Association of bacterial contamination of colostrum with passive immunity and growth rates in dairy heifer calves

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Abstract

Failure of passive transfer of immunity in calves is associated with poor-quality colostrum, determined by Immunoglobulin G (IgG) concentration. Another quality problem of colostrum is bacterial contamination, which can impair IgG absorption by the calf. Thirty-five samples from daily pooled first-milking colostrum collected over a period of six weeks were tested for IgG concentration and bacterial contamination. Seventeen of 35 first-milking colostrum samples (49%) had bacterial counts above a 100,000 CFU/ml threshold. Twenty-nine of the 35 pooled colostrum samples were fed to 63 newborn heifer calves, of which 12 (41%) had bacterial loads above 100,000 CFU/ml and were fed to 36 calves. Only eight samples (28%) had Brix values >22% and five samples (17%) fed to nine calves met the criteria of low bacterial load and high Brix (>22%). Twelve of the 63 calves (19%) had serum IgG concentrations <10 mg/ml so were classified as having failure of passive transfer, of which 10 of these calves were offered colostrum with high bacterial counts. However, there was no association of level of bacterial contamination with subsequent growth. There were no differences in serum IgG concentrations of calves which were fed colostrum that exceeded the quality threshold and those that were not. Calves with greater serum IgG concentrations grew faster (P<0.05).

Keywords: bacterial contamination; growth rates; heifer calves; passive immunity

Introduction

Passive immunity is transferred to new-born calves through maternal colostrum, and failure of this transfer is associated with multiple factors: poor colostrum quality, low volumes consumed and timing of feeding (Weaver et al. 2000; Godden et al. 2012). Colostrum quality is commonly determined by immunoglobulin G (IgG) concentration, and higher calf serum IgG concentrations are associated with lower risk of disease and death, and improved weight gains (Robison et al. 1988; Wittum & Perino 1995; Godden et al. 2012). Additionally, bacterial contamination of colostrum may reduce quality by impairing IgG absorption by the gut of young calves, thus preventing successful transfer of passive immunity (Godden et al. 2012; Gelsinger et al. 2015; Short et al. 2016). While the mechanism is not clear, it is suggested that colostral IgG binds to pathogens in colostrum, which decreases the IgG mass available for absorption by the calf intestine (Short et al. 2016). Bacteria may also interfere with IgG absorption sites in the gut, decreasing absorption (Gelsinger et al. 2015; Short et al. 2016).

There are many points in a commercial milk-harvesting system where microbial contamination can occur: from the skin of the udder, collection, handling and storage (Stewart et al. 2005). In New Zealand, Denholm et al. (2017) reported that only 8.6% of pooled colostrum samples had bacterial counts below the recommended threshold, whereas in US studies 15% of samples were below the threshold (McGuirk & Collins 2004). In a smaller study on six farms in Canada, 64% of samples were below the threshold but this varied among farms (Fecteau et al. 2002).

During spring 2014, we commenced a longitudinal study examining the effect of calf-rearing practises on growth and subsequent milk production of replacement heifer calves in a commercially managed, once-daily milking herd. The results presented in this paper are from an observational study on determining the level of bacterial contamination in pooled fresh colostrum fed to the heifer replacement calves, to see if there was an association between bacterial contamination of colostrum on subsequent IgG status and growth of dairy heifer calves.

Materials and methods

This study was approved by the Massey University Ethics committee. The study enrolled calves born at Massey University's Dairy 1 farm in Palmerston North, New Zealand, during the spring of the 2014-15 dairy season.

Between 21st July and 30th August 2014, a daily sample was taken from the fresh pooled first-milking colostrum fed to replacement heifer calves on their arrival to the calf-rearing shed. First-milking colostrum from 189 heifers and cows was used, with the number of cows' colostrum being pooled varying on a daily basis, depending on the number of cows calving each day (range 2 – 15). This resulted in 35 samples which were fed to 63 new-born heifer calves (<24 hours of age). For each pooled colostrum sample, the dams contributing to each sample were recorded as were the calves fed.

Sixty-three heifer calves (13 Holstein-Friesian (HF), eight Jersey (JE) and 41 Holstein-Friesian-Jersey crossbred (XB)) commenced the study. Pre-weaning calf management and experimental procedure was as described by Coleman et al. (2015) and Cardoso et al. (2015). Briefly, calves were offered 2L twice daily of pooled first-milking colostrum

on the day of arrival at the calf shed, and then fed pooled days 2-4 colostrum for 14 days until being allocated to one of two feeding treatments: low (2L milk twice-daily) and high (up to 4L twice daily) (Cardoso et al. 2015). There was no difference in growth rates between heifers in the two feeding treatments (Cardoso et al. 2015). After weaning, the heifers were managed under commercial conditions until first calving (Back et al. 2017).

