The influence of age and breed of cow on colostrum indicators of suckled beef calves

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Abstract

Rearing a calf to weaning is a key measure of performance in a beef breeding cow herd. Adequate intake of colostral antibodies by the calf in the first few hours of life is important for passive transfer of immunity, and so is beneficial for calf survival. This experiment aimed to examine the role of udder conformation, maternal age and breed-cross on the colostral status of suckled calves. Udder conformation of Angus, Angus-cross-Friesian, Angus-cross-Jersey and Angus-cross-Kiwicross cows was scored according to Animal Evaluation Limited and BreedPlan standards, and colostral status of calves was determined based on gamma glutamyltransferase activity, immunoglobulin G and total protein concentrations at 24-48 hours of age. Udder conformation was similar ($P>0.05$) among breed-crosses except Angus cows had looser front udder attachment, lower rear udder attachment and less desirable udders overall than Angus-cross-dairy cows ($P<0.05$). Most udder conformation scores did not affect colostral status of calves. The exception was teat placement score, for which more outward-pointing teats were associated with improved colostrum status of calves ($P<0.05$). Survival to weaning was greater for calves with adequate compared with inadequate colostral status ($P<0.001$).

Keywords: colostrum; survival; udder conformation; beef calves

Introduction

Maternal immunoglobulins (predominantly immunoglobulin G - IgG) cannot cross the placenta in cattle (Weaver et al. 2000; Elfstrand et al. 2002; Faber et al. 2005). As a result, calves are born hypogammaglobulinemic (have a naïve immune system) and absorption of colostral immunoglobulins is essential to establish passive immunity (Weaver et al. 2000; Quigley et al. 2002; Quigley 2004; Godden 2008). Successful passive transfer of immunity can be assessed by measuring the concentration of IgG or total protein (TP) or the activity of gamma glutamyltransferase (GGT) in serum of the calf. Assessment of IgG concentration in serum of 601 beef calves in Alberta and Saskatchewan indicated that 6% of calves had failure of passive transfer (FPT), and a further 10% had marginal passive transfer (Waldner and Rosengren 2009). These calves were mostly born in intensive nursery areas and supplementary colostrum was provided where needed in 124 of the 152 herds involved in that study. Had this supplementation not been offered, more calves may have had IgG concentrations indicative of FPT.

A report from the dairy industry in New Zealand indicated that 45% of calves did not consume sufficient colostrum from their dams prior to removal at 1.2-24.9 hours of age (Wesselink et al. 1999). Colostrum intake of dairy calves is often managed by removing calves from their dams within 12 hours of birth and providing colostrum to them via feeders or an oesophageal-tube feeding device. Such interventions are not practical in extensive beef herds and calves must obtain sufficient colostrum from their dam. The success of beef calves in achieving passive transfer of immunity has not previously been quantified in New Zealand.

In a previous study, calves born to Angus heifers took an average of 74 minutes to suckle from their dams after birth (Hickson et al. 2008b). There is potential for a range of factors to interfere to prevent successful suckling. Maternal aggression or inattention, lethargic calves, and udder conformation that makes it difficult for the calf to find the teats using normal instinctive teat-seeking behaviour, may all reduce colostrum intake. Beef-cross-dairy cows offer an advantage over straight-bred beef cows in a beef breeding cow herd because they produce more milk and wean heavier calves (Hickson et al. 2014), however, anecdotal evidence indicates that these cows are more prone to weakening of the suspensory ligament and udders that hang low to the ground as they age. In addition, there has been considerable genetic selection imposed on dairy cows that has not considered maternal behaviour (Sneddon et al. 2016) whereas beef-breed cows that do not rear a calf are routinely culled, thus, it is conceivable that beef-cross-dairy cows may not show as much maternal attention as beef-breed cows.

This experiment aimed to examine the impact of udder conformation, maternal age and breed-cross on the colostral status of their suckled calves.

