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Effect of genotype and diet on milksolids production, body condition, and reproduction of cows milked continuously for 600 days

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ABSTRACT

Milking cows for two consecutive years, with calving and mating occurring every second year, may exploit the superior lactation persistency of high yielding cows while improving reproductive performance. This study tested the feasibility of extended lactations in pastoral systems using divergent dairy cow genotypes (New Zealand [NZ] or Overseas [OS] Holstein-Friesian [HF]) and levels of nutrition (0, 3, or 6 kg concentrate DM/cow/day). Cows calved on 28 July 2003 and remaining cows were dried off by 6 May 2005. Of the 56 cows enrolled, 93% were milking at 500 days in milk (DIM) and 18% were milking at 650 DIM. Dietary treatments did not affect DIM (605 ± 8.3 ; Mean \pm SEM), but there was a trend ($P=0.09$) for OS HF to have longer lactations than NZ HF. Genotype \times diet interactions were detected for the total yield of milk and milksolids per cow, and as a percentage of liveweight. Differences between genotypes were greatest at the highest level of supplementation. Compared to NZ HF, OS HF produced 35% more milk, 24% more milk fat, 25% more milk protein, and at drying off had 1.9 units less body condition. Annualised milksolids production from NZ HF was 79% of a normal season's production, compared to OS HF that produced 94%. Compared to NZ cows, OS cows had a similar 21-day submission rate (85%), a lower 42-day pregnancy rate (56% vs. 79%), and a higher final empty rate (30 vs. 3%) when mated at 451 days after calving. These results indicate that productive extended lactations up to 650 days are biologically possible on a range of pasture diets, and with appropriate cow genetics and feed management may ameliorate poor reproductive performance in high yielding dairy cows without sacrificing milksolids production.

Keywords: Genotype; supplements; extended lactation

INTRODUCTION

Dairy systems based on lactations of 2 years or more have been proposed as an alternative to typical 300-day lactations (Knight, 1998; Rotz *et al.*, 2005). Simulation modelling indicates that such systems can provide long term economic and environmental benefits relative to traditionally managed farms, provided annual milk production per cow is within 7% of traditional farms and average lactation length is 3 or more years (Rotz *et al.*, 2005).

To date, the impact of level of nutrition on extended lactations has not been quantified, with all controlled studies of extended lactation having been conducted in similar confinement feeding systems (Arbel *et al.*, 2001; Bertilsson *et al.*, 1997; Knight, 1998; Osterman & Bertilsson, 2003; Rehn *et al.*, 2000; van Amburgh *et al.*, 1997). The application of extended lactations to lower producing farm systems has been addressed in the review of Borman *et al.*, (2004) who contended that extended lactations could be a suitable option for some pasture-based systems, but that this would depend on cow milk production potential, ability to grow pasture or feed supplements economically,

management expertise, environmental constraints, herd size and labour availability.

Expected benefits of extended lactations compared to 12-month seasonally calving systems include a reduced number of days dry within the cows lifetime; reduced per cow costs associated with mating, calving, animal health, and cow replacement; a more even spread of labour requirements, input costs and income throughout the year (Borman *et al.*, 2004); and improved animal well-being through reduced metabolic stress, exposure to fewer periods of high risk, and increased longevity (Knight 1998). Fundamental changes in the modern cow's ability to continue producing at high yields for a much longer proportion of lactation, and consequent low fertility (Thatcher *et al.*, 2005), has been a primary driver of interest in extended lactation.

The present study tested the ability of cows grazing pasture to achieve 670-day lactations when calving every two years. The first objective was to quantify the impact that level of nutrition had on achieving long lactations. The second objective was to compare the performance of Holstein-Friesian (HF) cows of New Zealand (NZ) or North American (overseas; OS) origin in a 24-month calving interval system.

