Positive relationship between live weight at first calving and first lactation milk production

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

[1]Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Private Bag 11-222, Palmerston North, New Zealand
R.C.Handcock@massey.ac.nz (Corresponding Author)
[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

This study investigated the effects of pre-calving live weight on milk production in first lactation New Zealand dairy heifers. Heifers were classified into five breed groups; Holstein-Friesian (F), Holstein-Friesian crossbred (FX), Jersey (J), Jersey crossbred (JX) and Holstein-Friesian-Jersey crossbred (FJ). There was a curvilinear relationship between live weight at 21 months of age and protein and fat yields for all breed groups. The relationship between live weight and milk yields was curvilinear for all breed groups apart from J which had a linear relationship only. At most live weights, F heifers produced more than J heifers, however, all breed groups produced similar yields when heifers were lighter (260 – 325 kg) at 21 months of age. For lighter heifers the response to a one kg increase in live weight was greater compared with heavier heifers, indicating there could be greater benefits of preferentially feeding lighter heifers to attain heavier pre-calving live weights. Within the live weight range studied (260 – 600 kg) there was no live weight at which maximum milk or protein yields was achieved. An increase in live weight was also associated with an increase in milk and protein yields for all breed groups. For fat yield, the maximum production was achieved by J heifers that were 497 kg. For all other breed groups, the maximum yields were predicted to be at live weights greater than 658 kg; beyond the live weight range studied. These results show the potential to increase first lactation milk production of New Zealand dairy heifers by increasing pre-calving live weight.

Keywords: live weight, milk yield, dairy heifer, growth

Introduction

New Zealand has a predominantly pasture-based dairy farming system that requires heifers to calve at 24 months of age in order to maintain a 365-day calving interval. The major dairy breeds are Holstein-Friesian (33.5%), Jersey (10.1%) and Holstein-Friesian-Jersey crossbred (FxJ; 47.2%) (Livestock Improvement Corporation & DairyNZ, 2016). Jersey heifers produced less milk (Livestock Improvement Corporation & DairyNZ, 2016; Sneddon *et al.*, 2016) and were lighter (Handcock *et al.*, 2017) than FxJ and Holstein-Friesian heifers.

Positive linear relationships between pre-calving liveweight and milk production and percentage of target live weight and milk production have been reported in New Zealand (van der Waaij *et al.*, 1997; McNaughton & Lopdell, 2013) and elsewhere (Dobos *et al.*, 2001). These estimates from the literature did not compare the relationship between live weight and milk production among heifers of differing breed makeup.

The aim of this study was to explore the relationship between live weight at 21 months of age and milk, fat and protein yields in first lactation dairy heifers and to understand whether the relationship differed for Jersey, Holstein-Friesian and crossbred heifers of varying breed proportions.

Materials and methods

Live weight records from 189,936 New Zealand dairy heifers that were spring-born (June to December) between 2006-07 and 2013-14 dairy seasons were extracted from the Livestock Improvement Corporation (LIC) database (Handcock *et al.*, 2017). Heifers with >12.5% (2/16) of breeds other than Holstein-Friesian or Jersey were not included in the dataset. Growth curves for the heifers were generated using a fourth-order Legendre polynomial (Handcock *et al.*, 2017). Using the individual growth curves, live weight at 21 months of age (639 days) was predicted for each heifer.

Calving dates and milk production records were also extracted from the LIC database and heifers were selected that calved at approximately two years of age (21 – 29 months of age) between June and December (n=175,142). Heifers with records outside of the following limits were excluded: 30 – 300 kg of protein, 40 – 400 kg of fat, 800 – 8000 L of milk yield (Gardner, 2017) and between 80 and 305 days in milk. This resulted in 140,113 heifers with suitable first lactation records.

Breed composition (expressed in 16^{th}) was used to classify heifers into one of five breed groups; Holstein-Friesian (F), Holstein-Friesian crossbred (FX), Jersey (J), Jersey crossbred (JX) or Holstein-Friesian-Jersey crossbred (FJ). The criteria used to classify breed groups is outlined in Table 1.