Materials and methods

Animals and treatments. The cows used in this experiment were generated via contract matings of four Angus bulls with straight-bred Angus, Holstein Friesian, Jersey and Kiwicross (Holstein Friesian and Jersey crossbreds) to produce straight-bred Angus (AA, n=68), Angus-cross-Holstein Friesian (AF, n=43), Angus-cross-Jersey (AJ, n=53) and Angus-cross-Kiwicross (AK, n=31) heifer calves (Hickson et al. 2014, 2015b). The heifers were purchased at weaning (November 2008 for beef-cross-dairy heifers and April 2009 for AA heifers) and managed together under commercial conditions at Massey University's Tuapaka farm in Palmerston North thereafter. The experiment was conducted with approval from the Massey University Animal Ethics Committee.

Cows were bred to Hereford bulls at first joining at 16 months of age, to Angus or Simmental bulls for second joining at 27 months of age, and to Charolais bulls for four joinings thereafter. Cows were culled from the herd at any stage if they failed to conceive during a single joining period or if they did not rear a calf to weaning in any lactation. In addition, two pregnant cows (n=1 AA, n=1 AJ) were culled for health-related reasons. Twin-born calves were excluded from the experiment (n=14 born to AA cows, n=10 born to AF cows, n=6 born to AJ cows and n=2 to an AK cow). In the first three years, five cows that lost their calf at birth accepted a substitute calf (n=3 AF, n=2 AJ). These cows were allowed to remain in the herd for subsequent lactations but the fostered calves were excluded from all measurements.

Measurements. Udder conformation was assessed according to Animal Evaluation Limited's scale for traits other than production (TOP) in dairy cows (Advisory Committee on Traits other than Production, 2014) at the peak of 3rd lactation (four years of age), and according to the BreedPlan BeefClass structural assessment (Simmental NZ, 2016) at the peak of 5th lactation (six years of age). In both cases, accredited assessors conducted the assessment. At the request of the assessor, calves were separated from cows for at least four hours prior to the BeefClass assessment to allow some filling of the udder to better display conformation. Traits assessed in the TOP assessment were udder support (1=weak, 9=strong suspensory ligament), front udder (1=loose, 9=strong attachment to body wall at front of udder), rear udder (1=low, 9=high attachment of udder to body at rear), front and rear teat placement (front and rear scored separately, 1=wide, 9=close), and udder overall (1=undesirable, 9=desirable). Traits assessed in the BeefClass assessment were teat size and shape (1=very small/thin, 9=very large/bulbous), udder evenness (1=front heavy, 9=back heavy) and udder attachment (1=low, 5=high attachment).

In all years, calves were weighed and identified to dams within 24 hours of birth. Serum samples were collected via jugular venepuncture at 24-48 hours of age from all calves that were alive at that age. Serum samples were analysed for GGT activity, IgG concentration and TP concentration using enzymatic calorimetric assay, turbidimetric assay and calorimetric assay, respectively by New Zealand Veterinary Pathology (Palmerston North, New Zealand). Colostral status was classified based on IgG concentration as "adequate" (IgG concentration >1600 mg/dL), "marginal" (800 mg/dL ≤ IgG concentration ≤1600 mg/dL) or "inadequate" (IgG concentration <800 mg/dL) (Wittum & Perino 1995), and as adequate (>200 U/L) or inadequate (≤200 U/L) based on GGT activity (Perino et al. 1993). A threshold level of 55 g/L was applied for adequate TP (Tyler et al. 1998). Calves that had inadequate IgG or TP concentration or inadequate GGT activity were classified as having FPT for that indicator.

Calves remained with their dams until weaning at 6-7 months of age, and all deaths of calves prior to this time were recorded. In some instances, the proximity of the farm to the veterinary teaching hospital meant weak or scouring calves received extraordinary care which included a short-term hospital admission. Such care is unlikely in a commercial farming situation, so calves that were hospitalised (n=1 AF, n=2 AJ) were recorded as having died at the point of hospitalisation for the purposes of this analysis. If a cow died during lactation (n=2 AA, n=1 AF, n=4 AJ, n=4 AK), the survival or otherwise of the calf she was rearing was entered as a missing value.

