Estimation of breed and heterosis effects for milk traits and somatic cell scores in cows milked once and twice daily in New Zealand

F Lembeye[a*], N Lopez-Villalobos[a], JL Burke[a] and SR Davis[b]

[a]*Institute of Veterinary, Animal and Biomedical science, Massey University, Private Bag 11-222, Palmerston North 4442, New Zealand;* [b]*LIC, Private Bag 3016, Hamilton 3240, New Zealand*

**Corresponding author.* Email: F.Lembeye@massey.ac.nz

Abstract

Crossbreeding is widely used by famers milking twice-a-day (TAD) to increase farm profitability. Effects of crossbreeding on farm productivity and profitability have not been investigated in farms practicing once-a-day (OAD) milking. The aim of the study was to estimate breed and heterosis effects for lactation length (LL), total yields of milk (MY), fat (FY) and protein (PY) and average somatic cell score (SCS) in cows milked OAD or TAD. Records from 36,276 Friesian (F), 31,560 Jersey (J) and 90,081 crossbred (F×J) cows that calved in spring between 2008 and 2012 were used. Compared to J cows, F cows had a higher MY (657 kg in OAD and 1034 kg in TAD), FY (2.9 kg in OAD and 7.8 kg in TAD), PY (13.6 kg in OAD and 22.4 kg in TAD) and SCS (0.28 in OAD and 0.05 TAD). Lactation length in OAD cows was five days shorter than in TAD cows (P<0.05). These results show a significant interaction between breed and milking frequency for production traits (P<0.001). Expressed as a percentage of the average of parental breeds, first-cross heterosis effects ranged between 4.92 to 6.84% for production traits, and were similar across milking frequencies. The estimates of breed and heterosis obtained in this study can be used for simulation studies to evaluate the profitability of crossbreeding systems under OAD and TAD milking systems of typical New Zealand dairy farms.

Keywords: breed effect; heterosis effect; milking frequency

Introduction

Pasture-based dairy farming in New Zealand has predominantly involved milking cows twice-a-day (TAD). However, since the late 1990s, milking once-a-day (OAD) has been adopted by some farmers for herd management and lifestyle benefits (Davis 2005).

Crossbreeding between Friesian (F) and Jersey (J) cows has been adopted since 1990 (Harris 2005) and it has brought favourable heterosis for production, fertility and survival traits, which has resulted in an increased overall farm profitability (Lopez-Villalobos et al. 2000). For New Zealand's dairy cattle, Harris (2005) summarized heterosis effects for economically important traits for cows milked TAD, but to date no studies have quantified breed and heterosis effects in cows milked OAD.

The objective of this study was to obtain breed and heterosis effects for milk traits , somatic cell score (SCS), and lactation length, in cows milked once and twice daily in grazing systems in New Zealand. These estimates of breed and heterosis effects for OAD can be used for simulation studies to compare the profitability of crossbreeding systems under OAD milking.

Materials and methods

Data

Total lactation records of milk yield (MY), fat yield (FY), protein yield (PY), average SCC and pedigree information were provided by Livestock Improvement Corporation (LIC) for the period 2008-2012. Initial data was restricted as follows. First, lactation records were sorted based on a milking frequency code. In the present study, OAD herds were considered those herds in which 100% of the cows were milked OAD. For comparison TAD farms selected were with a radius of 20 km from OAD herds. In some cases, for a given single map co-ordinate, a OAD herd was surrounded by several TAD herds, in which case all TAD herds were selected using GPS Visualizer (Schneider 2012). Second, only herds with more than 40 cows herd tested per season were considered in the analysis. Only records from spring-calving cows in their first five lactations with lactation lengths greater than 150 days and less than 305 days were considered. Also, only records from F, J and their crosses (F×J) were considered, discarding cows with no parental information. Cows were considered pure-bred when their breed composition was ≥93.75% from a particular breed (F or J).

After the restrictions were imposed, the dataset contained 326,327 lactation records (76,283 F; 183,667 F×J and 66,377 J). In total, the information included 127,885 lactation records from 334 herds milked OAD and 198,442 from 374 herds milked TAD.

