (data not shown). Records were not removed at these ages as the predicted LWT was not accurate enough to be defined as the "true" value. The cleaned dataset included 1,653,214 observations (0.2% of data removed) on the same 189,936 animals. An order-four Legendre polynomial was fitted to the cleaned dataset and was used for subsequent analysis. The individual regression coefficients were used to estimate LWT at 3, 6, 9, 12, 15, 18 and 22 months of age for each heifer.

Breed and heterosis effects for LWT at the different ages were estimated using a linear mixed model in SAS version 9.4 (SAS Institute Inc). The mixed model included the fixed effect of birth year, dam age (2 years old, or 3 years old and older), and island (North vs South) as class effects, the deviation from median birthdate (within-herd), proportion of F, proportion of Other breeds (O), heterosis FxJ, heterosis FxO and heterosis JxO fitted as covariates, and the random effect of herd of birth. The estimates of the regression coefficients were used to predict the LWT of F, J and F_1 F×J cows at different ages.

RESULTS

Predicted means and standard errors of LWT at different ages for the three breed groups are presented in Table 1. At all ages, F heifers were heavier than FxJ which in turn were heavier than J heifers. Figure 1 displays the deviation of F and FxJ from J, as well as the expected average of the parental breeds ((F + J)/2). Holstein-Friesian heifers were 15.8% heavier than J heifers at three months of age; decreasing to 14.9% at nine months of age and increasing to a maximum at 17 months of age. First cross FxJ heifers were between 10.5 and 12.2% heavier than J heifers from three to 19 months of age; decreasing to 7.6% by 22 months. The difference between FxJ and the expected average of the parental breeds ranged from 2.1 to 3.9% with the greatest difference occurring between 8 and 12 months of age.

The estimates for breed and heterosis effects for LWT are shown in Table 1. Breed differences between F and J was estimated to be greatest at 18 months of age. Heterosis, in absolute values was positive at all ages and greatest at 18 months of age. Heterosis (as a proportion of parent average) was greatest at 9 months of age.

Table 1. Live weight of Holstein-Friesian (F), Jersey (J) and first cross (F_1) Holstein-Friesian-Jersey crossbred (FxJ) heifers, and estimates of breed and heterosis effects at different ages

Age	Live weight (kg)			Breed effect	Heterosis (FxJ)	
(months)	F	F_1 FxJ	J	F-J (kg)	kg	% †
3	93.5 ± 0.3	89.2 ± 0.3	80.8 ± 0.3	12.8* ± 0.2	2.1* ± 0.1	2.4%
6	156.5 ± 0.5	150.9 ± 0.5	135.8 ± 0.5	20.7* ± 0.2	4.8* ± 0.2	3.3%
9	193.2 ± 0.6	187.1 ± 0.6	168.1 ± 0.6	25.1* ± 0.3	6.5* ± 0.2	3.6%
12	238.8 ± 0.7	230.0 ± 0.7	205.7 ± 0.7	33.1* ± 0.3	7.8* ± 0.3	3.5%
15	304.6 ± 0.7	291.1 ± 0.7	259.5 ± 0.8	45.2* ± 0.4	9.0* ± 0.3	3.2%
18	380.2 ± 0.8	362.2 ± 0.8	324.8 ± 0.8	55.3* ± 0.4	9.7* ± 0.3	2.8%
22	430.4 ± 0.7	417.4 ± 0.7	388.0 ± 0.8	42.4* ± 0.4	8.2* ± 0.3	2.0%

*Mean is significantly different from zero (P<0.0001).

† Expressed as a percentage of heterosis effects relative to the phenotypic average of the parental breeds ((F+J)/2).