Table 1. Breed composition, number of records (N) and mean ± SD live weight (LWT) of 21-month-old dairy heifers

Breed group	Breed composition	N	LWT (kg)
Holstein-Friesian (F)	$F \geq 14/16$	34,936	447.5 ± 37.7
Holstein-Friesian crossbred (FX)	$10/16 \leq F \leq 13/16$	46,690	432.9 ± 35.5
Holstein-Friesian-Jersey crossbred (FJ)	$F < 10/16$ and $J < 10/16$	31,373	419.7 ± 33.6
Jersey crossbred (JX)	$10/16 \leq J \leq 13/16$	17,395	405.5 ± 34.5
Jersey (J)	$J \geq 14/16$	9,719	378.2 ± 33.1

Statistical Analysis

The effect of LWT at 21 months of age on milk production parameters (milk yield, fat yield and protein yield) were analysed using mixed models in SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). The models included the fixed effect of breed group, the linear and quadratic effect of LWT nested within breed group, the deviation from median date of calving (within herd-year contemporary group) was fitted as a covariate and herd-year contemporary group was fitted as a random effect. Confidence intervals at the 95% level were used to test if LWT effects differed among breed groups. Live weight at which maximum milk, protein and fat yields were observed was calculated using the first derivative of the solutions from the mixed model.

Results

Live weight at 21 months of age had significant linear and quadratic effects on milk yield for all breed groups apart from J (Table 2). For J heifers only the linear effect of live weight on

milk yield was significant. The effect of live weight on fat yield and protein yield was significant for both the linear and quadratic effects for all five breed groups. The linear effect of live weight on fat yield was greater (P<0.05) for J heifers compared with the other breed groups.

Table 2. Regression coefficients ± s.e. for the linear and quadratic effects of live weight (LWT) of 21-month-old dairy heifers on milk yield, fat and protein in first lactation.

Breed group	LWT	P value	LWT^2	P value
		Milk yield (L)		
F	17.27 ± 1.56	<0.001	-0.0114 ± 0.0017	<0.001
FX	17.51 ± 1.43	<0.001	-0.0120 ± 0.0016	<0.001
FJ	14.25 ± 1.83	<0.001	-0.0087 ± 0.0022	<0.001
JX	12.63 ± 2.33	<0.001	-0.0074 ± 0.0029	0.010
J	12.06 ± 3.76	0.001	-0.0072 ± 0.0049	0.144
		Fat yield (kg)		
F	0.48 ± 0.08	<0.001	-0.0003 ± 0.0001	0.001
FX	0.67 ± 0.07	<0.001	-0.0005 ± 0.0001	<0.001
FJ	0.71 ± 0.09	<0.001	-0.0005 ± 0.0001	<0.001
JX	0.65 ± 0.11	<0.001	-0.0005 ± 0.0001	<0.001
J	1.28 ± 0.18	<0.001	-0.0013 ± 0.0002	<0.001
		Protein yield (kg)		
F	0.57 ± 0.06	<0.001	-0.0004 ± 0.0001	<0.001
FX	0.63 ± 0.05	<0.001	-0.0004 ± 0.0001	<0.001
X	0.61 ± 0.07	<0.001	-0.0004 ± 0.0001	<0.001
JX	0.50 ± 0.09	<0.001	-0.0003 ± 0.0001	0.002
J	0.68 ± 0.14	<0.001	-0.0006 ± 0.0002	0.002

F is Holstein-Friesian, FX is Holstein-Friesian crossbred, FJ is Holstein-Friesian-Jersey crossbred, JX is Jersey crossbred and J is Jersey.

The milk yield response to an increase in live weight from 299 to 300 kg was larger than the response to an increase from 499 to 500 kg for all breed groups (Table 3). Using the first derivative, the live weight at which the maximum milk and protein yields occurred were estimated to be between 730 and 856 kg live weight for milk yield and between 607 and 776 kg live weight for protein yield; beyond the live weight range of the heifers in this experiment (Table 3). For fat yield, the maximum production occurred when J heifers were 497 kg.