Somatic cell score was calculated as $SCS = \log_2(SCC)$, where SCC is the somatic cell count at a given herd test and the average SCS during the lactation was calculated from the average SCS at each herd test.

Statistical Analysis

A linear model was used to obtain breed and heterosis effects for total milk traits, average SCS and lactation length (LL) using PROC MIXED of SAS Version 9.3 (SAS Institute Inc., Cary, NC, USA). The model was:

$$y_{ijk}=\mu+HS_i+M_j+L_k+ML_{jk}+\beta_1 f_{j=1}+\beta_2 f_{j=2}+\beta_3 h_{j=1}+\beta_4 h_{j=2}+\beta_5 d+e_{ijk}$$

Where is the MY, FY, PY, LL or average SCS of herd-season *i*, milking frequency *j* and lactation number *k*, is population mean, is random effect of contemporary group *i* defined as cows calving in the same herd and production season, (*i*= 1, 2…2214); is the fixed effect of milking frequency *j* (*j* = 1 and 2); is fixed effect of lactation number *k* (*k* = 1, 2…5), is fixed effect of interaction between the lactation number *k* and milking frequency *j*, is the regression coefficient associated with the linear effect of proportion of F in milking frequency 1, is the regression coefficient associated with the linear effect of proportion of F in milking frequency 2; is the regression coefficient associated with the linear effect of coefficient of heterosis in milking frequency 1, is the regression coefficient associated with the linear effect of coefficient of heterosis in milking frequency 2, is the regression coefficient associated with linear effect of deviation days from median calving date of the herd *i* for a given season and is the residual random error associated with observation .

For each milking frequency, the estimate of the regression coefficient of the proportion of F and linear effect of heterosis, gives respectively the estimation of the breed effect between F and J and heterosis in the first-cross cow (Back & Lopez-Villalobos 2007).

Another mixed model was used to obtain least squares means (±standard error of the mean) for each breed. The model considered the fixed effects of milking frequency, lactation number, breed groups, their interaction, median calving date as a covariable, and the contemporary group as random effect.

Results

Least squares means for total MY, FY, PY, LL and average SCS for each breed group and milking frequency are presented in Table 1, and breed and heterosis effects are presented in Table 2. Across milking frequencies, J cows had lower total lactation yields of milk, fat and protein than F and F×J cows. Jersey cows milked OAD yielded. The relative differences between J cows milked OAD and TAD ranged from 17.6 to 21.3%, slightly lower than the difference of 18.7-24.2% in F and F×J cows, respectively (Table 1).

Table 1 Least squares means (±standard error of the mean) for lactation length, total yield of milk, fat and protein, average somatic-cell score of Friesian (F), Jersey (J) and crossbred (F×J) by milking frequency (MF)

Trait	OAD	TAD	OAD			TAD			Probability		
			F	F×J	J	F	F×J	J	Breed	MF	Breed×MF
Lactation length (days)	221 (0.94)	226.0 (0.78)	221.2[a] (0.94)	221.2[a] (0.95)	220.4[b] (0.94)	226.5[c] (0.78)	226.3[c] (0.78)	225.1[d] (0.79)	<.0001	<.0001	0.007
Milk yield (kg/year)	2950 (24.6)	3836 (20.5)	3198[a] (25.3)	3014[b] (24.7)	2637[c] (25.0)	4217[d] (20.7)	3941[e] (20.5)	3351[f] (21.2)	<.0001	<.0001	<.0001
Fat yield (kg/year)	153.4 (1.18)	188.0 (0.98)	153.1[a] (1.21)	157.1[b] (1.18)	149.8[c] (1.20)	189.0[d] (0.99)	193.2[e] (0.98)	182.0[f] (1.02)	<.0001	<.0001	<.0001
Protein yield (kg/year)	118.0 (0.95)	145.9 (0.79)	122.5[a] (0.97)	120.9[b] (0.95)	110.7[c] (0.96)	153.4[d] (0.79)	150.0[e] (0.79)	134.4[f] (0.82)	<.0001	<.0001	<.0001
Somatic cell score	6.46 (0.02)	6.20 (0.02)	6.57[a] (0.02)	6.44[b] (0.02)	6.37[c] (0.02)	6.22[d] (0.02)	6.18[e] (0.02)	6.20[de] (0.02)	<.0001	<.0001	<.0001

[a,b,c,d,e,f] Least square means with different superscripts in the same row are significantly different across milking frequencies and breed groups (P < 0.05).