MATERIALS AND METHODS

Design

Primiparous and multiparous OS and NZ HF grazed pasture and were fed 0, 3, or 6 kg DM/cow/day of a pelleted concentrate supplement (60% maize grain, 31% barley grain, 7% molasses, and 2% broil [wheat bran and pollard] on a DM basis) at the Dexcel Lye Dairy from June 2003 to May 2005. Cows were allocated to the six treatments (NZ0, NZ3, NZ6, OS0, OS3, OS6) based on genotype and breeding worth (BW), and within genotype treatments were balanced for sire, liveweight and expected calving date. Average age distribution within treatments was 9% first-lactation, 23% second-lactation, and 68% mixed age (third- to sixth-lactation) cows. NZ and OS HF had a BW of 124 ± 31.2 and 116 ± 37.1 , respectively, a Production worth (PW) of 113 ± 60.6 and 115 ± 59.2 , respectively, and a mean calving date of 26 July 2003 ± 25.6 and 1 August 2003 ± 26.4 , respectively (mean \pm SD; Table 1).

Cow selection

Cows used in this study were sourced from the Holstein-Friesian Comparison study (Kolver *et al.*, 2002) and were also used in the Response to Concentrate study (Kolver *et al.*, 2005). The OS HF genotype had >87.5% OS HF ancestry (North American) and the NZ HF genotype had <12.5% OS HF ancestry based on three-generation pedigrees.

Feeding and management

Cows were individually fed 0, 3 or 6 kg DM/cow/day (3.5 or 7 kg fresh matter/cow/day) each day of lactation, with individual residues being measured and sampled each milking. The 6 kg DM/cow/day level of supplementation was the highest rate that could be fed with high quality pasture without incurring protein or fibre deficiencies in the diet.

Cows were grazed as one herd and were offered 50 kg DM/cow/day. Post-grazing residuals were used to determine pasture allocation; 1800 kg DM/ha was targeted during spring and autumn and 2200-2400 kg DM/ha during summer. A total of 846 kg grass silage DM/cow was calculated to be consumed during the two-year lactation, and was fed for 37 days in August-September 2003 (3.6 kg DM/cow/day); 109 days from April to July 2004 (4 kg DM/cow/day); and 53 days from August to September 2004 (5.9 kg DM/cow/day) to maintain pasture residual targets.

The length of lactation for a "normal" 12-month calving interval was calculated from time of calving to a theoretical dry-off date based on condition score, time from calving, and daily milk

production, with a final imposed dry-off on the 16 May. Drying off decisions for the rest of lactation were based on milk production (<4 kg milk/day for two weeks; <5 kg milk/day for two weeks during the last two months of lactation).

Establishment of a 24-month calving interval

The second year (2003/2004 season) of the two-year Response to Concentrate study (Kolver *et al.*, 2005) was also used as the first year of the present Extended Lactation study. This provided information on reproductive performance in a normal 12-month seasonal calving system. Cows were mated over an 11-week period beginning on 25 September 2003, 82 days after the start of calving. A whole herd oestrous synchrony programme was employed prior to a 4-week period of artificial insemination, followed by 7 weeks of natural mating.

To establish a 24-month calving interval with these same animals, pregnancies based on ultrasound foetal aging were terminated beginning 46 days after conception. A long acting ester of dexamethasone product was administered by intramuscular injection (25 mg), and was used in accordance with the New Zealand Veterinary Code of Practice.

The start of the subsequent mating occurred on 28 September 2004, 451 days after start of calving. All but four cows (3 OS HF and 1 NZ HF) were cycling at the planned start of mating, based on pre-mating heats and ultrasound scanning measurements obtained from June to September 2004. The four non-cyclers were treated for cystic ovaries. Cows were inseminated on spontaneous oestrus for the first 5 weeks and then were naturally mated for 6 weeks.

The number of "at-risk" and "phantom" cows at each mating were quantified. At-risk cows were defined as those that had calved within 30 days of planned start of mating, had calving difficulties or twins, displayed uterine infections, discharge, or retained foetal membranes after calving, or had metabolic problems. Phantom cows were defined as cows that were inseminated once, didn't return, and were assumed pregnant but were found to be empty.

Measurements

Milk yield was recorded daily and milk composition determined weekly from a 35-ml subsample by infrared (Fourier Transform Infrared Spectroscopy FT120, Foss Electric, Denmark). Liveweight was recorded weekly and body condition score every second week. A representative 500-g sample of pre-grazed pasture and offered and refused concentrate was collected

on one day each week, and oven-dried at 100 °C for 24 hours for determination of DM.

Statistical analysis

All data were analysed using the residual maximum likelihood (REML) procedure of Genstat (Version 3.2). The 2x3 factorial design was analysed using a model that included genotype, linear and quadratic contrasts of diet, and linear and quadratic interactions as fixed effects, with sire and cow as random effects.