Table 3: Milk yield (L) response to a one kilogram increase in 21-month live weight (LWT) from 299 to 300 kg, 399 to 400 kg or 499 to 500 kg and the LWT at which maximum milk, protein and fat yields were estimated to occur.

Breed group	Milk yield (L) response to increase in LWT			LWT (kg) at maximum yield		
	299-300 kg	399-400 kg	499-500 kg	Milk yield	Protein yield	Fat yield
F	10.45	8.17	5.89	757	776	895
FX	10.33	7.93	5.53	730	730	694
FJ	9.06	7.34	5.61	824	722	678
JX	8.21	6.74	5.26	856	763	658
J	7.75	6.31	4.88	839	607	497

F is Holstein-Friesian, FX is Holstein-Friesian crossbred, FJ is Holstein-Friesian-Jersey crossbred, JX is Jersey crossbred and J is Jersey.

Figure 1 illustrates the relationship between live weight at 21 months of age and milk yield in the first lactation for the five breed groups. The milk yield response to increasing live weight is greater in lighter heifers (Table 3). Based on the 95% confidence intervals, at 300 kg live weight there were no differences in milk yield among the breed groups. Furthermore, F and FX heifers, and FX and FJ heifers produced similar amounts of milk at all live weights. However, by 350 kg, J heifers were producing less than the other four breed groups. This effect continued up until 500 kg live weight at which J and JX heifers were not different.

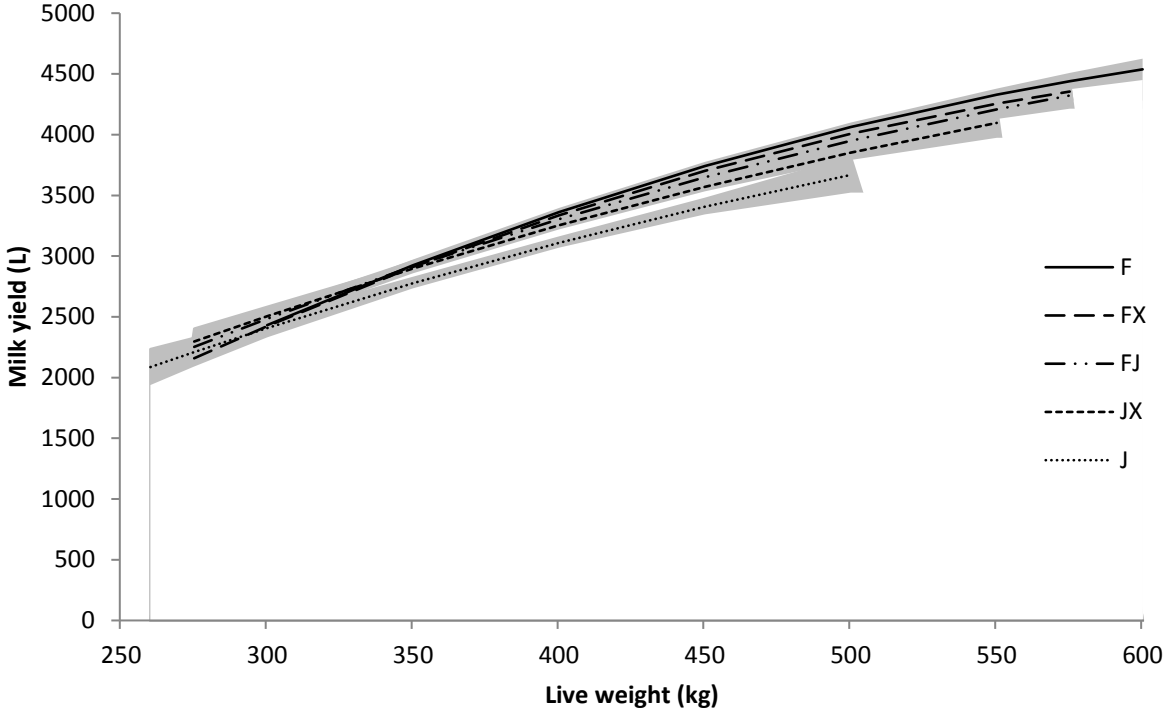

Figure 1. The relationship between live weight at 21 months of age and milk yield in 1st lactation dairy heifers. Where F is Holstein-Friesian, FX is Holstein-Friesian crossbred, FJ is Holstein-Friesian-Jersey crossbred, JX is Jersey crossbred and J is Jersey. The live weight range for each breed group is the range of live weights observed for that breed group.

