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Growth and milk production of dairy heifers born to two-year-old or mixed-age dams

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Abstract

Keeping replacement heifers that were the progeny of primiparous cows mated by artificial insemination, enhances rates of genetic gain. Heifers that were the progeny of primiparous cows were lighter at birth and grew at a slower rate to first calving compared with heifers born to multiparous dams. Heifers that were heavier before first calving produced more milk than did lighter heifers. This study aimed to determine if there were liveweight (LWT) or milk-production disadvantages for heifers born from primiparous compared with multiparous dams. Data comprised of LWT records from 189,936 New Zealand dairy heifers. Dams were allocated to four groups according to their age: two (2yo; n=13,717), three (3yo; n=39,258), four to eight (4-8yo; n=120,859) and nine years old or greater (≥9yo; n=16,102). Heifers born to 2yo dams were lighter (P<0.01) from three to 21 months of age than heifers born to 3yo and 4-8yo dams. The progeny of 2yo and 3yo dams produced similar milksolids yields during their first lactation (304.9±1.6 and 304.1±1.5 kg, respectively), but more (P<0.01) than that of 4-8yo dams (302.4±1.5) and ≥9yo dams (P<0.001; 297.8±1.6 kg). Heifers born to 2yo dams were lighter but produced more milk than heifers from older dams.

Keywords: dam; growth; milk; heifer

Introduction

It is common practice for 15-month-old dairy heifers to be naturally mated with Jersey bulls (Burke et al. 2007) and the resulting progeny are usually ‘bobbied’ (slaughtered between four and 10 days of age). Approximately one third of ‘bobby calves’ are the progeny of first-calving (two-year-old; 2yo) heifers (Livestock Improvement Corporation internal database, Hamilton, New Zealand). There is an increased awareness of, and consumer resistance to, the slaughter of these young calves (Fisher et al. 2017). Approximately 20% of heifers are artificially inseminated (AI) each year (Livestock Improvement Corporation & DairyNZ 2018), the resulting heifer calves are usually retained as replacements rather than “bobbied”, therefore, increased adoption of AI instead of natural matings could reduce the number of bobby calves produced by heifers. In addition, the rate of genetic gain in the dairy industry can be improved by using semen of high-genetic-merit bulls in 15-month-old heifers and by keeping replacement heifers from these younger dams (Johnson et al. 2018). However, heifers born to primiparous dams were lighter at birth (Hickson et al. 2015), had slower growth rates (Place et al. 1998) and tended to be lighter at calving (Heinrichs et al. 2005) compared with heifers born to multiparous dams.

Previous research has demonstrated that heifers that were lighter prior to first-calving produced less milk in first (Carson et al. 2002) and subsequent lactations (Handcock et al. 2019; McNaughton & Lopdell 2013; van der Waaij et al. 1997) compared with heifers that were heavier. As farmers are encouraged to mate 15-month-old heifers to AI instead of natural mating to increase genetic gain, it is of interest to identify if there are live weight (LWT) disadvantages between three and 21 months of age to the progeny of 2yo dams, and whether these heifers produce equivalent milk yields to those born to older dams. The aim of this study was to quantify heifer LWT and milk production in the progeny of primiparous or multiparous dams.

Materials and methods

Initial dataset

Liveweight records from 189,936 New Zealand dairy heifers born between 2006 and 2013 between June and December were extracted from the Livestock Improvement Corporation database (Handcock et al. 2018). Heifers were included if they had at least two LWT records between birth and 12 months of age and at least two LWT records between 13 months of age and first calving at two years of age (between June and December). Growth curves were generated for each heifer using random regression of a fourth-order Legendre polynomial in ASReml (Gilmour et al. 2015), as described by Handcock et al. (2018). Using the regression coefficients from the growth curves, LWT were predicted for each heifer between three and 21 months of age.

Only heifers with known dam and sire and ≤2/16 (12.5%) of breeds other than Holstein-Friesian (F) or Jersey (J) were included in the dataset. Dams were allocated to four groups according to their age: 2yo (n=13,717), three years old (3yo; n=39,258), four to eight years old (4-8yo; n=120,859) and nine years old or greater (≥9yo; n=16,102).

