Effect of a plasma-derived colostrum replacement feeding program on adult performance and longevity in Holstein cows

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Objective—To evaluate longevity, milk production, and breeding performance in adult Holstein cows fed either a plasma-derived commercial colostrum replacer (CR) or raw bovine maternal colostrum (MC) at birth.

Design—Randomized controlled clinical trial.

Animals—497 heifer calves born in 12 commercial dairies located in Minnesota and Wisconsin.

Procedures—All calves were separated from their dams within 30 to 60 minutes after birth and systematically assigned to be fed either MC (control group [n = 261 calves]) or CR (treatment group [236]). Calves were observed from birth up to adulthood (approx 54 months old), during which time death and culling events plus milk yield and breeding performance data were collected. Time to death, time to culling, time to death or culling combined, time to first calving, and time to conception intervals were evaluated by use of proportional hazards survival analysis models. Number of times inseminated per conception and lifetime milk yield (up to 54 months old) were evaluated by use of general linear models.

Results—Cows fed CR as calves at the time of birth were no different than cows fed MC as calves with respect to overall risk of death, culling, or death or culling combined (from birth to 54 months of follow-up and from first calving to 54 months old); lifetime milk yield; and breeding performance.

Conclusions and Clinical Relevance—No difference was detected in overall risk of death or culling, milk production, or reproductive performance between cows fed CR and those fed MC as calves at birth. (*J Am Vet Med Assoc* 2010;236:1230–1237)

Failure of passive transfer, defined as serum IgG concentration < 10 g/L in 1- to 2-day-old calves, has been found to have detrimental effects on daily weight gain while increasing the risk of morbidity and death in calves during the preweaning period.[1,2] Failure of passive transfer has also been negatively associated with long-term performance including decreased milk yield and longevity in lactating cows.[1,2] Feeding an adequate volume of clean, high-quality MC soon after birth is necessary to reduce the incidence of FPT in calves.[3,4]

Colostrum replacement products, derived from either bovine plasma (or serum) extracts or lacteal derivatives, are formulated to provide ≥ 100 g of IgG/dose in addition to a variety of nutrients including vitamins, minerals, fats, lactose, and protein.[5–7] They are marketed as a convenient alternative to MC to be fed to calves in situations in which quality or quantity (or both attributes) of MC is compromised for the possible prevention of FPT.

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Supported by the Minnesota Rapid Agricultural Response Fund, the American Protein Corporation Incorporated, the USDA-CSREES NRI Competitive Grants Program (No. 1716-669-6304), and the Johne's Disease Integrated Program.

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Abbreviations

AFC	Age at first calving
CI	Confidence interval
CR	Plasma-derived commercial colostrum replacer
FPT	Failure of passive transfer
JD	Johne's disease
MAP	*Mycobacterium avium* subsp *paratuberculosis*
MC	Maternal colostrum

Studies on the efficacy of various commercial CR products to prevent FPT have had mixed results. In a previous study, Swan et al[8] reported observing a 93% FPT rate among calves fed CR and a 28% FPT rate among calves fed MC. Other studies,[9,10] especially those involving feeding higher amounts of IgG in CR products, have reported better efficacy at preventing FPT. Despite the high FPT risk in CR-fed calves, Swan et al[8] reported that preweaning risk of morbidity and death was not different between CR-fed and MC-fed calves. Testing those same calves in adulthood for infection with MAP revealed that feeding CR, compared with MC, after birth resulted in a 44% reduction in risk of MAP infection. Therefore, in addition to its potential role in preventing FPT in calves in the short term, CR products may be useful management tools with the potential for assisting in preventing transmission of pathogens that are potentially transmissible to calves through ingestion of MC, including MAP.[4,6,7]

Ingestion of large volumes (≥ 4 L vs ≤ 2 L) of high-quality MC by calves has been positively associated with increased milk yield and longevity later in adult lactating cows.[2] However, although CR-feeding programs have the potential to prevent FPT and to play a role in paratuberculosis (MAP) control programs,[7,8] their effect on longevity (ie, the probability of not being removed from the herd for any reason including death, sale, or culling up to a particular age), milk yield, and breeding performance in adult lactating cows had not been described. The objective of the study reported here was to compare the effect of a CR-feeding program with an MC-feeding program for calves at birth on subsequent longevity, milk yield, and breeding performance of cows during the first 54 months after birth.