Calves were monitored for scouring but no cases occurred in the first 14 days while in the calf shed, or once outside, grazing in their treatment groups.

Measurements

Blood samples for serum IgG testing were taken from all calves via jugular venipuncture 24 hours after arrival at the calf shed. The sub-sample of the pooled first-milking colostrum was tested for IgG concentration and bacterial contamination. Colostrum and serum IgG concentrations were determined by an automated turbidimetric assay (TIA; Besser et al. 1988) by New Zealand Veterinary Pathology, Palmerston North. Serum IgG concentrations were determined as adequate (> 16g/L) or inadequate (≤ 16 g/L) (Wittum & Perino 1995). A Brix value (as determined by a refractometer (OPTi digital hand-held refractometer, Brix 54, Bellingham + Stanley, Thermo Fisher Scientific) was used to estimate if the pooled colostrum samples had values of 22% or greater (equivalent to 50 g/ml IgG; Coleman et al. 2015). Level of bacterial contamination was determined by a total bacteria count following inoculation of agar plate and incubation at 30°C (SAITL, Hamilton). A threshold of 100,000 CFU/ml was used to describe high or low bacterial load (Fecteau et al. 2002; Short et al. 2016; Denholm et al. 2017).

Live weights for 63 calves were measured at arrival at the calf shed (<24 hours of birth, standing in a sheep crate) and then regularly every two weeks. One JE heifer died (bloat) prior to the 400-d weight measurement, one HF heifer died (clostridial infection) prior to the 600-d weight measurement and five non-pregnant XB were removed prior to the 600-d weight measurement. Live weight was categorised as: at weaning, weight at 200 days, weight at 400 days and weight at 600 days, which equates to 6, 13 and 20 months of age. Thirteen months was taken as closest to planned start of mating when some intervention of underweight animals could be undertaken, and 20 months for closest to calving. Average daily liveweight gain (ADG) was taken as birth to weaning (weaning weight minus birth weight divided by age at weaning), 200-day gain was from weaning till 200 days, 400-day gain was weaning till 400 days and 600-day gain was weaning till 600 days.

Statistical analysis

Bacterial data were log transformed to give a normalised distribution. Liveweight data were analysed using the GLM procedure in SAS 9.4 (SAS Institute Inc., Cary, NC) with bacterial load of colostrum, colostrum IgG concentration, calf serum IgG concentration and age at the event (weaning, 200 days, 400 days, and 600 days) fitted as covariates, and breed as a fixed effect. The Means procedure in SAS was used to generate a 95th percentile range for serum IgG concentration, weaning, 200, 400 and 600 day weights, and liveweight gain rates to weaning, 200, 400, and 600 days.

Results

Seventeen of the 35 colostrum samples (49%) had bacterial counts above the 100,000 CFU/ml threshold. A large range of bacterial counts was recorded, with the average of samples below the threshold being 22,320 CFU/ml compared to the average of samples above the threshold of 4,887,300 CFU/ml. The bacterial load over time was evaluated and was found to not be significantly altered by time (P>0.05). Twenty-nine of the 35 pooled colostrum samples were fed to the new heifer calves, of which 12 (41%) had bacterial loads above 100,000 CFU/ml and were fed to 36 calves. Only eight samples (28%) had Brix values >22% and five samples (17%) fed to nine calves met the criteria of low bacterial load and high brix.

Twelve of the 63 calves (19%) had serum IgG concentrations <10 mg/ml so were classified as having failure of passive transfer: 10 of these calves been fed colostrum with high bacterial counts. However, there was no difference in serum IgG concentration of calves which were fed colostrum that exceeded the bacterial threshold and those that were not (P>0.05, 95% CI 16.17 to 26.99 *vs* 19.75 to 28.91 respectively).

Bacterial load of colostrum did not impact live weight (kg) or weight gain (kg/d) of calves at any of the investigated time points (P>0.05, Table 1). Breed influenced live weight and ADG at all points (P<0.01, Table 1), with Holstein-Friesian calves being heaviest and growing fastest while Jersey calves were the lightest and grew slowest.

Calf serum IgG concentration had a significant effect on 200- and 600-day weights, and liveweight gain to 600 days (P<0.05), indicating calves with greater serum IgG concentrations grew faster.