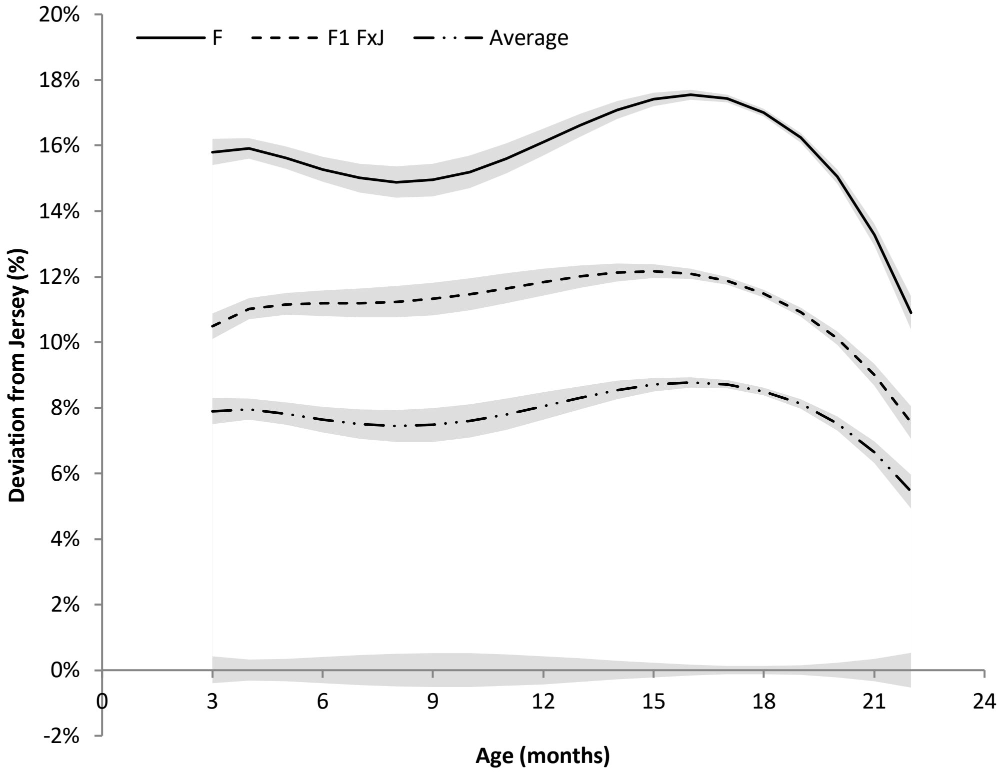

Figure 1. Deviation of estimated live weight of Holstein Friesian (F), Holstein Friesian-Jersey crossbred (F_1 FxJ) and the expected average of the parental breeds ((F + J)/2; Average) from Jersey (J) heifers ("0" line) derived from the fourth-order Legendre polynomial. Grey shading represents 95% confidence intervals for each breed

DISCUSSION

The LWT of F heifers was consistently heavier than FxJ and J heifers, as expected based on the difference in mature size (Hickson *et al.* 2012; Livestock Improvement Corporation and DairyNZ 2016). However, the growth pattern was different; F heifers were not a constant percentage heavier than FxJ or J heifers (Figure 1). If the growth pattern was similar among the breeds the slope of the lines in Figure 1 would be zero for both F and FxJ. From four to nine months of age the difference between F and J decreased; over this same period, the difference between FxJ and J was constant. Furthermore, heterosis exhibited by FxJ heifers was the greatest (3.6%) at nine months of age. The difference indicates that at different ages, one breed has a greater potential for growth compared with the other and heterosis significantly contributes to the difference in growth pattern.

Heterosis estimates for mature FxJ cows range from 7.2 kg to 10 kg (Harris *et al.* 1996; Harris 2005); similar to the values in the current study from nine months of age onwards. Heterosis varied throughout the growth period in first generation FxJ heifers in the USA (Hilder and Fohrman 1949); and were similar at 3 (2.2%), 6 (3.2%) and 18 months of age (2.5%) to what was reported in the current study. At 9, 12 and 15 months of age, heterosis estimates for the current study were greater than those reported by Hilder and Fohrman (1949) (1.3, 0.4 and 1.4% respectively). The estimates reported by Hilder and Fohrman (1949) are from a total of 18 calves that were reared in a predominantly indoor system. In contrast, the results reported in the current study are from 189,936 heifers reared in a pasture based system, which may explain the differences in heterosis estimates between the two studies.

In conclusion, New Zealand dairy heifers exhibited heterosis effects throughout the growth period and F, J and FxJ heifers displayed different growth patterns. The weight for age targets may therefore be different for these breeds, due to the differing growth patterns.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Katie Eketone for extracting the data provided by Livestock Improvement Corporation (Hamilton, New Zealand).

REFERENCES

Burke C., Blackwell M. and Little S. 2007. The InCalf Book for New Zealand dairy farmers. DairyNZ, Hamilton.

Gilmour A.R., Gogel B.J., Cullis B.R., Welham S.J. and Thompson R. 2015. ASReml User Guide Release 4.1 Structural Specification. VSN International Ltd, Hemel Hempstead, HP1 1ES, UK.

Handcock R.C., Lopdell T. and McNaughton L.R. (2016). *Proc. N.Z. Soc. Ani. Prod.* **76**: 3.

Harris B.L. (2005). *N Z Vet J.* **53**: 384.

Harris B.L., Clark J.M. and Jackson R.G. (1996). *Proc. N.Z. Soc. Ani. Prod.* **56**: 12.

Hickson R.E., Balcomb C.C., Fraser K.R., Lopez-Villalobos N., Kenyon P.R. and Morris S.T. (2011). *Proc. Assoc. Advmt. Anim. Breed. Genet.* **19**: 51.

Hickson R.E., Kenyon P.R., Lopez-Villalobos N., Laven R.L., Fraser K.R., Balcomb C.C. and Morris S.T. (2012). *Proc. Soc. Sheep & Beef Cattle Vet. NZVA.* **2012**: 4.22.1.

Hilder R.A. and Fohrman M.H. (1949). *J. Agri. Res.* **78**: 457.

Leche T.F. (1971). *Aus. J. Agri. Res.* **22**: 829.

Litherland A.J., Woodward S.J.R., Stevens D.R., McDougal D.B., Boom C.J., Knight T.L. and Lambert M.G. (2002). *Proc. N.Z. Soc. Ani. Prod.* **62**: 138.

Livestock Improvement Corporation and DairyNZ. 2016. New Zealand Dairy Statistics 2015-16. Livestock Improvement Corporation, DairyNZ, Hamilton, New Zealand.

McNaughton L.R. and Lopdell T. (2013). *Proc. N.Z. Soc. Ani. Prod.* **73**: 103.

Pietersma D., Lacroix R., Lefebvre D., Cue R.I. and Wade K. (2006). *Can. J. Anim. Sci.* **86**: 325.