Materials and Methods

Herd selection and description—Herds to be included in the present study were selected on the basis of criteria described in detail in previous reports.[7,8] Briefly, 12 commercial Holstein herds were recruited as convenience samples to participate in the study; 9 of these were located in southeastern Minnesota, whereas the remaining 3 herds were located in western Wisconsin. The size of participating herds ranged between 190 and 1,500 cows (median, 594 cows). Fifty-two percent of Minnesota and 54% of Wisconsin dairy herds were within this category in terms of herd size.[11] Mean milk production (rolling herd average) for each farm ranged between 9,773 and 13,636 kg/y (21,500 and 30,000 lb/y), with a median of 11,727 kg/y (25,800 lb/y). Bulk-tank somatic cell count ranged between 180,000 and 280,000 cells/mL (median, 240,000 cells/mL). In all participating herds, lactating cows were housed in free stalls and synchronized artificial insemination breeding programs were used.

All participating herds were infected with MAP, with the burden of infection varying among herds. The estimated MAP infection prevalence for each herd ranged between 0.43% and 64% (median, 8%).[7] Of the 9 farms in Minnesota, 8 were participants in the Minnesota Voluntary JD Control Program. Only 1 of the 3 farms enrolled from Wisconsin reported participating in a similar voluntary JD control program.

Colostrum was routinely fed to calves through a bottle at 6 of the 12 study farms, whereas the calves at the remaining 6 farms received colostrum via an esophageal tube. Calves were raised on-site at 6 farms, whereas staff of the other 6 farms transported calves at 1 to 3 days of age to be raised off-site at the facilities of a professional heifer grower. The study was approved by the Institutional Animal Care and Use Committee of the University of Minnesota.

Study design—A prospective clinical trial study was conducted to evaluate longevity, milk production, and reproductive performance in heifer calves fed either raw MC (control group [n = 261 calves]) or CR (treatment group [236]) product at birth. Heifer calves born between July and October 2003 were enrolled in the study. Samples and data collection were completed in December 2007 when study animals were approximately 54 months old.

Each enrolled heifer calf was separated from its dam within 30 to 60 minutes after birth and was not allowed the opportunity to suckle its dam. By use of a systematic allocation procedure (ie, alternating such that a calf was assigned to one group and the subsequent calf was assigned to the other group), calves were assigned to be fed raw MC (control group) or a single dose of CR[a] (treatment group). The MC fed to a calf originated from its dam, although there were instances in which an insufficient quantity of MC was available from a dam, which necessitated that refrigerated colostrum from other dams was fed instead. The CR contained 125 g of IgG/dose and was mixed with 2 L of warm water, as per manufacturer's instructions, prior to feeding.

Calves in 11 of the 12 participating herds were fed 3.8 L of MC at the first feeding, whereas calves in the other herd were fed 1.9 L of MC during the first feeding. Calves in 5 herds were routinely provided a single meal of MC followed by a commercial milk replacer thereafter. In the other 7 herds, calves were routinely provided a second meal consisting of 1.9 L of MC within 8 to 12 hours after the first colostral feeding. In those herds, calves assigned to the treatment group were fed a second meal consisting of 1.9 L of a commercial milk replacer supplemented with a single dose of a commercially available colostrum supplement product[b] within 8 to 12 hours after the first CR meal was fed. In contrast to CR, colostrum supplement products are intended to provide < 100 g of IgG/dose when fed to calves and are not formulated to replace MC. The colostrum supplement product used in this study contained 45 g of IgG/dose, and both CR and colostrum supplement products originated from the same manufacturer. Preweaning diets (up to 56 days of age) for all calves consisted of commercial milk replacer and unrestricted amounts of water and calf starter pellets.

Records and samples—For each enrolled calf, farm staff recorded the identification of the dam, identification of the calf, birth date, number of calves born (singletons or twins), type of colostrum fed (CR or MC), calving score, and interval from birth until feeding of colostrum. All records of illness or death were also recorded.

Paired 20-mL samples of MC fed to each calf in the MC group were collected into sterile sample tubes that were subsequently labeled with the respective identification of the calf and farm identification prior to freezing at −20°C for subsequent analysis to determine contamination with MAP. The intent was to establish whether calves were exposed to MAP via MC.

Calves were weaned at approximately 56 days of age and monitored until adulthood. Calves included in the present study were also part of previous studies[7,8] to determine the effects of feeding CR, compared with MC, on serum IgG and total protein concentrations as measured at 1 to 8 days of age[8]; risks of morbidity and death between birth and weaning[8]; and the relative risk of MAP infection at approximately 30, 42, and 54 months of age.[7]

Data collection—Prior to weaning study calves, death events were manually recorded by the producers and associated professional heifer grower as described

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previously.[8] Data on calves were not officially collected by the investigators between weaning and the first MAP-testing event at 30 months of age. However, records of deaths, sale of animals, or culling events during this period were accessed from records maintained manually by the producers. Despite this effort, some heifers were lost from the study during this period. These heifers were censored at the last known date present within the herd (weaning date). There were no losses to follow-up in the period between the first MAP-testing events (30 months of age) until conclusion of the study (54 months of age).