A “normal” lactation for each treatment was defined as the period from calving to the theoretical dry-off date (calculated as 296 ± 23.6 days in milk; DIM), and “normal” reproductive performance refers to outcomes of the September 2003 breeding season. “Annualised” production was defined as the production achieved during the 24-month calving interval divided by two years to give an annual production. The ratio of annualised to normal production indicates the relative advantages or disadvantages of extended lactation on an annual basis.

Reproductive data was analysed using generalised linear models with binomial error

distribution and logit link including genotype, diet, and the interactions as fixed effects. Significant effects for all analyses were declared at P<0.05 and trends at P<0.15. Significance levels for the genotype x diet_{Quadratic} interaction are not presented as none were significant except for liveweight at drying off.

RESULTS

Both genotypes consumed all of the 3 kg concentrate DM/day offered, and 94% of the 6 kg concentrate DM/day offered. As OS HF fed 6 kg concentrate DM/d had more DIM than NZHF, OS HF consumed more concentrate than NZ HF on the 6 kg concentrate/d treatment (Table 1).

In a normal lactation (the first 296 DIM), OS HF produced the same amount of milksolids as NZ HF, and supplementation with increasing levels of concentrate produced a linear increase in milksolids yield. However the genotype x diet_{Linear} interaction indicated a trend for OS HF to produce more than NZ HF when fed 6 kg concentrate DM/d (Table 1).

TABLE 1: Cows per treatment, mean calving date, milk production, liveweight, and body condition of New Zealand (NZ) and overseas (OS) Holstein-Friesians grazing pasture and fed 0, 3, or 6 kg concentrate DM/cow/day during extended lactation.

Treatment	NZ0	NZ3	NZ6	OS0	OS3	OS6	SED	P value		
								Genotype	Diet	GxD
Cows per treatment	10	9	10	8	9	10				
Calving date (2003)	19 July	5 Aug	20 July	31 July	9 Aug	26 July				
Concentrate										
kg DM/cow/day		2.99	5.51		3.00	5.71	0.097	NS	<0.001	NS
kg/cow/lactation		1817	3123		1802	3611	146.9	0.05	<0.001	<0.05
Production										
Milking at final dry-off (% of herd)	20	22	0	38	56	50				
Days in milk	595	608	567	623	604	630	27.0	0.09	NS	NS
Milk yield (kg/cow)	8908	10929	9931	10814	13962	15448	1101.9	<0.001	<0.01	0.13
Milkfat (%)	4.88	4.62	4.24	4.46	4.19	3.92	0.258	<0.05	<0.001	NS
Milk protein (%)	3.82	3.76	3.72	3.74	3.74	3.65	0.116	NS	0.12	NS
Milksolids (kg/cow)	762	919	789	881	1109	1180	89.8	<0.001	<0.05	0.07
Annualised milksolids ² (kg/cow)	381	460	395	441	555	590	44.9	<0.001	<0.05	0.07
Normal milksolids ³ (kg/cow)	489	551	530	494	556	625	37.7	NS	<0.01	NS
Milksolids efficiency (% LW)	144	163	135	145	188	183	16.2	<0.01	NS	<0.05
Response (g MS/kg conc. DM)		86	9		127	83				
Liveweight										
Start of lactation ⁴ (kg/cow)	512	508	512	623	591	605	48.6	<0.05	NS	NS
Dry off (kg/cow)	638	712	692	714	706	784	34.6	0.07	<0.01	NS
Body condition										
Start of lactation ⁵	5.78	5.99	5.81	5.78	5.45	5.89	0.661	NS	NS	NS
Dry off	7.74	8.53	9.03	6.30	6.10	7.26	0.677	<0.001	<0.01	NS
Response (BCS units/t conc. DM)		0.10	0.42		0.11	0.29				

¹L = Linear contrast; Q = quadratic contrast

²Production during the 24-month calving interval divided by two years to give an annual production

³Production during the period from calving to the theoretical dry-off date in a 12-month calving interval system (calculated as 296 ± 23.6 DIM)

⁴One week post-calving

⁵Immediately prior to calving

On all diets during extended lactation, OS HF produced more milk with a lower milkfat content, more milksolids expressed as kg/cow or as a percent of liveweight, gave a greater milksolids response to concentrate, had a higher liveweight at the start of lactation, maintained lower body condition during lactation, and dried off at a higher liveweight but lower body condition compared to NZ HF (Table 1). OS HF had the same milk protein content, gained the same amount of liveweight, had the same body condition at calving, and gave a similar body condition score response to concentrate as NZ HF.