Using recorded pedigree, and sire and dam breed proportions, individual animals’ breed proportions were determined, and were used to calculate coefficient of specific heterosis between F and J, F and Other breeds (O), and J and O using the following formula:

$$h_{ij} = \alpha_{si}\alpha_{dj} + \alpha_{sj}\alpha_{di}$$

where h_{ij} is the coefficient of expected heterosis between breeds *i* and *j* in the progeny; α_{si} and α_{sj} are proportions of breeds *i* and *j* in the sire, respectively; and α_{di} and α_{dj} are proportions of breed *i* and *j* in the dam, respectively (Dickerson 1973).

Milk production dataset

Additional data of calving dates and milk production records were extracted from the Livestock Improvement Corporation database (2008/09 to 2016/17 spring-calving dairy seasons) and merged with the growth curves of the 189,936 heifers. Selected heifers calved at approximately two years of age in the spring-calving period (between June and December; n=175,142). The remaining 175,142 heifers were subject to the following criteria: heifers with a calving date but no milk yields (n=22,701) were removed from the data set due to uncertainty as to whether they were not herd tested or if they did not lactate. Heifers with a first-lactation length of less than 80 days were excluded (n=11,982). Additionally, records outside of the following limits were also excluded: 30 – 300 kg of milk protein, 40 – 400 kg of milk fat, 800 – 8000 L of milk yield (n=346). Lactations that were greater than 305 days were truncated at 305 days. This resulted in 140,113 heifers with suitable first-lactation records located in 1,326 herds.

Second- and third-lactation yields were subject to the same criteria as first-lactation yields. There were 108,876 heifers with suitable second-lactation records and 51,449 heifers with suitable third-lactation records. Heifers born after the 2012/13 spring-calving dairy season (n=50,584) were not considered for the third-lactation dataset as, at the time of data extraction, they were not old enough to have had three full lactations.

The milk production traits studied were; milk fat (FY), protein (PY), milksolids (MS: sum of milk fat and milk protein), milk (MY) and energy-corrected milk (ECM) yield. The ECM formula used was from Beever and Doyle (2007), and derived from Tyrell and Reid (1965) and calculated as follows:

ECM = milk yield × (383 × fat percentage + 242 × protein percentage + 783.2)/3,140

Genetic merit subset

It was expected that the progeny of 2yo dams would have superior genetic merit to the progeny of older dams, therefore, a subset of data was created to compare genetic merit. Heifers born in 2011 were selected from each dataset above and merged with their breeding values (BV) and breeding worth (BW) from the 31 May 2013 Animal Evaluation (AE) run, extracted from the Livestock Improvement Corporation database. The May 2013 BVs were selected as these were the closest estimates of genetic merit without the heifers' milk production (variable of interest in this study) included in the estimation of the BVs. In addition, only one year group could be compared, as BVs between different AE runs are not comparable.

Statistical analysis

The least-squares means of breed proportions, heterosis and genetic merit were analysed using a generalised linear model that included the fixed effect of dam age.

The least-squares means of LWT between three and 21 months of age predicted from the Legendre polynomial were analysed using linear mixed models that included the fixed effects of age of dam, birth year and the random effect of herd. Deviation from median date of birth (within-herd), proportion of F, proportion of O, heterosis FxJ, heterosis FxO and heterosis JxO were fitted as covariates.

The least-squares means of milk production were analysed using linear mixed models that included the fixed effects of age of dam, and the random effect of herd-year. Deviation from median date of first calving (within-herd-year), proportion of F, proportion of O, heterosis FxJ, heterosis FxO and heterosis JxO were fitted as covariates.

Results

The progeny of 2yo dams made up 7.2% of the population studied. A further 20.7% were the progeny of 3yo, 63.6% of 4-8yo and 8.5% of ≥9yo dams. The progeny of 2yo dams had high proportions of J and heterosis FxJ, compared with the progeny of mixed-age dams (Table 1). The subset of 2011-born heifers were comparable to the base population studied; there were similar proportions of heifers born from 2yo, 3yo, 4-8yo and ≥9yo dams (7.4, 21.0, 62.7 and 8.9%, respectively; Table 1) as in the base population.

Table 1 Least-squares means (± SEM) proportions of Holstein-Friesian (F), Jersey (J), and heterosis (Het FxJ) of 189,936 heifers and genetic merit‡ of a subset of dairy heifers born in 2011/12 that were the progeny of two-year-old (2yo), three-year-old (3yo), four- to eight-year-old (4-8yo) or nine-year-old and greater (≥9yo) dams.