For heifer calves that entered the milking herd (following a first-calving event), records of death, sale, or culling events were directly retrieved from the herd management computer software[c] programs installed on each study farm. Data on milk yield and breeding performance indices were retrieved from the Minnesota and Wisconsin Dairy Herd Improvement Association on a trimonthly basis until the study was concluded at 54 months of follow-up.

Longevity indices—For the analysis of longevity, the outcomes (indices) of interest included death for any reason, evaluated from birth up to 54 months of follow-up and from date of first calving up to 54 months of age for the subgroup of heifers that entered the milking herd; culling for any reason, evaluated from birth up to 54 months of follow-up and from the date of first calving up to 54 months of age for the subgroup of heifers that entered the milking herd; and combined death and culling event outcomes, evaluated from birth up to 54 months of follow-up and from date of first calving up to 54 months of age for the subgroup of heifers that entered the milking herd.

The time to death and time to culling event outcome variables for each heifer calf enrolled in the study were calculated from its birth date to the date of death or culling, respectively, or when the study came to conclusion at 54 months of follow-up, at which point all heifers that remained alive or had not yet been culled were censored from the analysis. For heifers that had a first-calving event, time to death and time to culling event outcomes were calculated from the date of first calving to the date of either death or culling, respectively, or when the study came to conclusion at 54 months of follow-up, at which point all cows remaining in the study were censored. The time to combined death or culling event outcomes were similarly calculated for each heifer from its birth date to the date of either death or culling or when the study came to conclusion at 54 months of follow-up, at which point all heifers that remained alive or had not yet been culled were censored from the analysis. For heifers that had a first-calving event, time to combined death or culling event outcomes were calculated for each heifer from its first calving date to the date of either death or culling or when the study was concluded at 54 months of age, at which point all heifers that remained alive or that had not yet been culled were censored from the analysis.

Analysis of longevity data—In this and subsequent analyses, summary statistics and multivariable analyses were completed with standard statistical software.[d] In all instances, significance was considered for values of $P \leq 0.05$.

The proportions of animals with death (yes or no), culling (yes or no), and combined death and culling (yes or no) event outcomes were calculated for each group (CR vs MC). Differences in the risk of death, culling, and combined death and culling event outcomes recorded from birth up to 54 months of follow-up between groups (CR vs MC) were unconditionally tested by use of a simple χ^2 test. A similar analysis was repeated for all heifers that had a first-calving event, with the starting point for analysis being the date of first calving for each heifer and follow-up ending at 54 months of age when the study was concluded.

Herd-adjusted survival plots were produced to describe the distribution of time to combined death or culling intervals since the date of birth for each calf and for heifers that entered the milking herd since the date of first calving.

Six separate proportional hazards models[12] were used to evaluate the effect of feeding CR, compared with MC, on outcomes including time to death from birth up to 54 months of follow-up, time to death from first calving up to 54 months of age, time to culling from birth up to 54 months of follow-up, time to culling from first calving up to 54 months of age, time to death and time to culling events combined from birth up to 54 months of follow-up, and time to death and time to culling events combined from first calving up to 54 months of age. Because cows in the same herd were more likely to be similar (vs cows in other herds) with respect to study outcomes, robust estimates of variance[13] were applied to all models to adjust for the within-herd cluster effects. The proportional hazards model assumption[12] was evaluated in all 6 models by plotting a nonzero slope of scaled Schoenfeld residuals for the treatment group (CR vs MC) variable against time at risk associated with each model. A formal statistical test was performed in which nonsignificant ($P > 0.05$) findings indicated fulfillment of the proportional hazards assumption. The goodness of fit of the final models was evaluated by generating plots of cumulative hazard functions against Cox-Snell residuals, with a cumulative hazard approximating a 45° line with a zero intercept, suggesting a good fit of the model to the data.[14–16]

Breeding performance indices—Description of the effect of treatment (CR vs MC) on breeding performance was restricted to data recorded in the first and second lactation periods. Breeding performance indices of interest included AFC, likelihood of first-calving events (ie, birth-to-first calving interval), number of times inseminated per conception, and calving to conception intervals for study cows that conceived.

In this study, AFC was calculated for all heifers that had a first-calving event from their date of birth to the recorded date at first calving. Records of heifers that never had a first-calving event either because of death or removal from the herd (or any other reason) were included in the analysis as censored observations for the evaluation of likelihood (or risk) of a first-calving event outcome.

Number of times inseminated per conception was considered only for cows confirmed pregnant during the first and second lactation periods. Cows known to have been bred but that failed to conceive within a given lactation were excluded from this analysis.

Calving-to-conception interval (ie, days not pregnant) was calculated from the date of the first and second calving events to the date of the last insemination that resulted in a conception for all cows during the first and second lactation periods. For cows culled or those that died, the observation time was calculated from their calving dates to the reported date of death or removal from the herd. If such cows were not confirmed pregnant at the time of their culling or death, then their records were censored during the analysis because their calving-to-conception intervals remained undefined.