Discussion

The relationship between live weight at 21 months of age and first lactation milk production for New Zealand dairy heifers was curvilinear. Heifers that were heavier produced more milk than heifers that were lighter, and the response to a one kg increase in live weight was greater for lighter heifers compared with heavier heifers, indicating there could be greater milk production benefits of preferentially feeding lighter heifers to attain heavier pre-calving live weights.

Previous studies have reported positive relationships between pre-calving liveweight and milk production, but have only reported linear effects (van der Waaij *et al.*, 1997; Dobos *et al.*, 2001; McNaughton & Lopdell, 2013). A 5.35 L response to a one kg increase in live weight of Australian Holstein-Friesian heifers was reported by Dobos *et al.* (2001), slightly less than what was found in current study for a one kg increase from 499 to 500 kg in F heifers. van der Waaij *et al.* (1997) reported a 6.65 L response, similar to a one kg increase from 399 to 400 kg in the current study. Heifers in the study by van der Waaij *et al.* (1997) were on average 370 kg at 21 months.

Within the liveweight ranges studied, an increase in live weight was always associated with an increase in milk and protein yields, although at heavier live weights the response was less than at lighter weights. For breed groups other than J, the maximum fat yields also occurred at live weights outside of the range studied. In contrast, first lactation Australian Holstein-Friesian heifers had an estimated maximum milk, protein and fat yields occurred at 559, 563 and 568 kg, respectively (Dobos *et al.*, 2001).

These results show the potential to increase first lactation milk production of New Zealand dairy heifers by increasing pre-calving live weight. Further research on the growth pattern necessary to achieve larger 21 month-old live weight is required. As well as the relationships between live weight at younger ages and milk production in first and subsequent lactations.

Conclusion

There was a positive curvilinear relationship between live weight at 21 months of age and milk, fat and protein yields in first lactation dairy heifers. Heifers that were heavier at 21 months of age produced more milk than heifers that were lighter, regardless of breed group.

Acknowledgements

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

List of References

Dobos, R.C., K.S. Nandra, K. Riley, W.J. Fulkerson, I.J. Lean & R.C. Kellaway, 2001. Effects of age and liveweight at first calving on first lactation milk, protein and fat yield of Friesian heifers. Aust. J. Exp. Agri. 41: 13-19.

Gardner, R.R., 2017. Milk Production and Survival of Spring-calving Carryover Cows in New Zealand Dairy Herds. Master's Thesis, Massey University, New Zealand.

Handcock, R.C., N. Lopez-Villalobos, L.R. McNaughton, G.R. Edwards & R.E. Hickson, 2017. Growth curves of New Zealand Holstein-Friesian, Jersey and Holstein-Friesian-Jersey crossbred heifers. In: Proc. N.Z. Soc. Ani. Prod., Rotorua, New Zealand. p 64-68.

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

McNaughton, L.R. & T. Lopdell, 2013. Effect of heifer live weight on calving pattern and milk production Proc. N.Z. Soc. Ani. Prod. No. 73. p 103-107, Hamilton, New Zealand.

Sneddon, N.W., N. Lopez-Villalobos, S.R. Davis, R.E. Hickson, L. Shalloo & D.J. Garrick, 2016. Supply curves for yields of dairy products from first-lactation Holstein Friesian, Jersey and Holstein Friesian-Jersey crossbred cows accounting for seasonality of milk composition and production. In: Proc. N.Z. Soc. Ani. Prod., Adelaide, Australia. p 139-143.

van der Waaij, E.H., P.J.B. Galesloot & D.J. Garrick, 1997. Some relationships between weights of growing heifers and their subsequent lactation performances. NZ J Agri Res 40: 87-92.