There was a trend for OS HF to have more DIM (Table 1). Of the 56 cows enrolled, 93% were milking at 500 DIM and 18% were milking at 650 DIM. A greater ($P < 0.05$) proportion of the OS HF herd was still in milk at 500 DIM (100 vs. 86%) and at 550 DIM (96% vs. 80%) compared to NZ HF, respectively, but differences were not significant at 600 DIM (74 vs. 62%) and only a trend ($P = 0.10$) apparent at 650 DIM (26 vs. 10%).

Compared to NZ HF in a normal lactation, OS HF had a lower 21-d submission rate and 42-d pregnancy rate, a higher final empty rate and number of phantom cows, and a similar first service conception rate and number of at-risk cows. In the extended lactation mating period, OS HF had a lower 42-d pregnancy rate, a higher final empty rate and number of phantom cows, and a similar 21-d submission rate, first service conception rate, and number of at-risk cows compared to NZ HF (Table 2).

Supplementation with increasing levels of concentrate for an extended lactation produced a linear increase in milk and milksolids yield, liveweight, condition score, liveweight gain, and condition score gain during lactation, and a linear decrease in milkfat content (Table 1). There was a trend for a linear increase in milk protein content with increasing supplementation. Milksolids as a percentage of liveweight increased quadratically with supplementation, and there was a trend for a quadratic increase in milksolids per cow. Supplementation did not significantly change DIM, initial liveweight or condition score, or reproductive parameters (Table 1).

A genotype \times diet_{Linear} interaction was detected for milk and milksolids yield (kg/cow and as a percent of liveweight) during extended lactation (Table 1). Annualised yields of milk, fat, protein and milksolids produced in extended lactations were numerically lower (0-29%) than achieved in normal lactations, and DIM, milkfat and protein content numerically higher (3-9%) than achieved in normal lactations (Table 3). On an annualised basis, OS HF had more DIM, higher yields of milk, fat, protein and milksolids, similar milk protein content, and a trend for a higher milkfat content in the extended lactation system compared to a normal lactation, than did NZ HF. On an annualised basis, supplementation produced a linear increase in milkfat and protein content, and a quadratic increase in yield of milk, fat, protein, and milksolids in the extended lactation system compared to a normal lactation. No GxD interactions were detected (Table 3).

TABLE 2: Mean reproductive performance of New Zealand (NZ) and overseas (OS) Holstein-Friesians from a normal¹ versus extended² lactation mating.

Treatment	Normal		Extended		SED	P value	
	NZ	OS	NZ	OS		Normal	Extended
Reproduction							
21-d submission rate (%)	93	59	86	85	10	<0.01	NS
First service conception rate (%)	38	19	59	48	13	0.12	NS
42-d pregnancy rate (%)	62	26	79	56	12	<0.01	<0.05
Final empty rate (%)	14	48	3	30	11	<0.01	<0.01
No. of at-risk cows ³	41	41	0	0			
No. Phantom cows ⁴	0	11	0	15			

¹Reproductive performance Spring 2003 mating (planned start of mating 84 days after planned start of calving)

²Reproductive performance of the same cows Spring 2004 mating (planned start of mating 451 days after planned start of calving)

³Cows that had calved within 30 days of planned start of mating, had calving difficulties or twins, displayed uterine infections, discharge, or retained foetal membranes after calving, or had metabolic problems

⁴Cows that were inseminated once, didn't return, and were assumed pregnant but were found to be empty

TABLE 3: Ratio of annualised¹ extended lactation versus normal² lactations for days in milk, milk production and composition.