Analysis of breeding performance data—Proportion of heifers with a first-calving event, mean AFC, mean number of times inseminated, mean number of times inseminated per conception, and mean calving-to-conception interval were summarized. Differences in the distribution of the preceding variables between treatment groups (CR vs MC) were unconditionally tested with a simple χ^2 test for categorical outcomes, Wilcoxon rank sum test for continuous and count outcomes with skewed distributions, and *t* tests for continuous outcomes with normal distributions (ie, AFC only).

A proportional hazards model[12] was used to describe the effect of feeding CR, compared with MC, on AFC (ie, risk or hazard of a first-calving event). Adjustment for herd effect, evaluation of the proportional hazards assumption, and test for model fit were completed by use of the approaches already described for the longevity data (see analysis for longevity data).

Effect of treatment (CR vs MC) on the number of inseminations per conception during the first and second lactation periods was evaluated by use of 2 separate generalized linear models. Number of times inseminated per conception was assumed to follow a Poisson distribution. Effect of treatment (CR vs MC) on the number of times inseminated per conception was described by use of the logit link function. Robust estimates of variance were applied to both models to adjust for herd effects.

Herd-adjusted survival plots were produced to describe the distribution of calving-to-conception intervals between groups (CR vs MC) while considering censored events for cows that failed to conceive. Effect of feeding CR, compared with MC, on first and second lactation calving-to-conception intervals was evaluated with 2 separate proportional hazards models.[12] Adjustment for herd effect, evaluation of the proportional hazards assumption, and test for model fit were completed by use of methods previously described for the longevity data.

Milk yield index—Milk produced per lactation (ie, first and second lactations) and lifetime milk yield (up to 54 months of age) were the outcomes of interest. Data on lactation length (days) for each cow in the study were retrieved. For cows that died or were culled before completing or having a particular lactation period stopped, overall milk yield reported up to the last day prior to either death or culling in that lactation period was included.

Analysis of milk yield data—Differences in the unadjusted means between CR and MC groups for first and second lactation and overall lifetime (up to 54 months of follow-up) milk yields were tested by use of 2-sample *t* tests (assuming equal variance for the means).

Three separate generalized linear models were used to describe the effect of feeding CR, compared with MC, on first and second lactations and on overall lifetime milk yield (ie, up to 54 months of follow-up). Frequency distribution plots (not shown) indicated that the milk yield outcomes (first and second lactations plus lifetime milk yields) followed a normal (Gaussian) distribution pattern. Treatment (CR vs MC) was assumed to affect milk yields linearly. An identity link function was therefore used to describe the effect of feeding CR, compared with MC, on milk yield. Independent variables forced into each model included treatment (CR vs MC), calving season (winter, January to March; spring, April to June; summer, July to September; and fall, October to December), AFC (0 = AFC ≤ 24 months and 1 = AFC > 24 months), and lactation length (days). Robust estimates of variance were applied to all models to adjust for the within-herd cluster effects.[14,17] Except for the group (CR vs MC) and lactation-length variables, all other variables that did not satisfy a Wald test $P \leq 0.05$ cut-point were removed from the final models.

Results

Four hundred ninety-seven Holstein heifer calves born between July and October 2003 were enrolled in the study; 261 of these received MC, and 236 received CR. One hundred ninety-eight of 261 (76%) heifers in the MC group had a first-calving event, and 165 of 236 (70%) heifers in the CR group had a first-calving event.

The imbalance in number of calves enrolled between the MC and CR groups was attributed to the fact that early during the study, personnel on some participating dairies, who were working weekend shifts, only fed MC to newborn calves. It is unlikely that this error introduced a bias in the study findings.

The number of heifers lost to follow-up between weaning and the first MAP-testing event (30 months of age) was twice as high in the CR group (12/236 [5.1%]), compared with the MC group (6/261 [2.3%]), although these values did not differ significantly (χ^2 = 3.33; $P = 0.07$). Cumulative incidence for losses during the follow-up period was 20 of 497 (4.0%). By assuming that the calves lost to follow-up were censored from the study at weaning, potential bias attributable to a loss to follow-up, which would have disproportionately affected the CR group, may have been avoided in this analysis.

Descriptive summary for longevity outcomes—The proportion of animals that had death, culling, or combined death and culling event outcomes from birth to 54 months of follow-up and from date of first calving

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up to study conclusion at 54 months of age were determined (**Table 1**).