Sixth calves were subjected to assessment of milk intake by the weigh-suckle-weigh technique (Barton 1970; Hickson et al. 2008a) after a 16- to 20-hour separation at a mean age of 100 days. During this assessment, observation was made of which teats were sucked by the calf.

Statistical methods

Data analysis was completed using SAS v9.3 (SAS Institute, Carey, NC). Udder scores were analysed using a generalised model assuming a Poisson distribution. Sire and breed were considered as fixed effects, but sire did not contribute to variation in udder score so was removed from the model and the model re-run.

The distributions of IgG and total protein concentrations and of GGT activity were tested for normality using the Kolmorgov-Smirnov test. The distribution of GGT activity was normalised using a square root transformation prior to analysis. Colostral status parameters (GGT activity, IgG and total protein concentration) were analysed using mixed models that allowed for repeated measures on each cow. Age and breed-cross were fitted as fixed effects. The interaction between age and breed-cross was considered but removed from the final models because it was not significant (P>0.05).

General linear models that included the fixed effect of breed-cross were used to test the effect of udder conformation during third or fifth lactation on colostrum indicators of third and fifth calves, respectively. The udder traits were considered as covariates, in a separate model for each trait.

Logistic regression based on a binomial distribution with a logit transformation was used to determine the odds ratios for survival to weaning for calves with FPT based on IgG concentration and GGT activity. Breed-cross and age of the dam were considered as fixed effects but removed because they were not significant (P>0.05).

Results

Udder conformation was similar (P>0.05) among breed-crosses at both third and fifth lactation (Table 1), with the exception that AA cows had looser front udder attachment, lower rear udder attachment and less desirable udders (lower overall udder score) than beef-cross-dairy cows (P<0.05) on the TOP assessment. Rear udder attachment was also lower for AF than for AJ cows based on the TOP assessment (P<0.05).

Table 1 Udder conformation assessed using Animal Evaluation Limited's Traits Other Than Production structural assessment standards at third lactation and BreedPlan's BeefClass structural assessment at fifth lactation for suckled cows that were straight-bred Angus (AA), Angus-cross-Holstein Friesian (AF), Angus-cross-Jersey (AJ) and Angus-cross-Kiwicross (AK). Values are back-transformed least squares means and 95% CI.

	AA	AF	AJ	AK	P value
TOP assessment at third lactation					
n	36	28	33	16	
Udder support (1-9)	4.9 (4.2-5.7)	4.3 (3.6-5.1)	4.8 (4.1-5.6)	4.4 (3.5-5.5)	0.624
Front udder attachment (1-9)	2.2[a] (1.8-2.8)	3.8[b] (3.2-4.6)	4.6[b] (4.0-5.4)	4.1[b] (3.2-5.2)	<0.001
Rear udder attachment (1-9)	2.8[a] (2.3-3.4)	4.4[b] (3.7-5.3)	5.7[c] (4.9-6.6)	4.6[bc] (3.6-5.7)	<0.001
Front teat placement (1-9)	3.3 (2.8-4)	3.8 (3.2-4.6)	4.0 (3.3-4.7)	3.6 (2.7-4.6)	0.540
Rear teat placement (1-9)	4.8 (4.1-5.5)	5.6 (4.8-6.6)	5.4 (4.6-6.2)	5.6 (4.6-6.9)	0.435
Overall udder (1-9)	2.8[a] (2.3-3.4)	3.8[b] (3.1-4.5)	4.7[b] (4.0-5.5)	4.1[b] (3.2-5.2)	0.001
BeefClass assessment at fifth lactation					
n	28	20	17	9	
Teat size and shape (1-9)	5.6 (4.6-6.9)	3.6 (2.7-4.6)	4.6 (3.6-5.7)	4.1 (3.2-5.2)	0.705
Udder evenness (1-9)	4.6 (3.8-5.4)	4.3 (3.5-5.3)	4.8 (3.9-6.0)	3.9 (2.8-5.4)	0.713
Udder attachment (1-5)	3.6 (3.0-4.4)	2.6 (2.0-3.4)	3.1 (2.3-4.0)	2.6 (1.7-3.8)	0.161