Discussion

A large number of samples from pooled first-milking colostrum failed to meet bacterial contamination (49%) and Brix (32%) values used to indicate good quality colostrum. Of the samples from colostrum fed to the replacement heifer calves, the proportion of samples that were below the bacterial threshold (59%), and met the bacterial count and brix threshold (17%) for good quality colostrum were greater than those presented by Denholm et al. (2017) in New Zealand (8.6% and 2.1% respectively) but within the range presented in overseas studies (McGuirk and Collins 2004, Fecteau et al. 2002). Denholm et al. (2017) presented data from a larger study in which samples were collected from 100 farms during early, mid and late season. The current study used samples from one farm, and these were taken over the first part of calving when the replacement heifers were chosen. As reported by Fecteau et al. (2002), the number of samples meeting quality thresholds can be

Table 1 Mean live weight and liveweight gains at weaning, 200 days of age, 400 days of age and 600 days of age by breed for heifers born at Massey Dairy 1 and the model fit parameters from the generalised linear model including the r-squared value and P values for each fitted variable.

	Live weight (kg)				Average daily gain (kg/d)			
	Weaning (n=63)	200 day (n=63)	400 day (n=62)	600 day (n=56)	Birth to weaning	Weaning to 200 days	Weaning to 400 days	Weaning to 600 days
HF	105.9±1.5[a]	232.1±3.76[a]	322.8±5.08[a]	459.1 ± 7.97[a]	0.81±0.02[a]	0.99±0.02[a]	0.67±0.01[a]	0.68±0.01[a]
JE	84.2±2.12[c]	184.7±5.10[c]	259.2±6.87[c]	364.1 ± 11.2[c]	0.67±0.02[b]	0.85±0.03[c]	0.56±0.02[c]	0.55±0.02[c]
XB	96.7±0.83[b]	215.7±2.09[b]	298.9±2.86[b]	427.2 ± 4.5[b]	0.78±0.01[a]	0.94±0.01[b]	0.63±0.01[b]	0.64±0.01[b]
95% CI								
Under log	93.5-100.7	210.6-231.0	289.7-312.4	413.4-444.4	0.73-0.81	0.93-1.00	0.61-0.65	0.61-0.65
Over log	93.6-98.9	202.2-216.6	286.9-305.8	408.5-438.1	0.72-0.79	0.90-0.96	0.61-0.65	0.61-0.66
Model fitness								
r²	0.584	0.694	0.619	0.568	0.559	0.318	0.398	0.461
P values for fitted variables								
CFU	0.388	0.626	0.674	0.833	0.151	0.193	0.785	0.854
Pooled IgG	0.289	0.287	0.650	0.799	0.376	0.952	0.884	0.833
Calf serum IgG	0.831	0.023	0.059	0.018	0.625	0.027	0.073	0.125
Calf age (days)	0.658	<0.001	<0.001	0.015	<0.001	0.098	0.053	0.319
Calf breed	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001

HF: Holstein-Friesian; JE: Jersey; XB: Holstein-Friesian-Jersey crossbred; Under log: under the log bacterial count limit; Over log: over the log bacterial count limit; CFU: colony forming units. Pool IgG: pooled first milking colostrum: Calf IgG: concentration of IgG in calf serum

[abc] differing superscripts within a column indicate significantly different means (P<0.05).

impacted by various factors: colostrum that was fed to bull calves had higher bacterial contamination indicating less attention to hygiene, there was variation among farms and between warm and cold months.

Despite a high number of samples of pooled colostrum showing high bacterial contamination, there appeared to be no evidence of an impact on IgG absorption by calves. This is different to results published by Godden et al. (2012) and Gelsinger et al. (2015) however, these two studies examined reducing bacterial load by pasteurisation, whereas the current study used a processing threshold to assign high or low status. However, it must be acknowledged that there are several limitations to the current study, in that there was a small number of animals monitored and colostrum samples tested, and the timing of the feeding of the tested colostrum relative to changes in gut permeability. In addition, heifer calves in the current study were raised with the aim of having all on or above liveweight target until 22 months of age (Back et al. 2017). This is in contrast to calves in the studies by Godden et al. (2012) and Gelsinger et al. (2015) that were monitored to weaning and for the first seven days after birth, respectively. Post-weaning management may have masked some of the effects of pre-weaning colostrum management. Despite a small number of calves, the positive effect of higher IgG status within 48 hours of birth on growth was demonstrated, and this is consistent with the study of Robison et al. (1988). Rate of growth is determined by many factors, however in this case the calves with the higher serum IgG concentrations may

have been better able to withstand pathogenic challenges and stresses associated with management practises around weaning. Further analysis is being conducted on this data set with regards to growth and milk production as these calves have now finished their second lactation.

This study is a description of what was observed on a commercial dairy farm. From this small data set, we found no association between bacterial contamination of first-milking colostrum and heifer-growth rates, but there was a positive association between calf serum IgG concentration and growth.

Acknowledgments

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