From birth up to 54 months of follow-up, 113 of 497 (23%) animals died in total, with 55 of 261 (21%) animals belonging in the MC group and 58 of 236 (25%) animals belonging in the CR group. Similarly, the cumulative proportion of animals culled for any reason between birth and 54 months of follow-up was 149 of 497 (30%), with 81 of 261 (31%) animals in the MC group and 68 of 236 (29%) animals in the CR group. Combined death and culling events between birth and 54 months of follow-up were recorded for 262 of 497 (53%) animals in total, with 136 of 261 (52%) animals in the MC group and 126 of 236 (53%) animals in the CR group. No significant differences in unadjusted risks of death, culling, and combined death and culling events were observed between groups (CR vs MC) over the period of birth to 54 months of age (Table 1).

From point of first calving up to 54 months of age, the cumulative number of death events was 30 of 363 (8%) cows, with death events recorded for 15 of 198 (8%) MC-group cows, compared with 15 of 165 (9%) CR-group cows. Similarly, the cumulative proportion of cows culled for any reason between first calving and 54 months of age was 118 of 363 (33%), with culling events recorded for 64 of 198 (32%) MC-group cows, compared with 54 of 165 (33%) CR-group cows. Combined death and culling events between first calving and 54 months of age were recorded for 148 of 363 (41%) cows overall, with these events recorded for 79 of 198 (40%) MC-group cows and 69 of 165 (42%) CR-group cows. Similarly, no significant differences in unadjusted risks of death, culling, and combined death and culling events were observed between groups (CR vs MC) during the period of first calving to 54 months of age (Table 1).

Survival plots depicting the distribution of time to combined death or culling event outcome intervals between treatment groups (CR vs MC) from the point of birth (ie, birth date) and first calving (ie, for heifers that had a first-calving event) were made (**Figure 1**). No difference in length of time to combined death or culling event outcome intervals between groups (CR vs MC) was observed during both periods.

Multivariable models analysis for the longevity outcomes—Proportional hazards models for the effect of feeding CR, compared with MC, on time to death, time to culling, time to combined death or culling event outcome from birth up to 54 months of follow-up, and from the first-calving date up to 54 months of age were determined. Statistical testing indicated no evidence suggesting violation of the Cox proportional hazards assumption. Similarly, examination of the shapes of the plots of the cumulative hazard function versus Cox-Snell residual suggested that the final Cox models provided good fits for the data (results not provided).

The hazard ratio comparing death events in the CR group with the MC group from birth up to 54 months of follow-up was 1.22 (95% CI, 0.92 to 1.62; $P = 0.17$). Similarly, the hazard ratio comparing culling events in the CR group with the MC group from birth up to 54 months of follow-up was 1.01 (95% CI, 0.63 to 1.64; $P = 0.95$). For combined death and culling events, the

Table 1—Comparison of number of calves fed CR, compared with MC, at birth with respect to unadjusted risk of death and culling at various stages up to 54 months of age.

	CR (n = 236)		MC (n = 261)		
Birth to 54 months of age	**No. of events**	**%**	**No. of events**	**%**	***P* value**
Death events					
Birth to first calving	42	18	15	5.7	0.46
First lactation	7	3	6	2	0.64
Second lactation	8	3	7	3	0.65
Birth to 54 mo	58	25	55	21	0.35
Culling events					
Birth to first calving	14	6	17	7	0.79
First lactation	18	8	25	10	0.44
Second lactation	23	10	30	11	0.53
Birth to 54 mo	68	29	81	31	0.59
Death plus culling events					
Birth to first calving	56	24	57	22	0.62
First lactation	25	11	31	12	0.65
Second lactation	31	13	37	14	0.74
Birth to 54 mo	126	53	136	52	0.78
	CR (n = 165)		**MC (n = 198)**		
First calving to 54 months of age	**No. of events**	**%**	**No. of events**	**%**	***P* value**
Death events					
First lactation	7	4	6	3	0.54
Second lactation	7	4	7	4	0.73
First calving to 54 mo	15	9	15	8	0.60
Culling events					
First lactation	18	11	25	13	0.61
Second lactation	23	14	30	15	0.75
First calving to 54 mo	54	33	64	32	0.94
Death plus culling events					
First lactation	25	15	31	16	0.89
Second lactation	30	18	37	19	0.90
First calving to 54 mo	69	42	79	40	0.71