[abc] Values within rows without superscripts in common differ at the P<0.05 level.

Table 2 Effect of breed and age of dam on gamma glutamate transferase (GGT) activity and immunoglobulin G (IgG) and total protein (TP) concentration 24-48 hours after birth and percentage of calves classified as having adequate colostral status according to GGT, TP and IgG status in the first six calves born to straightbred Angus (AA), Angus-cross-Holstein Friesian (AF), Angus-cross-Jersey (AJ) and Angus-cross-Kiwicross (AK) cows. Values are least squares means and 95% confidence intervals. Values for GGT activity are back transformed.

	n[1]	IgG (mg/dL)	Total Protein (g/L)	GGT activity (IU/L)	Adequate IgG[2] (% of calves)	Adequate TP[3] (% of calves)	Adequate GGT[4] (% of calves)
Age of cow							
2	149	2266[a] (2067-2466)		1470[b] (1255-1703)	72 (64-79)		90[ab] (84-94)
3	116	2487[ab] (2293-2682)	73[c] (71-75)	1172[a] (1018-1336)	80 (71-86)	94[c] (88-97)	95[ab] (89-98)
4	104	2883[c] (2610-3155)	61[b] (59-63)	1502[b] (1317-1698)	84 (76-90)	77[b] (68-84)	97[b] (91-99)
5	70	2617[bc] (2384-2851)	59[b] (57-62)	1173[a] (985-1377)	83 (72-90)	64[ab] (52-74)	97[b] (90-99)
6	75	2473[ab] (2191-2756)	55[a] (52-58)	1233[ab] (1006-1482)	78 (68-86)	51[a] (39-62)	93[ab] (85-97)
7	66	2406[ab] (2049-2764)	60[b] (56-63)	1069[a] (824-1347)	68 (56-78)	67[ab] (54-77)	87[a] (77-93)
P value		0.014	<0.001	0.016	0.065	<0.001	0.043
Breed-cross of cow							
AA	193	2239[a] (2064-2413)	59[a] (57-61)	850[a] (735-974)	71[a] (64-77)	67 (58-75)	92 (87-95)
AF	144	2637[b] (2436-2837)	63[b] (61-65)	1405[b] (1233-1588)	76[ab] (69-83)	77 (67-84)	93 (87-96)
AJ	158	2584[b] (2390-2778)	62[b] (60-64)	1372[b] (1208-1546)	76[ab] (69-83)	76 (66-83)	94 (89-97)
AK	85	2629[b] (2371-2887)	62[b] (59-65)	1489[b] (1262-1734)	86[b] (77-92)	76 (63-85)	97 (90-99)
P value		0.006	0.005	<0.001	0.042	0.302	0.327

[abc] Values within columns within main effects without superscripts in common differ at the P<0.05 level.
[1] Number of calves. Total protein was not measured in calves born to two-year-old cows, so n=145 AA, n=108 AF, n=116 AJ and n=62 AK.
[2] IgG concentration >1600 mg/dL
[3] TP concentration ≥55g/L
[4] GGT activity >200 U/L