Table 2 Estimated breed and heterosis effects for total yield of milk, fat, protein and average somatic cell score by milking frequency (MF).

Trait	MF[1]	Breed effect[2]			Heterosis effect[3]			
		Estimate	SE	P-value	Estimate	SE	%[4]	P-value
Lactation length (days)	1	0.96	0.20	<.001	0.64	0.17	0.29	<.001
	2	1.33	0.17	<.001	1.14	0.14	0.51	<.001
Milk yield (kg)	1	657[a]	8.30	<.001	161.3	6.95	5.49	<.001
	2	1033.6[b]	6.87	<.001	185.4	5.66	4.92	<.001
Fat yield (kg)	1	2.9[a]	0.41	<.001	10.4[a]	0.34	6.84	<.001
	2	7.8[b]	0.34	<.001	13.7[b]	0.28	7.39	<.001
Protein yield (kg)	1	13.6[a]	0.29	<.001	7.6[a]	0.24	6.49	<.001
	2	22.4[b]	0.24	<.001	8.9[b]	0.20	6.21	<.001
Somatic cell (Score)	1	0.28[a]	0.02	<.001	-0.01	0.01	-0.21	0.282
	2	0.05[b]	0.01	<.001	-0.04	0.01	-0.72	<.001

[1] MF 1=Milking once-daily, MF 2=Milking twice-daily. [2] Difference Friesian-Jersey. [3] Difference first cross cow Friesian × Jersey - (Friesian + Jersey)/2). [4] Expressed relatively to the phenotypic average of the parental breeds under once or twice-daily, as appropriate. [a,b] Within traits, breed and heterosis effects with different superscripts are significantly different between milking frequencies (P<0.05).

Jersey, F×J and F cows milked OAD had a 2.7, 4.2 and 5.6% higher SCS than their counterparts milked TAD. Cows milked OAD had 5 days shorter lactation compared to their equivalent TAD, which represents a reduction of 2.1-2.3% (Table 1).

Estimated breed effects were significantly different from zero for all the milk traits studied (P<0.001; Table 2). Overall F cows were superior compared to J cows in both milking frequency; however, the superiority of F cows was higher in TAD. Estimation of F compared to J was 376.6 kg; 4.9 kg and 8.8 kg higher for MY, FY and PY in TAD. Friesian cows had significantly higher SCS levels than J cows in both systems, but this difference tended to be greater in OAD compared to TAD. The results confirm a significant interaction between breed and milking frequency (Table 2).

Heterosis effects for production traits were positive and significantly different from zero (P<0.001) for both TAD and OAD (Table 2). In absolute values, heterosis effects in TAD tended to be higher than in OAD milking, but in percentages values heterosis effects were similar in both TAD and OAD milking. Heterosis effects for SCS were negative and were only significantly different from zero (P<0.01) in TAD milking systems. Heterosis effects expressed as a percentage of the average of the parental breed were lower than 1% for LL.

Discussion

In this study, the relative reductions in milk yield of cows milked OAD compared to cows milked TAD were 24, 24 and 21% for F, F×J and J, respectively. The relative reduction of milk yield in J cows was similar to the value of 20% reported by Clark et al. (2006) but the reductions of milk yield in F and F×J cows were less than the value of 30% reported by Cooper (2000) and Clark et al. (2006) based on experimental data.

The relative reductions in milk solids (fat + protein) caused by OAD compared to TAD milking were 20, 19 and 15% for F, F×J and J, respectively. These results suggest that J cows were less affected by OAD milking than F cows, as found in other studies (Clark et al. 2006).

Comparisons of this study with experimental reports are difficult because in the present research, stocking rate records were not available. Despite this, quantitatively the smaller difference between milking frequency observed in F and F×J in this study, compared to the studies of Clark et al. (2006) and Cooper (2000), might indicate a degree of adaptation in those breeds to the OAD system. An early study (Woolford et al. 1985) suggested that an important component of the decrease in milk yield when cows went from being milked TAD to OAD had a genetic effect and therefore, there are some cows which are more tolerant and better able to adapt to OAD in successive lactations than other cows.