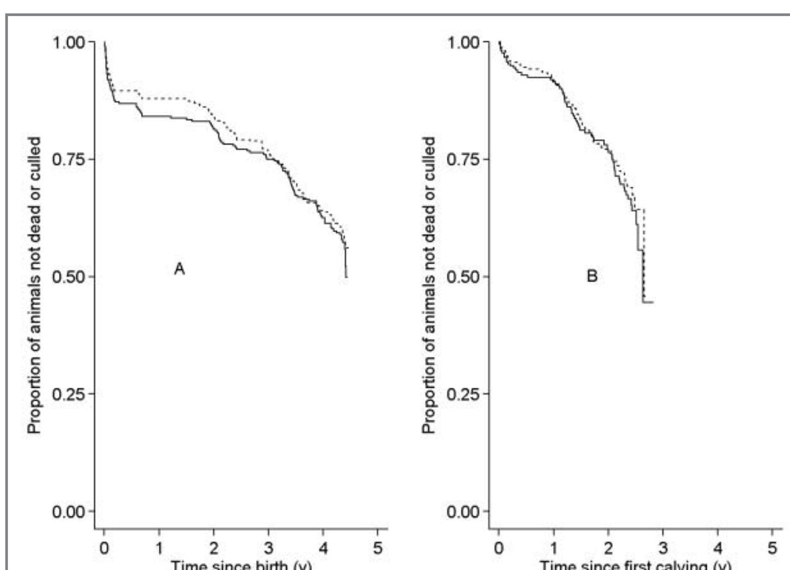

Figure 1—Herd-adjusted survival plots for the analysis of time to death or culling combined outcome from date of birth (A) and first calving (B) for cows fed CR (solid lines) or MC (dotted lines) as calves at the time of birth.

Table 2—Comparison (unadjusted) of milk yield and breeding performance indices between cows fed CR as calves and cows fed MC as calves.

	CR (n = 165)		MC (n = 198)		
Variable	Mean ± SD	No. of cows	Mean ± SD	No. of cows	*P* value
AFC (mo)	24.3 ± 1.85	165	24.4 ± 1.99	198	0.47*
No. of times inseminated					
First lactation	2.84 ± 2.29	154	3 ± 2.86	187	0.73†
Second lactation	2.61± 2.1	124	2.84 ± 2.17	154	0.33†
No. of times inseminated per conception					
First lactation	2.74 ± 2.2	141	2.7 ± 2.2	174	0.62†
Second lactation	2.36 ± 1.67	110	2.54 ± 1.83	128	0.45†
Calving-to-conception interval (d)					
First lactation	139 ± 89	141	138 ± 103	174	0.68†
Second lactation	118 ± 62	110	121 ± 68	128	0.98†
Milk yield (kg)‡					
First lactation	11,889 ± 4,601	147	12,232 ± 4,109	181	0.48*
Second lactation	11,972 ± 4,698	127	11,451 ± 4,587	162	0.34*
Lifetime	22,681 ± 10,166	159	22,944 ± 9,469	195	0.80*

**P* values based on Student *t* tests. †*P* values based on the Wicoxon rank sum test. ‡To convert kilograms of milk to pounds of milk, multiply value by 2.2.

hazard ratio comparing the CR group with the MC group was 1.1 (95% CI, 0.77 to 1.58; *P* = 0.61) from birth up to 54 months of follow-up.

Considering only animals that had a first-calving event reported, the hazard ratio estimate for the risk of death in the CR group, compared with the MC group, was 1.22 (95% CI, 0.72 to 2.04; *P* = 0.46) from the point of first calving up to 54 months of age. For the culling events outcome, the hazard ratio for the risk of culling in the CR group, compared with the MC group, from point of first calving up to 54 months of age was 1.01 (95% CI, 0.62 to 1.64; *P* = 0.98). For combined death and culling event outcome risk, the hazard ratio estimate comparing the CR group with the MC group was 1.05 (95% CI, 0.67 to 1.64; *P* = 0.85) from the point of first calving up to 54 months of age.

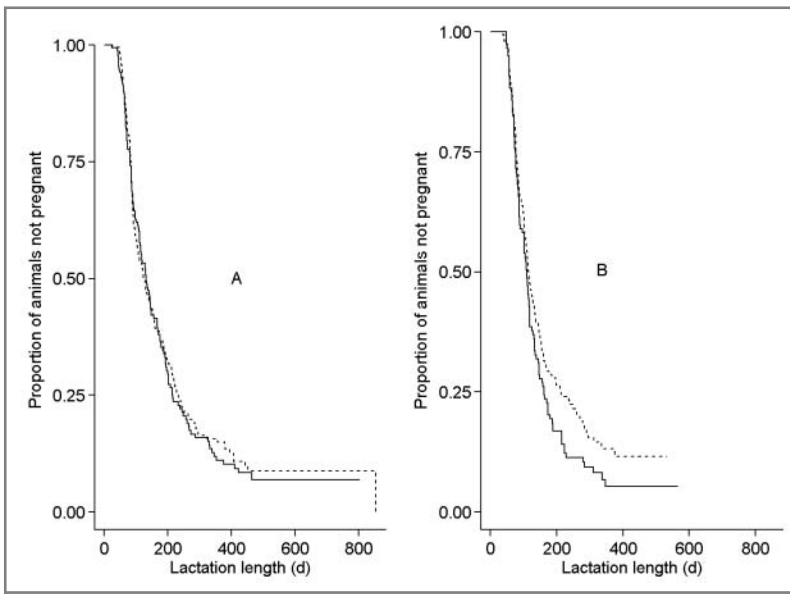

Figure 2—Herd-adjusted survival plots for the analysis of time to conception outcome in the first (A) and second (B) lactation period for cows fed CR (solid lines) or MC (dotted lines) as calves at the time of birth.