The colostrum indicators were lower for calves born to AA cows than for calves born to beef-cross-dairy cows (P<0.05). There was variation across years, and some discrepancies among colostrum indicators, with no clear pattern of age effects evident (Table 2). Overall, 75% of calves had adequate IgG concentration and 92% of calves had adequate GGT activity. A lesser proportion (87%) of calves from seven-year-old cows had adequate GGT activity compared with calves from four- and five-year-old cows (97%; P<0.05). Ninety-four percent of calves born to three-year-old cows had adequate TP concentration, which was greater than the 51-77% of calves born to cows aged four or older ($P<0.05$). The concentration of IgG and total protein and the activity of GGT were less for AA than for beef-cross-dairy cows ($P<0.05$). Despite this, there was no difference among cow breed-crosses in the proportion of calves that had adequate GGT activity ($P>0.05$) and the proportion of calves with adequate IgG concentration differed only between calves born to AA and AK cows ($P<0.05$).

Udder support, front or rear udder or udder overall at third lactation did not affect the colostrum indicators of third calves ($P>0.05$; data not shown). Front teat placement influenced IgG and TP concentration ($P<0.05$), but not GGT activity ($P>0.05$) of third calves. Total protein concentration increased by 2.7 ± 1.1 g/L ($P=0.01$), and IgG concentration increased by 432 ± 161 mg/dL ($P<0.01$) for every 1-point decrease in front teat placement score; that is, outward pointing teats increased colostral status. Rear teat placement affected only IgG concentration, which increased by 314 ± 149 mg/dL ($P=0.04$) for every one-unit decrease in rear teat placement score. There was no effect ($P>0.05$) of BeefClass udder scores in fifth lactation on colostrum indictors of fifth calves. Sixth calves sucked from 91% of front quarters but only 63% of rear quarters during a single sucking bout at a mean age of 100 days.

Calves that received inadequate colostrum based on either GGT activity or IgG activity were less likely to survive to weaning than calves that received adequate or marginal colostrum ($P<0.001$; Table 3). Survival rates did not differ among dam breed-crosses or among cow ages. Most of the calves that died between blood sampling and weaning had received inadequate colostrum (63% (95% CI 36-84%)) based on GGT activity, whereas only 5% (95% CI 3-7%) of calves that survived to weaning had inadequate colostrum based on GGT activity. The odds of dying prior to weaning was 31 (95% CI 10-98) times greater for calves with FPT, based on GGT activity, than for other calves. For calves that had FPT based on IgG concentration, this odds ratio was 48 (95% CI 18-125).

Table 3 Percentage (95% CI) of calves in various colostrum classifications that survived to weaning. Calves were born to straightbred Angus (AA), Angus-cross-Holstein Friesian (AF), Angus-cross-Jersey (AJ) and Angus-cross-Kiwicross (AK) cows over six years.

	n	Percentage survived to weaning
Colostrum status based on IgG concentration		
Adequate	430	99^{b} (98-100)
Marginal	82	99^{b} (92-100)
Inadequate	59	83^{a} (71-91)
P value		<0.001
Colostrum status based on GGT activity		
Adequate	528	99^{b} (98-100)
Inadequate	43	77^{a} (62-87)
P value		<0.001

Discussion

The udder conformation of the cows was generally similar among breeds, although AA cows had lower rear attachment and looser front attachment than beef-cross-dairy cows and this was reflected in the udder overall scores. The beef-cross-dairy cows' scores were between the Angus scores and the breed averages for two-year-old Jersey and Holstein Friesian cows (E Donkersloot, Pers. Comm., July 2015). These less-desirable scores of the crossbred cows compared with the dairy parent are likely to be partly the influence of the Angus genetics, and also the natural change in udder conformation with age and increasing number of lactations.

At fifth lactation, the cows' udders appeared to be showing the degradation of ligament support typical of older breeding cows, but still there were no differences among breed-crosses indicating that the deterioration was similar for breed types and any perceived greater deterioration among beef-cross-dairy cows was a reflection of the greater udder size not of more rapid deterioration in conformation. At this age, udders were somewhat front-heavy, and were attached lower than ideal, but teats were close to the ideal size and shape. The front-heavy aspect of the udders is likely a consequence of some calves consuming milk predominantly from the front quarters.