Treatment	NZ0	NZ3	NZ6	OS0	OS3	OS6	SED	P value ³			
								Genotype	Diet _L	Diet _Q	GxD _L
DIM	0.99	1.00	0.96	1.05	1.08	1.05	0.058	<0.05	NS	NS	NS
Milk (kg/cow)	0.75	0.79	0.71	0.84	0.94	0.88	0.053	<0.001	NS	<0.05	NS
Milkfat (%)	1.04	1.04	1.05	1.03	1.06	1.07	0.318	0.06	<0.01	NS	NS
Milk protein (%)	1.06	1.06	1.03	1.07	1.09	1.07	0.171	NS	<0.05	NS	NS
Milkfat (kg/cow)	0.78	0.82	0.74	0.87	0.99	0.94	0.060	<0.001	NS	<0.05	NS
Milk protein (kg/cow)	0.80	0.84	0.73	0.90	1.02	0.94	0.062	<0.001	NS	<0.05	NS
Milksolids (kg/cow)	0.79	0.83	0.74	0.89	1.00	0.94	0.061	<0.001	NS	<0.05	NS

¹Production during the 24-month calving interval divided by two years to give an annual production

²Production during the period from calving to the theoretical dry-off date in a 12-month calving interval system (calculated as 296 ± 23.6 DIM)

³L = Linear contrast; Q = quadratic contrast

The lactational profile of milksolids production and body condition score are presented in Figures 1 and 2.

FIGURE 1: Milksolids production of New Zealand (NZ) and overseas (OS) Holstein-Friesians grazing pasture and fed 0, 3, or 6 kg concentrate DM/cow/day for more than 600 days in milk (DIM).

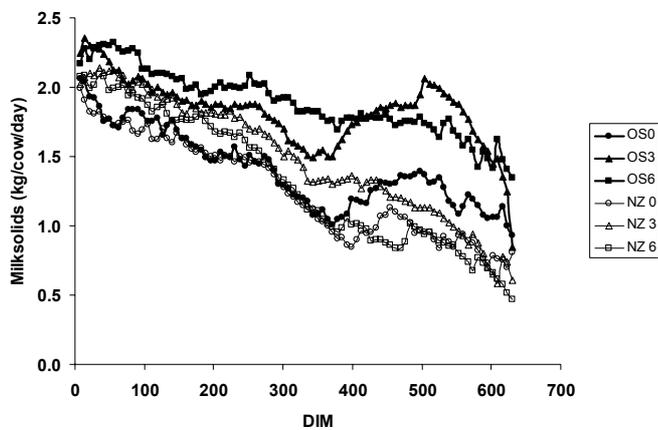
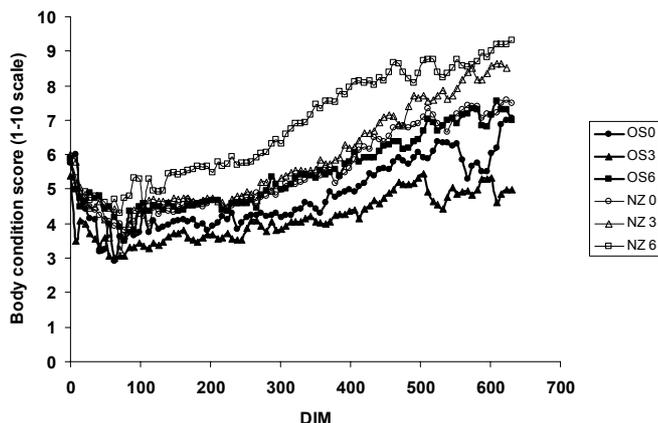


FIGURE 2: Body condition score of New Zealand (NZ) and overseas (OS) Holstein-Friesians grazing pasture and fed 0, 3, or 6 kg concentrate DM/cow/day for more than 600 days in milk (DIM).



DISCUSSION

This study demonstrated that milking cows for two-year lactations (24-month calving interval) is possible on pasture-based diets, with some genotype and diet combinations experiencing no loss of annualised production. This presents a unique application of extended lactation technology as previous studies of 18-month calving intervals have been in systems with confined feeding and high levels of production with access to bST or frequent milking (Osterman & Bertilsson, 2003; Van Amburgh *et al.*, 1997).

Consistent with these previous studies, the current study has shown there to be wide variation between individual cows in their ability to continue milking for longer than 300 days. OS HF cows with a history of selection in systems not confined to 12-month seasonal calving were more suited to extended lactation, with 48% milking through until the final dry-off date compared to 14% of NZ HF cows. However both genotypes could milk for 500 days after which cows began to be dried off.