Descriptive summary for breeding performance outcomes—One hundred ninety-eight of the 261 (76%) heifers enrolled in the MC group had a first-calving event, and 165 of the 236 (70%) heifers in the CR group had a first-calving event. The difference in the percentage of first-calving events between groups was not significant. Unadjusted means for number of times inseminated, number of times inseminated per conception, calving-to-conception intervals (first and second lactation), and AFC between CR and MC groups were not significantly different **(Table 2)**.

Survival plots depicting the distribution of calving-to-conception intervals between treatment groups (CR vs MC) in the first and second lactation were made **(Figure 2)**. No difference in the length of the calving-to-conception interval between groups (CR vs MC) was observed in both the first and second lactation periods, respectively.

Multivariable models analysis for breeding performance outcomes—Feeding CR, compared with MC, had no significant effect on AFC (ie, risk of a first-calving event; *P* = 0.34), number of times inseminated per conception in the first (*P* = 0.83) and second (*P* = 0.32) lactations, and calving-to-conception intervals (or pregnancy risk) in the first (*P* = 0.7) and second (*P* = 0.21) lactations.

Descriptive summary for milk yield outcomes—Unadjusted means for milk yield during the first and second lactation periods and lifetime milk yield up to 54 months of follow-up were not significantly different between CR and MC groups (Table 2).

Multivariable models analysis for the milk yield outcomes—Generalized linear modeling indicated that feeding CR, compared with MC, significantly decreased first lactation milk yield by 429 kg (*P* = 0.02). In the second lactation, feeding CR, compared with MC, increased milk yield by 452 kg but this effect was not significant (*P* = 0.18). However, lifetime milk yield (ie, up to 54 months of age) of cows was not significantly ($P = 0.5$) different between groups (CR vs MC). Calving season and AFC were removed from these models for failure to satisfy a Wald test $P \leq 0.05$. Lactation length remained a significant ($P < 0.001$) predictor of average milk yield in all models after adjusting for the group variable (CR vs MC).

Discussion

The main strength of this study was its original design (ie, randomized controlled clinical trial), which made it possible to potentially infer a cause-and-effect relationship between type of colostrum fed (CR or MC) at birth and future milk yield, breeding performance, and longevity in the herd. Calves fed 1 dose of CR (containing 125 g of IgG), compared with MC, at birth had a significantly higher risk of FPT during calfhood.[8] As such, cows fed CR as calves in the present study were expected to perform worse than cows fed MC as calves with respect to lifetime milk yield, breeding performance, and longevity outcomes. The rationale being that the high incidence of FPT of calves fed CR[8] could possibly compromise future performance of heifers in the CR group once they became lactating cows. The latter was premised upon evidence from earlier studies[2,18] indicating that heifer calves that have FPT (or are fed ≤ 2 L of raw MC at birth), compared with calves that have satisfactory passive transfer of maternal IgG (or are fed ≥ 4 L of raw MC at birth), are more likely to produce less milk as lactating cows; also, longevity is comparatively compromised in calves that have FPT.

However, despite the significant increase in risk of FPT reported for calves fed CR at birth,[8] there was no significant difference between groups (CR vs MC) in the present study with respect to overall risk of removal from the herd (ie, longevity) and breeding performance outcomes. In the present study, cows fed CR as calves produced significantly less milk in the first lactation than did cows fed MC as calves. This observation was in agreement with findings from earlier studies indicating that calves that had FPT (vs calves that did not) or consumed less colostrum (≤ 2 L vs ≥ 4 L; assuming an inverse relationship between volume of intake and risk of FPT) at birth were more likely to produce less milk and had a decreased projected mature equivalent milk and fat production during the first lactation period, respectively.[2,18] However, the effect of feeding CR, compared with MC, on second lactation and overall lifetime milk yield were not significantly different. This observation contradicted reports of an earlier study[2] indicating that calves fed ≥ 4 L of colostrum produced significantly more milk than did calves fed ≤ 2 L of colostrum (assuming an inverse relationship between volume of intake and risk of FPT) in the second lactation period.

In a previous study,[7] the incidence of subclinical MAP infection was significantly higher in heifer calves fed MC at birth, compared with that in heifer calves fed CR at birth. In other studies, negative relationships have been found between subclinical MAP infection in cows and overall milk yield,[19–21] culling risks,[19,22] and breeding performance.[20,23] In the present study, it is possible that subclinical MAP infections in MC-fed calves offset any detrimental effects of FPT in CR-fed calves on later performance outcomes. This may provide 1 explanation for the failure to observe a significant difference in performance between CR-group and MC-group cows in the present study.