Reduction in LL in OAD compared to TAD was lower than the 14 days (5.4%) noted by Clark et al. (2006). Tong et al. (2003), using data from the first two seasons reported by Clark et al. (2006), reported that the difference between mean LL in TAD and OAD was reduced from 26 to 8 days, therefore, this supports the possibility of adaptation to OAD milking (Woolford et al. 1985).

A greater breed effect was observed in TAD than in OAD systems. Bryant et al. (2007) found that the difference in productive performance among breeds is related to the environment in which the breeds are evaluated. For instance, they considered milk solids yields of the herd (as an indicator of nutritional environment) as a factor that influence breeds performance. Bryant et al. (2007) noted that breed effects between J and North American or European Holstein Friesian were 561, 1.3 and 9.3 kg, respectively for MY, FY and PY in low-producing cows, which were smaller than the difference of 1151, 3.1 and 23.0 kg in high-producing cows. Considering herds milked OAD and TAD as low and high-MS-yield herds respectively, and a smaller breed difference in OAD milking, the results of this study, might suggest that J cows are better adapted than F cows when milked OAD where cows have lower availability of dry matter due to higher stocking rate (Cooper & Clark 2001).

The SCS results disagree with the work of Clark et al. (2006) who did not find any breed×milking frequency interaction. In this study, F cows had significantly higher SCS than F×J and J cows under OAD suggesting that F cows are more sensitive under OAD than F×J and J cows. In agreement with this study, Prendiville et al. (2010) did not find any significant differences for SCS between F and J breeds in TAD systems in Ireland, but in New Zealand, Berry et al. (2007) showed that J cows had higher SCS compared to F milked TAD.

The percentages of heterosis for productive traits found in this study are similar to the 5.5% reported by Prendiville et al. (2010) between F and J under TAD. For New Zealand conditions, Harris (2005) reported heterosis for first-cross cows slightly lower than our findings (139, 7.7 and 5.5 kg of MY, FY and PY and -0.1 for SCS) milked TAD systems.

Given the breed×milking frequency interaction found in this study, milking OAD or TAD could be considered as two separate environments. The results also showed a heterosis×milking frequency interaction. Therefore, milking frequency influenced the expression of heterosis since the estimated regression coefficient for FY and PY were different across milking frequency (Table 2). Likewise for breed effect, Bryant et al. (2007) reported a heterosis×environment interaction for milk traits, although they investigated crosses of F and J with North American or European Holstein-Friesian, finding limited or no heterosis in high-altitude and low-MS-yield environments.

In contrast with the results under TAD conditions, no significant heterosis on SCS was found by Prendiville et al. (2010) and Norberg et al. (2014). Conversely, Van Raden & Sanders (2003) documented a small positive (unfavourable) heterosis effect on this trait. They proposed that increased milk production of crossbred cows may cause stress in the udder, resulting in a small increase in SCS. The results observed in cows milked TAD are similar to the work of

Dechow (2007) who reported favourable heterosis on SCS. Because of the inconsistency of the effect of heterosis on SCS, the results should be interpreted with caution.

The results presented in this study are important because farmers generally cull the less productive cows on the basis on their production worth (PW), which represents the genetic superiority or inferiority of a cow to convert 5 ton of feed dry matter into farm profit (Dairy NZ 2015). Production worth considers the production values for MY, PY, FY and live weight each weighted by their respective economic values (Holmes et al. 2002). Production values are calculated as the sum of estimated breeding values plus heterosis effects and permanent environmental effects (Holmes et al. 2002). Therefore, PW is higher in crossbred F×J than in pure breeds (Lopez-Villalobos et al. 2000). Under OAD conditions, PW of crossbred cows might be relatively higher than their counterpart milked TAD due to smaller breed differences between F and J, suggesting that relative to pure breeds, crossbreeding in OAD systems could increase farm profitability in a higher magnitude than in TAD.

In conclusion, breed differences in production traits between F and J cows in New Zealand differed with milking frequency, but the heterosis effects were different only for FY and PY. The estimates of breed and heterosis reported in this study can be used for simulation studies to evaluate if crossbred cows milked OAD are more profitable than F and J cows as found in TAD milking systems and under New Zealand-grazing conditions.