	Age of dam			
	2yo	3yo	4-8yo	≥9yo
All heifers				
n	13,717	39,258	120,859	16,102
F Proportion	0.439[a] ± 0.002	0.635[b] ± 0.001	0.642[c] ± 0.001	0.636[b] ± 0.002
J Proportion	0.546[c] ± 0.002	0.352[b] ± 0.001	0.347[a] ± 0.001	0.355[b] ± 0.002
Het FxJ	0.503[d] ± 0.002	0.387[a] ± 0.001	0.403[b] ± 0.001	0.415[c] ± 0.002
2011/12 born				
n	1,766	5,119	15,273	2,123
F Proportion	0.402[a] ± 0.006	0.616[c] ± 0.004	0.620[c] ± 0.002	0.602[b] ± 0.006
J Proportion	0.583[c] ± 0.006	0.373[a] ± 0.004	0.370[a] ± 0.002	0.389[b] ± 0.006
Het FxJ	0.487[d] ± 0.006	0.400[a] ± 0.004	0.415[b] ± 0.002	0.433[c] ± 0.006
BW‡ ($)	135.47[c] ± 0.91	136.35[c] ± 0.54	128.17[b] ± 0.31	113.18[a] ± 0.83
Fat BV‡ (kg)	13.41[a] ± 0.16	16.24[c] ± 0.10	15.28[b] ± 0.06	13.72[a] ± 0.15
Prot BV‡ (kg)	9.06[a] ± 0.20	14.33[d] ± 0.12	13.59[c] ± 0.07	10.88[b] ± 0.19
Milk BV‡ (L)	11.92[a] ± 8.68	247.77[c] ± 5.10	243.49[c] ± 2.95	187.03[b] ± 7.92
LWT BV‡ (kg)	-13.79[a] ± 0.58	3.96[c] ± 0.34	3.81[c] ± 0.20	0.94[b] ± 0.53

[a-d]Values with differing superscripts within a row indicate significant differences at $P<0.05$.

‡Estimates of genetic merit were from the May 2013 Animal Evaluation run, prior to the heifers' first calving.

BW=Breeding worth, BV=breeding value, Prot=protein, Milk=milk volume, LWT=live weight

Based on genetic merit prior to first calving, heifers that were the progeny of 2yo and 3yo dams had the highest BW (P<0.001), followed by the progeny of 4-8yo dams and dams ≥9yo had the lowest BW (P<0.001; Table 1). Fat and protein BV were greatest (P<0.001) for heifers that were the progeny of 3yo dams and milk volume and LWT BV were lowest (P<0.001) for the progeny of 2yo dams (Table 1). Fat BV was similar for the progeny of 2yo and 9yo dams (P>0.05) and less than that of 4-8yo dams (P<0.001; Table 1).

Due to the differences in breed proportions of progeny born to 2yo vs older dams, LWT was corrected for all breed and heterosis effects. Despite this, throughout the heifer-rearing phase (three to 21 months of age), the progeny of 2yo dams were significantly lighter than the progeny of mixed-age dams (Table 2). Heifers with dams aged 4-8yo were the heaviest (P<0.05) at all ages studied (Table 2).

Heifers that were the progeny of 2yo and 3yo dams produced similar quantities of milksolids in first lactation (304.9±1.6 and 304.1±1.5 kg, respectively), but greater (P<0.01) than that of 4-8yo dams (302.4±1.5 kg). Progeny of dams ≥9yo had the lowest milksolids production in first (P<0.001; 297.8±1.6 kg), second (P<0.001; 341.6±1.8 kg), and third lactations (P<0.01; 393.2±2.4 kg). Heifers that were the progeny of 2yo dams produced the greatest (P<0.05) fat and milksolids yields in second lactation (Table 3). Heifers that were the progeny of 2yo and 3yo dams produced similar quantities of protein in first and second lactation, but greater (P<0.01) than that of 4-8yo and ≥9yo dams (Table 3). Energy-corrected milk yields were greater (P<0.05) for the progeny of 2yo dams compared with the progeny of dams ≥9yo for all three lactations (Table 3). Similarly, the progeny of 2yo dams produced greater (P<0.01) ECM and milksolids in first and second lactation than did the progeny of 4-8yo dams, but there was no difference by third lactation (Table 3).

Table 3 Least-squares means ± SEM for milk fat (FY), protein (PY), milksolids (MS), milk yields (MY) and energy-corrected milk (ECM) yields in first, second and third lactation for dairy heifers that were the progeny of two-year-old (2yo), three-year-old (3yo), four- to eight-year-old (4-8yo) or nine-year-old and greater (≥9yo) dams.