Alternatively, the failure to observe an effect of feeding CR, compared with MC, in the present study might have resulted from the fact that there really is little to no influence of either the CR- or MC-feeding programs on longevity, breeding performance, and overall milk yield, although perhaps other management factors unrelated to type of colostrum fed to calves present in study herds may have played a more important role in influencing performance outcomes, effectively overshadowing any effect of feeding CR, compared with MC, if present. In a recent study, Hultgren and Svensson[24] reported that certain heifer-rearing conditions including crowded (> 7 calves) housing of 3- to 7-month-old calves in slatted pens (vs litter pens) were negatively associated with length of productive life (ie, increased risk of removal from the herd after first calving) of Swedish dairy breeds. However, all heifers in the present study were subjected to similar husbandry conditions including housing throughout the study duration, making influence on their future performance by such management practices a less likely factor. Moreover, possible unmeasured variations in management practices among herds were adjusted for in the statistical models by use of robust variance estimates.[13,14,17,25]

Although the mechanisms by which colostrum intake might influence future lactation performance are not currently understood, it seems reasonable to suggest that feeding MC (or CR) might influence longevity, milk yield, and breeding performance by ensuring adequate transfer of passive immunity in calves upon ingestion followed by a reduction in the risk of neonatal calfhood disease incidence in heifer calves and optimum daily weight gains during the early preweaning and postweaning periods. However, previous observational studies have mostly revealed conflicting findings for the relationship between passive immunity or calfhood disease incidences and subsequent longevity, milk yield, and breeding performance of dairy heifer calves upon becoming lactating cows. For example, no significant association was observed between calfhood morbidity and first lactation milk yield or long-term survival rate after calving in Holstein calves born on 25 New York farms.[26,27] Conversely, calves with a respiratory syndrome were significantly less likely to have a first-calving event (ie, translating into a 3- to 6-month increase in AFC) and often required assistance at calving, compared with herd mates that did not experience respiratory syndromes.[28–30] In 2 studies,[2,18] adequate passive transfer of immunity (or ingesting ≥ 4 L vs ≤ 2 L of high-quality MC by calves) was not significantly associated with AFC, although high concentrations of serum IgG or ingesting ≥ 4 L (vs ≤ 2 L) of high-quality MC by calves was a significant predictor for milk yield and projected mature equivalent milk and fat production during the first lactation period. In these same studies, it was revealed that ≥ 21.5% of calves that had a high degree of FPT (ie, serum IgG ≤ 12 mg/mL within 24 hours after birth) died or were culled for low production,[18] whereas calves ingesting ≤ 2 L (vs ≥ 4 L) of

MC were more likely to be culled for low milk production or poor udder health.[2] However, although significant differences in risk of FPT between CR and MC groups were present, the cows in this study did not have significant differences in calfhood morbidity risks between groups (CR vs MC),[8] making it impossible to verify any possible role that preweaning calfhood morbidity events may have played with respect to influencing future performance of study cows.

Therefore, in the face of conflicting findings, readers are advised to be cautious while interpreting results of the present study given the lack of corroborative data, because no studies had previously attempted to address similar questions with the study design used here. Perhaps the response could be different if lacteal-derived (vs plasma-derived) colostrum replacement products were fed in comparison to raw MC. It is also possible that the effect of feeding CR, compared with MC, on longevity, production, and reproductive efficiency could be different under herd management systems that are different from those of the herds in the present study. Further investigations are needed with regard to these questions.

Finally, although feeding adequate high-quality colostrum remains a key element for neonatal calf health and future productivity,[1,3,4,18] feeding raw MC from cows of unknown (or known) JD status or cows in JD endemic herds is also a significant risk factor for transmission of MAP in young calves.[7,31–33] Therefore, feeding CR instead of MC may be 1 management tool to be used for decreasing the risk of MAP infection in heifer calves at birth as previously reported,[7] while maintaining optimum productivity in the lactating adult cow. One advantage with feeding a CR product is that it allows the flexibility for potentially increasing the IgG mass fed (to approx ≥ 200 g/dose) to substantially reduce the high incidence of FPT that was observed with feeding CR in the present study cohorts.[8–10] However, an obvious limitation to increasing the mass of IgG fed in CR products would be the increased cost to producers. The long-term benefits and economic cost benefit of this practice requires evaluation.

a. Secure, American Protein Corp, Ames, Iowa.
b. Lifeline, American Protein Corp, Ames, Iowa.
c. Dairy Comp 305, Valley Agricultural Software, Tulare, Calif.
d. Stata Corp, College Station, Tex.

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