Outward facing teats are a consequence of a relaxed medial suspensory ligament (Nickerson & Akers 2002) and are considered undesirable in machine-milked dairy cows. In the present study, these outward-facing front teats increased the colostral status of calves, presumably through increasing the intake of colostrum, and consequently were advantageous in a situation where calves rely on suckling to receive colostrum.

Calves born to AA cows had less GGT activity and lower concentrations of TP and IgG than calves born to beef-cross-dairy cows. Bush et al. (1971, 1973) demonstrated that IgG concentration in calf serum was strongly influenced by the total amount of IgG consumed, but not by the concentration of IgG in the colostrum. There is also individual variation in uptake of immunoglobulins among calves, but this contributes no more than 32% of the variation in serum IgG concentration (Bush et al. 1971). Therefore, it is likely that differences in IgG concentration resulted from differences in IgG intake among the breed crosses.

Coleman et al. (2015) reported similar IgG concentrations among colostrum from Jersey, Friesian and Kiwicross cows, but there are no reports available detailing the IgG concentration of colostrum from Angus cows in New Zealand. Thus, it is not clear whether the greater colostral status of calves born to beef-cross-dairy cows resulted from a greater volume of colostrum consumed, or from consuming better-quality colostrum. The beef-cross-dairy cows in this experiment have been reported to produce greater volumes of milk during lactation than the AA cows (Roca Fraga et al. 2013), and no differences were detected in the protein concentration of their milk in midlactation (Hickson et al. 2015a), which makes the former hypothesis more likely.

The consequences for a calf of not consuming adequate colostrum were dire in the present experiment, with a 31 to 48-fold increase in mortality rate prior to weaning for calves with inadequate GGT activity or IgG concentration. This is consistent with a previous report of a 14-fold increase in pre-weaning mortality, from 3% to 42% for low versus high IgG calves (Muir et al. 2006). Failure of passive transfer of immunity is known to increase the risk of morbidity and mortality (Wittum & Perino 1995; Quigley et al. 2002; Quigley 2004; Deelen et al. 2014, Windeyer et al. 2014) and decrease pre-weaning growth (Windeyer et al. 2014). Greater quantities of good quality colostrum fed to dairy heifers resulted in greater weight gain and milk production in the first and second lactation (Faber et al. 2005). In the present experiment, the majority of calves that survived to blood sampling at 24-48 hours of age, but died before weaning, had not consumed adequate levels of colostrum. It should be noted that cause of death was not reported, and it cannot be determined whether or not the affected calves died from disease for which they had an inadequate immune response as a result of FPT neonatally. It may be that some calves had not received colostrum because they were inherently weak or had an inattentive or aggressive mother or they had not established an appropriate cow-calf bond, and both FPT and the death of the calf were symptoms of this.

There were no differences among breed-crosses or cow age in survival rate of calves, however, it is acknowledged that numbers were relatively low to detect differences in this trait within these subgroups. It is possible that over a larger sample of calves, differences in survival may have been detected as a result of the differences in colostrum indicators between calves born to AA and beef-cross-dairy cows. Alternatively, the lower colostrum indicators of AA calves may have been sufficient for adequate passive transfer of immunity and there may be no survival benefit to the calves of beef-cross-dairy cows from exceeding this threshold by a greater margin.

In conclusion, the conformation of udders of beef-cross-dairy cows was similar or superior to that of straightbred Angus cows. Deterioration of the udder's medial suspensory ligament with age that resulted in more outward-facing teats facilitated consumption of colostrum by the calf. Calves from beef-cross-dairy cows consistently had greater colostral status than calves from Angus cows, but the proportion of calves for which FPT occurred was generally similar among cow breed-crosses. Adequate passive transfer of immunity greatly improved the likelihood of survival to weaning for suckled beef calves.

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