Lactation	Age of dam			
	2yo	3yo	4-8yo	≥9yo
First				
FY (kg)	169.3[c] ± 0.9	168.5[c] ± 0.8	167.9[b] ± 0.8	165.9[a] ± 0.9
PY (kg)	135.7[c] ± 0.7	135.6[c] ± 0.7	134.6[b] ± 0.7	131.9[a] ± 0.7
MS (kg)	304.9[c] ± 1.6	304.1[c] ± 1.5	302.4[b] ± 1.5	297.8[a] ± 1.6
MY (kg)	3475[b] ± 19	3497[c] ± 18	3476[b] ± 18	3422[a] ± 19
ECM (kg)	3976[c] ± 21	3972[c] ± 20	3951[b] ± 19	3893[a] ± 20
Second				
FY (kg)	193.2[c] ± 1.0	191.9[b] ± 1.0	191.7[b] ± 0.9	189.1[a] ± 1.0
PY (kg)	157.3[c] ± 0.8	156.8[c] ± 0.8	156.0[b] ± 0.8	152.6[a] ± 0.8
MS (kg)	350.5[d] ± 1.8	348.7[c] ± 1.7	347.6[b] ± 1.7	341.6[a] ± 1.8
MY (kg)	3998[b] ± 22	4015[bc] ± 20	4004[b] ± 20	3936[a] ± 21
ECM (kg)	4565[c] ± 24	4550[bc] ± 22	4538[b] ± 22	4463[a] ± 23
Third				
FY (kg)	219.8[ab] ± 1.5	219.9[b] ± 1.3	219.4[ab] ± 1.3	218.2[a] ± 1.4
PY (kg)	178.1[bc] ± 1.2	178.7[c] ± 1.0	177.5[b] ± 1.0	175.0[a] ± 1.1
MS (kg)	397.9[bc] ± 2.6	398.6[c] ± 2.3	396.8[b] ± 2.2	393.2[a] ± 2.4
MY (kg)	4512[ab] ± 30	4560[c] ± 27	4539[b] ± 26	4497[a] ± 28
ECM (kg)	5178[bc] ± 33	5196[c] ± 30	5175[b] ± 29	5131[a] ± 32

[a-d]Values with differing superscripts within a row indicate significant differences at P<0.05.

Table 2 Predicted live weight (least-squares means ± SEM; kg) between three and 21 months of age (mo) of dairy heifers that were the progeny of two-year-old (2yo), three-year-old (3yo), four- to eight-year-old (4-8yo) or nine-year-old and greater (≥9yo) dams.

Age (mo)	Age of dam			
	2yo	3yo	4-8yo	≥9yo
3	89.0[a] ± 0.3	90.3[b] ± 0.3	91.0[d] ± 0.3	90.5[c] ± 0.3
6	149.9[a] ± 0.5	151.4[b] ± 0.5	152.1[c] ± 0.5	151.3[b] ± 0.5
9	186.6[a] ± 0.6	187.5[c] ± 0.6	188.1[d] ± 0.6	187.1[b] ± 0.6
12	230.3[a] ± 0.7	231.1[b] ± 0.6	231.8[c] ± 0.6	230.4[a] ± 0.7
15	291.6[a] ± 0.7	293.2[c] ± 0.7	294.1[d] ± 0.7	292.4[b] ± 0.7
18	362.2[a] ± 0.8	365.1[c] ± 0.7	366.3[d] ± 0.7	364.3[b] ± 0.7
21	411.6[a] ± 0.7	415.0[c] ± 0.7	415.9[d] ± 0.7	414.2[b] ± 0.7

[a-d]Predicted live weights with differing superscripts within a row are significantly different (P<0.05).