Acknowledgments

The principal author acknowledges the support from Programa Formación de Capital Humano Avanzado, Becas Chile, CONICYT doctoral scholarship and information provided by Livestock Improvement Corporation (Hamilton, New Zealand). Comments by Nick Sneddon and Alan Hurley from Massey University, Palmerton North, are grateful acknowledged.

References

Back PJ, Lopez-Villalobos N 2007. Breed and heterosis effects for milk protein composition estimated in two stages of lactation in New Zealand dairy cows. Proceedings of the New Zealand Society of Animal Production 67: 399-402.

Berry DP, Lee JM, Macdonald KA, Stafford K, Matthews L, Roche JR 2007. Associations among body condition score, body weight, somatic cell count, and clinical mastitis in seasonally calving dairy cattle. Journal of Dairy Science 90: 637–648.

Bryant JR, Lopez-Villalobos N, Pryce JE, Holmes CW, Johnson DL, Garrick DJ 2007. Effect of environment on the expression of breed and heterosis effects for production traits. Journal of Dairy Science 90: 1548-1553.Clark DA, Phyn CVC, Tong MJ, Collis SJ, Dalley DE 2006. A systems comparison of once-versus twice-daily milking of pastured dairy cows. Journal of Dairy Science 89: 1854-1862.

Cooper C 2000. Once-a-day milking: Possible and profitable? Proceedings of the South Island Dairy Event. Pp 152-163.

Cooper C, Clark D 2001. Once-a-day milking systems to improve productivity. Australian Journal of Dairy Technology 56: 181.

Davis SR 2005. Lactational traits of importance in dairy cows and applications for emerging biotechnologies. New Zealand Veterinary Journal 53: 400-405.

Dairy NZ 2015. Cow indices. http://www.dairynz.co.nz/animal/animal-evaluation/interpreting-the-info/cow-indices/ [accessed January 30, 2015].

Dechow CD, Rogers GW, Cooper JB, Phelps MI, Mosholder AL 2007. Milk, fat, protein, and somatic cell score and days open among Holstein, Brown Swiss and their crosses. Journal of Dairy Science 90: 3532-3549.

Harris BL 2005. Breeding dairy cows for the future in New Zealand. New Zealand Veterinary Journal 53: 384–389.

Holmes CW, Brookes IM, Garrick DJ, Mackenzie DDS, Parkinson TJ, Wilson GF 2002. Milk Production from Pasture: Principles and Practices. Massey University, Palmerston North, New Zealand. 602 Pp.

Lopez-Villalobos N, Garrick DJ, Holmes CW, Blair HT, Spelman RJ 2000. Profitabilities of some mating systems for dairy herds in New Zealand. Journal of Dairy Science 83: 144-153.

Norberg E, Sørensen LH, Byskov K, Kargo M 2014. Heterosis and breed effects for milk production, udder health and fertility in Danish herds applying systematic crossbreeding. Proceedings of 10th World Congress on Genetics Applied to Livestock Production, Vancouver, Canada. Abstract No 836. https://asas.org/docs/default-source/wcgalp-posters/836_paper_9687_manuscript_838_0.pdf?sfvrsn=2 [accessed November 12, 2014].

Prendiville R, Pierce KM, Buckley F 2010. A comparison between Holstein-Friesian and Jersey dairy cows and their F_1 cross with regard to milk yield, somatic cell score, mastitis, and milking characteristics under grazing conditions. Journal of Dairy Science 93: 2741-2750.

Schneider A 2012. About GPS Visualizer. http://www.gpsvisualizer.com/about.html [accessed 20 June 2014].

Tong MJ, Clark DA, Cooper CV 2003. Progressing forward with OAD milking. Dexcel Field Day Booklet, 20 March 2003. Pp 7-9.

VanRaden PM, Sanders AH 2003. Economic merit of crossbred and purebred US dairy cattle. Journal of Dairy Science 86: 1036–1044.

Woolford MW, Copeman PJA, Napper AR, Phillips DSM, Williamson JH, Uljee EJ 1985. Milking intervals: are changes worth while? Proceedings of the Ruakura Farmers' Conference. pp 120-128.