Also consistent with previous studies is the maintenance of high milk fat and protein content during the extended phase of lactation which offsets the decline in milk volume. This suggests that extended lactations may be more suited to suppliers of manufacturing milk than liquid milk suppliers. Milk protein was maintained at approximately 4.1% throughout the 300 days of extended lactation. This was irrespective of genotype or feeding treatment and shows the dominance of stage of lactation on milk composition. As milk protein was elevated to a greater extent than milkfat, the protein:fat ratio was higher during extended lactation, which resulted in a 1.5% higher milk payout for the entire lactation compared to milk produced in the first 300 days

(\$4.06 vs. \$4/kg milksolids). Premiums for supply of winter milk from this system would further increase payout. Also in agreement with previous reports (Osterman and Bertilsson, 2003) a low somatic cell count and infection rate was maintained throughout extended lactation in this study, although SCC did increase with stage of lactation (Lacy-Hulbert *et al.*, 2006).

The current study encompassed a range of genotype and nutrition treatments. For some of these combinations (OS HF fed 3 kg concentrate DM/day), lactations of 600 days could be achieved with no loss of milksolids production when compared on an annual basis to a normal 10-month lactation. Recently in Victoria, Auld (2005) reported annualised milksolids being reduced by 1, 2, 5, and 7% when cows in pasture-based systems underwent 15, 18, 21, or 24-month calving intervals compared to cows producing 500 kg MS/cow in traditional 12-month calving interval systems. This result is very similar to the 6% milksolids reduction experienced by the OS6 treatment in the current study, which used a similar cow genotype and level of supplementation. In confinement systems, Osterman & Bertilsson (2003) also reported cows with an 18-month calving interval producing the same amount of energy-corrected milk per day in a confinement feeding system as cows with a 12-month calving interval.

Milksolids losses of 17-26% were incurred by NZ HF cows in the current study, which likely reflects the lack of selection pressure for production outside of a seasonal 12-month calving system. Also reflective of this was the large increase in liveweight and body condition of NZ HF during the two-year lactation. Although many NZ HF cows continued to produce during extended lactation, the excessive body condition presents a management issue both for the current season, and the following season. This suggests that both persistency of milk production and maintenance of acceptable body condition will be important for future selection of cows suitable for extended lactations.

A second lactational peak was evident in some of the treatments during the second spring. This peak was most evident on the 0 and 3 kg concentrate DM/day treatments and with OS HF cows. No second peak occurred on the 6 kg concentrate DM/day treatment which suggests that this lactational pattern may be a function of feeding, most likely the level of nutrition during the preceding winter. Similarly, the greater second lactational peak exhibited by OS HF may reflect a

greater feed deficit during the preceding winter relative to NZ HF. Auld (2005) also reported no second lactational peak in a study with cows and diets similar to the OS6 treatment of the current experiment.

The direct comparison of reproductive performance during extended lactation and normal lactation is confounded in this study by year (different seasons, different breeding policy), and the ability to test fertility effects was limited. However the greater fertility of the NZ HF was apparent, and is consistent with previous studies (Kolver *et al.*, 2002, 2005). The results do suggest that the differences in submission rate, pregnancy rate, and empty rate between the two genotypes is reduced by the removal of the 12-month calving interval constraint. All but four cows were confirmed cycling at the start of mating 451 days after calving, and were in positive energy balance and had desirable body condition. However a final empty rate of 30% was still recorded for the OS HF. The higher number of phantom cows within OS HF treatments suggests that maintenance of pregnancy previously identified as a growing issue in seasonally calving herds (Cavaliere *et al.*, 2003) remains a cause of poor fertility in extended lactation. These results also suggest that factors other than negative energy balance are causing the infertility problems in OS HF cows in grazing systems. In intensive feeding systems, Lucy (2001) identified that the reasons for the decline in HF fertility were multifactorial and not associated entirely with an negative energy balance. These results point to an underlying sub fertility that does not appear to be addressed by improving energy balance through feeding or DIM.

In conclusion, milking cows for two-year lactations appears possible on pasture-based diets. Extended lactation technology likely will have initial application to split calving systems, possibly implementing 18-month calving intervals rather than the 24-month interval tested here. Further work is underway to develop appropriate cow selection measures, and to evaluate the profitability and risk of pasture-based, extended lactation farm systems.

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