Discussion

As expected, heifers that were the progeny of 2yo dams were lighter than the progeny of older dams (Heinrichs et al. 2005; Hickson et al. 2015; Place et al. 1998). Although small, the difference in LWT is likely to be due to 2yo heifers being lighter during pregnancy than older cows (Livestock Improvement Corporation & DairyNZ 2018), as they are yet to attain mature LWT. The data presented in this study showed that heifers that were the progeny of 2yo dams have greater proportions of Jersey compared with heifers that were the progeny of older dams and, therefore, were expected to be lighter (Handcock et al. 2018). This was evident in the mean LWT breeding values which were -13.79 kg for the progeny of 2yo and 3.81 kg for 4-8yo. The statistical model used for LWT corrected for the breed composition of the heifer, which reduced the difference between heifers born from 2yo compared with older dams. For example, the breed-adjusted means for 21-month LWT reported in the current study were 411.6 kg and 415.9 kg for the progeny of 2yo and 4-8yo dams, respectively (difference of 4.3 kg), whereas, the unadjusted means for LWT at 21 months of age were 414.8 kg and 426.5 kg for the progeny of 2yo and 4-8yo dams, respectively (difference of 11.7 kg). Therefore, the observed differences in LWT of the progeny of 2yo vs progeny of mixed age dams were mainly due to differences in breed composition, with only a small difference due to dam age effects.

Previous research has demonstrated a positive relationship between LWT prior to first calving and milk production (Handcock et al. 2019; McNaughton & Lopdell 2013; van der Waaij et al. 1997). However, in the current study, the progeny of 2yo heifers produced significantly greater milksolids than did the progeny of mixed-age dams in first and second lactation, even though they were lighter. Results from Austrian dual-purpose Simmental cows also showed that the progeny of younger dams produced greater ECM yields than did older dams (Fuerst-Waltl et al. 2004). The progeny of dams ≥9yo in the current study had the lowest milk production, similar to that reported by Fuerst-Waltl et al. (2004). Genetic merit is likely to explain some of the differences observed, with the progeny of dams ≥9yo having lower BW than that of the progeny of younger dams. However, the BW differences appear to be driven by the lower milk volume and LWT BVs of the progeny of 2yo dams compared with those of older dams, and not by superior fat or protein BVs. Both milk volume and LWT BVs have a negative economic value for calculating BW (Livestock Improvement Corporation & DairyNZ 2018), therefore, lower values are desirable for these two traits. Furthermore, the mean milk volume and LWT BV of Friesian bulls (767 kg and 46.2 kg, respectively) were greater than the mean milk volume and LWT BV of Jersey bulls (-475 kg and -53.2 kg, respectively) (Livestock Improvement Corporation & DairyNZ 2018). Therefore, some of the differences in BW between the progeny of 2yo dams and the progeny of older dams are likely to be a function of breed, as the progeny of 2yo dams had greater proportions of J compared with older dams.

The model used by Fuerst-Waltl et al. (2004) included the additive genetic effect of animal in order to correct for any bias from older dams having lower genetic merit than that of younger dams. An attempt was made to correct for differences in genetic merit based on dam age with inconsistent results (data not shown). One reason for the inconsistency of results may be due to Mendelian sampling, which means that an individual heifers' true genetic merit is not exactly halfway between that of her dam and sire. The pre-calving BVs and BW presented in the current study are not exact estimates of genetic merit, as they are based only on the performance of an individuals' ancestors. Once a heifer has begun to lactate and been herd tested, her own milk-production data feeds into the estimation of BVs, creating a better estimate of her true genetic merit for milk production. Although more accurate, using a heifer's first lactation milk production to estimate her BV creates a confounded relationship between BV and milk production if BVs are used to correct for genetic merit. In addition, BVs already account for breed differences (DairyNZ 2016), therefore, BVs and breed proportions cannot be included in the same statistical models. Further research is required to compare heifers born from 2yo with those from older dams of similar genetic merit and breed makeup, in order to confirm the impact age of dam has on LWT and milk production irrespective of genetic and breed effects.

Results of a simulation study showed that the greatest effect on genetic gain (measured as BW) was achieved by excluding the lowest BW cows from producing replacement heifers (i.e., mated to beef not dairy) (Johnson et al. 2018). Inclusion of the highest BW cows and 15-month heifers mated to AI was also recommended as a method to generate sufficient replacement heifers of high genetic merit (Johnson et al. 2018). Results from the present study indicate that the progeny of young dams are expected to be marginally smaller than the progeny of older dams, provided 15-month-old heifers are mated to bulls of similar breed makeup to those used in the main herd. Importantly, the milk production of these heifers born from younger dams is expected to be equal to that of 3yo dams, and greater than that of older dams. In addition, results from the current study indicated that retaining replacements from cows aged nine and over was not recommended, as these heifers had lower genetic merit and produced less milk than did those with younger dams. It is not known what effects age of dam may have on reproductive performance and survival of dairy heifers. Future research should be completed to compare reproductive performance and survival of the progeny of younger versus older dams.

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